Blue Growth

Scenarios and Drivers for Sustainable Growth from the Oceans, Seas and Coasts

Maritime Sub-Function Profile
Environmental Monitoring

Call for tenders No. MARE/2010/01

Client: European Commission, DG MARE

Rotterdam/Brussels, 13th August 2012

The research for this profile report was carried out in the period April – August 2011. This report has served as an input to the main study findings and these have been validated by an Expert meeting held on 9/10th November 2011 in Brussels. The current report serves as a background to the Final Report on Blue Growth.

Contents

1 State of Play

1.1 Summary description of the nature of the subfunction

The monitoring of oceans, seas and coasts generates the required knowledge on the state and functioning of the marine environment. This is a basic prerequisite for obtaining sustainable growth in the interconnected global economy, for achieving *Good Environmental Status* of marine waters in accordance to the Marine Strategy Framework Directive and for fulfilling the environmental pillar of the Integrated Maritime Policy[1].

Knowledge creation begins with **data collection** in our seas and oceans. Subsequently**, data assembly and analyses** generate the needed information to enhance the understanding of the functioning of the seas. The acquired knowledge can then be applied, **data application by data users**, to support the protection and health of the marine environment, to monitor the impact of ecosystem services and to deliver sustainable development growth. This creates the link to the economic value chain. Although "Environmental Monitoring" is referred to as a *subfunction* within the context of "Blue Growth", in principle it is a crucial tool to ensure a safe and sustainable well-being and economic usage of marine resources. It is also a way to evaluate the impact of ecosystem goods and services on the ecosystem.

1.2 Description of the current structures

The cycle from knowledge creation to the economic value chain can be subdivided in three levels: a) data collection, b) data processing and c) data use including downstream service applications. Within this process, one can distinguish between three key purposes for environmental monitoring:

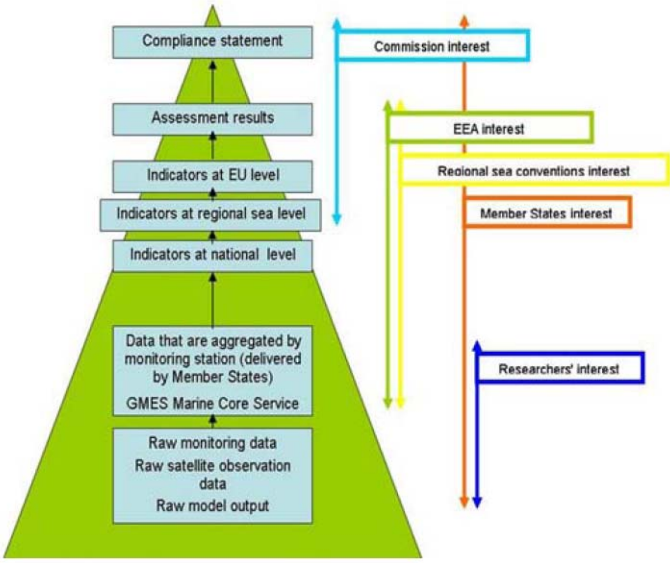
1) Monitoring for policy and supervision, structurally repeated and conducted by governments aimed at compliance, surveillance and adaptive management.
2) Monitoring for scientific reason, focusing on increasing knowledge on specific parameters, processes and systems
3) Monitoring for industry and private companies, e.g. data collection driven by more efficient exploitation of resources, such as oil exploration

As shown in the figure below, overlap exists primarily between categories 1) and 2) (Category 3 is not represented here but is discussed in a separate section underneath). Data collection is mainly the interest and responsibility of the Member States. However, changes in one country's waters affect those of its neighbours. Therefore, data collected at the national level is aggregated at the regional sea level, in accordance to Regional Sea conventions[2] such as OSPAR, HELCOM. The need to ensure coherence in knowledge for purposes such as safe navigation, resource use, coastal protection or fisheries and water quality management demands for the integration of monitoring activities and results at the EU level. Based on national data, EEA conducts assessments on the state of environment in the different regional seas. Other national monitoring programmes are driven by policy compliance at the commission level as required by the Water Framework Directive (WFD) and the Marine Strategy Framework Directive (MSFD). The EU has the legislative and financial means to create a truly European architecture and to add value in the integration of the different national monitoring efforts.

---

[1] European Commision, Marine Knowledge 2020 marine, COM(2010) 461

[2] European Commission, Towards a strategy to protect and conserve the marine environment, COM/2002/0539 final



Construction of monitored indicators at the different levels [3]

Existing monitoring infrastructures are in the form of:

- **In situ data collection and observing systems** funded by Member States to meet national needs, e.g. environmental protection but also defence and safety (discussed in subfunctions 6.1 and 6.2), to fulfil national obligations under Regional Conventions and Directives, to sustain research programmes and participate in international programmes partially funded by non-EU states. In situ observations are carried out using FerryBoxes[4], moorings, floats and other innovative instruments such as robotic floats, gliders[5], automated sensors that provide real-time data. They provide the ground truthing component of the marine core services as defined in the Global Monitoring for Environment and Security (GMES) programme (see below).
- **Space-based Earth Observation (EO) systems** funded by Member States with the support of ESA and EUMETSAT and other national programmes which sustain research programmes to meet operational needs, develop and demonstrate technology, improve industrial capacity and build markets. This also allows for access to EO systems funded and operated by non-European Space Agencies. EO provides ocean observations from space as the second component of GMES.
- **Modelling** may be considered as an auxiliary component of the existing monitoring infrastructure.

Through data assimilation techniques, ocean observations (in situ and space) are integrated in computer models to generate three-dimensional spatial and temporal coverage of the ocean state, prediction of changes and real-time forecasting. Examples of (near) real time systems include the EMSA CleanSeaNet[6] oil spill and vessel monitoring satellite service. This service, covering all European sea areas, is free of charge to all Coastal States and is integrated within the national and regional oil pollution surveillance and response chains. More details are included in Subfunction 6.2.

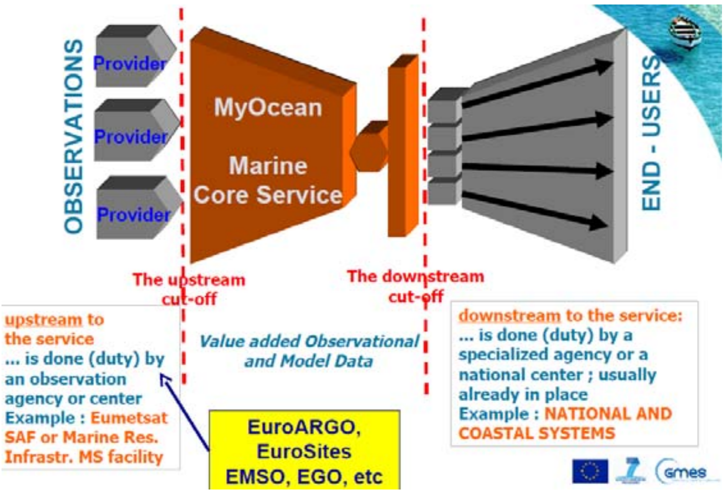
[3] European Commission, Building a European marine knowledge infrastructure: Roadmap for a European Marine Observation and Data Network, SEC(2009) 499

[4] *Science (*2008), FerryBoxes Begin To Make Waves, Vol 322

[5] Testor et al. (2010)

[6] http://cleanseanet.emsa.europa.eu/

Historically, the structure of this subfunction has been scattered at a local scale. It was organized around the national monitoring programs, aimed at fulfilling very specific needs (defence, technology, etc.). In essence, the marine environmental monitoring was based on ad hoc short-term research projects/programs[7]. In this fragmented contest, the Global Ocean Data Assimilation Experiment (GODAE)[8] was initiated fifteen years ago as a coordinated international effort to establish global operational oceanography. In 2006, the Commission invited the EU to consider setting up EMODNET as a network through a Green Paper[9]. EMODNET, supported by Marine Observation and Data Expert Group (MODEG), is a tool to optimize and bring coherence to the current fragmented initiatives that gather marine data, and to facilitate access to primary marine data for public authorities, maritime services, related industries and researchers. It builds on the existing pan-European infrastructure of national marine data centres. The proposed integration and data linkage for enhancing value-added services and sustainable maritime development is one of the cornerstones of an integrated approach for maritime policy. EMODNET will contribute to SEIS[10], the overarching framework through which environmental information will be handled over time. WISE-Marine[11] (an extension of the current Water Information System for Europe (WISE)) will serve as the main platform for exchanging and sharing information and underlying data within the scope of reporting obligations required by the MSFD. Like EMODNET, WISE-Marine is due to be based on the SEIS principles, including the principle that information which is collected once should be shared with others for multiple purposes. Other European Community data initiatives include GMES, Euro-ARGO[12] and SeaDataNet[13]. The GMES initiative aims to provide, on a sustained basis, reliable and timely services related to environmental and security issues in support of public policy makers' needs. Through the GMES marine core service MyOcean[14], core oceanic information in all benefit areas (resources management, safety, environment and climate forecast) are provided for several categories of key users, such as EU agencies (e.g. EEA or EMSA); the Member states service providers (e.g. coastguards); intergovernmental bodies and their members (e.g. the OSPAR Commission). The ocean monitoring and forecasting core services rely on the existence of ocean observation (in situ and space) and data assimilation through operational oceanographic models as illustrated in figure below.



[7] Ryder (2007), Sustainable Marine Environmental Information Services to Meet Collective European Needs
[8] http://www.godae.org/
[9] European Commision Green Paper, Towards a future Maritime Policy for the Union: A European vision for the oceans and Seas, COM(2006) 275 final
[10] European Commision, Towards a Shared Environmental Information System (SEIS), COM(2008) 46 final
[11] http://www.water.europa.eu/
[12] Euro-ARGO: European component of a worldwide in situ global ocean observing system based on autonomous profiling floats
[13] SeaDataNet: Pan-European infrastructure for Ocean and Marine data management
[14] http://www.myocean.eu.org/

There is an operational interaction (as well as partial overlap) between EMODNET and EMSO, Euro-ARGO, SeaDataNet, INSPIRE, SEIS. Both EMODNET and GMES are expected to have strong interactions with the Global Ocean Observation System (GOOS) which is the oceanic component of the Global Earth Observation System of Systems (GEOSS). GOOS, the active version of GODAE, is mainly implemented by the United Nations Educational, Scientific and Cultural Organization (UNESCO) and has a European component called EuroGOOS and regional alliances (BOOS, NOOS, IBIROOS, MFS-MOON and Black SeaGOOS).

As part of the unifying initiatives, a number of European networks exist; such as ESONET (European Seas Observatory NETwork) offering a platform for networking institutions, persons, tools and know-how on deep sea observatories of observatories and EMSO, the large-scale European Research Infrastructure on Multidisciplinary Seafloor Observatory. Besides, other European environmental monitoring networks, such as the European Gliders Observatory (EGO) and the European Meteorological Network (EUMETNET) also exist which are not directly funded by EU. The European Environment Information and Observation Network (EIONET), set up by EEA supports data management through a network of Member State representatives and international collaboration etc.

With respect to the in situ and space components, we can identify the following “clusters” which are leading within this subfunction:
- European Environmental Agency (EEA) together with ICES (International council of the
- Exploration of the Sea)
- National Oceanography Center, Southampton, UK (in particular related to gliders)
- Coriolis (French ARGO), France
- IFREMER, France
- Mercator, France
- EARTO / EMECO
- WHOI and NOAA (USA)
- Scripts Institution of ocean (Florida, USA)

However, it should be noted that there is a tendency to find “clusters” in areas with strong national support. In the past, UK, Norway, Denmark, Germany etc. were forerunners but nowadays you find different communities in different areas depending on activity: GMES Marine, policy, marine research, including basic/applied/operational oceanography and modelling.

Monitoring by industry and private companies

Large quantities of data relating to the marine environment are collected, analyzed and used by a variety of private entities all over Europe. Such data has a primary role of promoting the development of economic activities relating to the maritime sector and developing new industrial products and services. In contrast to public goods and services, private goods and services are those provided by private (or public) sectors for a financial consideration, therefore also driven by market forces. For this reason, there is little incentive by the private sector to finance public goods and services. The demand for private goods and services generally depends on their cost to the consumer or user as well as knowledge of the existence of such marine data. Private suppliers of marine data may rely partly on the data supply from public research institutions, including governmental departments, universities and other public research entities. Private suppliers may add value to existing data through additional research, modeling and other operations, even when such data is, in some cases, freely-available.

Generally the purpose, extent and prospecting of the data collected by the private sector is both commercial and confidential. There are a number of common factors in the way private entities manage marine data. Firstly, the collection and often processing of data is generally outsourced to third parties, such as specialist companies or consultancy groups. It is difficult to distinguish between companies that conduct data collection or application since many effectively do both activities and major players are in effect data brokers[15]. Secondly, most data collection and application is project-related and therefore is carried out on a short-term basis. This implies that such monitoring campaigns are not likely to be part of longer-term monitoring programmes. The application of data collected within the scope of an individual project is many times limited to single-use and it not often readily available for re-use in other projects or by other parties. Data licenses/annual subscriptions may be purchased by private companies, which limit private entities to data use rather than data ownership.

Economics of Environmental Monitoring

Information, including marine data, is an economic good and/or service for which there is demand by different end users in EU economies. Marine data is an important component for many economic activities. For example, it plays an important role in the financial and economic analysis of coastal development and offshore projects. An overview of economic sectors on which marine data will have an economic impact is compiled by MRAG Ltd (2009). Any analysis of the beneficial impacts of marine data per se on environmental management, shipping, coastal and port engineering and other marine infrastructure should, however, also take into account the wider economic benefits through improved access to marine data.

The collection, analysis, storage and dissemination of marine data are part of the information economy which has grown rapidly in the EU. The growth of the information economy has impacts on other sectors of the economy, including the production and service sectors. Monitoring activities are generally based on an "input-output" model[16], which may be used to assess the inter-sectoral impacts of policy changes and the relationships between different sectors of the economy. New emerging business models include the integration of data collected by providers with the downstream data use by end users, including private companies. The bulk of such systems is provided by the core services that provide value-added observation and model data. This is the basic model adopted by the GMES MyOcean (see figure above) to promote the use and sharing of observation data in support of the monitoring of the state of the environment and its short and long-term evolution. It offers a reliable, robust, sustainable service, stimulating innovation and growth in the private sector. This system will avoid resource duplication, ensure that all subsystems are interoperable and integrated through the application of a common procedure for the development and operation of its (sub)systems.

Public goods and services, including marine data, which is made freely available to users, are open to all members of society including individuals, the private and public sectors. In EU countries, access to marine data collected and analyzed by public sector institutions – R & D establishments, government departments, universities etc. is often available against payment, although in some cases data might be available for free to private sector and public sector users/beneficiaries.

Data Users and Costs

Data Users can be broadly categorized as public entities, such national research institutes, and private including commercial companies. There are various applications for which environmental data is collected, processed and applied. Within MyOcean, four main market areas have been identified:

1) **marine safety** (search and rescue, off shore)

---

[15] MRAG Ltd. (2009), Marine Data Infrastructure, Framework Service Contract, No. FISH/2006/09

[16] EUROSTAT and Flemming (2007). SEPRISE – Socio – Economic Analysis Scoping Report

2) **marine and coastal environment** (water quality, harbours, coastal monitoring; near the coast and open sea)
3) **marine resources** (fish management/ ecosystem management)
4) **climate and weather monitoring** (ice in Atlantic, coupling of forecasting systems)

The outcome of an inventory of MyOcean data users for each market area[17], carried out two years after the start of the project is given below:

The inventory suggests that 320 registered MyOcean users make use of 100 % of the catalogue products. Although the majority of the users are research institutes/universities (58 %), private entities account for 18 %. The demand (as % use) and examples of application for each market areas are given below:
Maritime safety (40 %): Drivers for better ice information in Arctic and Baltic Sea
Marine and coastal environment (27 %): Marine Water Quality Information Services by AQUAMAR consortium; impact of offshore discharge activities, environmental impact on fish farming, environmental impact assessments, aquaculture precision farming, support to marine infrastructures
Marine resources (4 %): Aquaculture applications by ASIMUTH consortium, determination of sea lice and larval distribution, Harmful Algal Bloom civilities, determination of carrying capacity **Climate and weather monitoring (29 %)**: ESA Climate Change Initiative

Examples of commercial entities and applications using MyOcean marine services

- **BMT ARGOSS** uses satellite observations and meteorological and oceanographic models to compile and analyse complex and essential environmental information to support planning of maritime operations and design of offshore and coastal structures and environmental impact assessments.
- **Jeppesen** providers of Jeppesen Charts & Navigational Services, including electronic navigational charts and "weather-navigation" route planning tools. This innovative tools combine electronic charts and the most accurate wind and wave forecast into the chart display systems, giving the possibility to plan the optimal sea route for a safe voyage
- **CLS** leaders in satellite-based environmental data collection, locations and ocean-onservations by satellite through Argos. Argos provides environmental monitoring from remote stations, either fixed or mobile, fitted with an Argos transmitter. Sensors on Argos platforms collect data on atmospheric pressure, sea temperature, alarm management for example.

According to the European Commission[18], the EU already invests ~ €110 million per year to support space measurements through the FP7 GMES Initiative. Around €45 million are spent by the EU annually to support the collection of data related to fisheries. Each year at least €815 million are spent by bodies responsible for national defence, coastguards, fisheries, environmental standards and research on environmental monitoring. This conservative and non-exhaustive estimate is based on the spending of France, Netherlands, Spain and UK and upscaled to European level using GDP as a weighting factor, based on the MRAG Ltd approach (Annex 4). The expenditure by private companies may even surpass that of public authorities as indicated by the annual spending of €1.5 billion by a Dutch company specialising in marine data. Figures on the spending by private companies on data related to mineral prospecting, as well as data on waves, currents, tides etc. are usually confidential. According to the study by MRAG Ltd, it is hard to determine accurately the spending that goes to data collection and data processing as result of the fragmented nature of current marine monitoring infrastructure.

[17] Figures taken from presentation by P. Bahurel at the MyOcean Users meeting, April 2011, Stockholm
[18] European Commission, European Marine Observation and Data Network Impact Assessment, COM(2010) 461, SEC(2010) 999

Based on the study by MRAG Ltd (2009), the annual spending for data fleets based on the 5 representative European countries amounts to ~ €208 million, whereas the annual spending by public bodies (ESA, EUMetsat, CNES) for retrieving satellite images is estimated at ~€415 million for 2011. The annual spending by public regulatory bodies is estimated at ~ €13.6 million as compared to ~ €100 billion for private entities (both upscaled to EU-22*). The latter is based on the annual spending of key commercial companies such as Fugro (€1 billion), London Gateway (€11 million), Spot Image (€6.5 million), Total S.A. (€5 million), among others.

The turnover from data users is ~ €91.5 million for public regulatory bodes (all Member States surveyed) as compared to ~ €513 billion for private entities. The latter is based on annual turnover of key commercial companies such as Shell (~€305 billion), Fugro (~€2.2 billion), Total S.A. (~€180 billion), REPSOL (€5.5 billion), London Gateway (~€2.2 billion), among others (MRAG Ltd, 2009).

* average minimum spends extrapolated to EU-22 Member States with coastalines by the GDP, Population, Exclusive Economic Zone (EEZ) and Coastline. Detailes on the upscaling appraoch are found in Annex 4: Upscaling of costs to EU-22.

Although the costs and benefits of ocean observations are uncertain, it remains that they are large and growing. In particular, growth in the value-added sector is expected which will promote employment in the medium term[19]. It is difficult to estimate precisely these benefits since they are interconnected and reach into many sectors of society, making them difficult to track. The economic theory is only beginning to grapple with the valuation of **ecosystem services,** which although not tradable, are nevertheless crucial[20] (Fisher et al., 2010).

According to the European Commission[21], it is estimated that on the whole Europe's current annual spending on ocean data collection and monitoring is above €1 billion for public bodies and about €3 billion for private ones. On the other hand, in the study by MRAG Ltd, the annual spending by public regulatory bodies is estimated at ~ €13.6 million as compared to ~ €100 billion by private companies. This implies that the estimates of spending by public and private entities still remain highly uncertain.

1.3 Regulatory environment

The main European Directives related to 'Environmental Monitoring" are:

a. Marine Strategy Framework Directive (MSFD, aiming at reaching or maintaining a Good Environmental Status by 2020 through the monitoring of environmental indicators grouped under 11 descriptors)[22]
b. INSPIRE Directive (Infrastructure for Spatial Information in Europe)[23]
c. Bathing Water Quality Directive[24]

[19] European Commission, European Marine Observation and Data Network Impact Assessment, COM(2010) 461, SEC(2010) 999
[20] Fisher et al. (2010), Ocean Information for society: sustaining the benefits, realizing the potential, OceasnObs'09 conference statement
[21] European Commission, European Marine Observation and Data Network Impact Assessment, COM(2010) 461, SEC(2010) 999
[22] Directive 2008/56/EC establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive)
[23] Directive 2007/2/EC of the European Parliament and of the Council of 14 March 2007 establishing an Infrastructure for Spatial Information in the European Community (INSPIRE)
[24] Directive 2006/7/EC concerning the management of bathing water quality and repealing Directive 76/160/EEC.

d. The Sustainable Development imperative which is written into the Rome Treaty and is now being developed through the Green Paper on Maritime Policy[25]
e. Environmental Information Directive (on public access to environmental information)[26]
f. Integrated Coastal Zone Management Directive (defines the principles of sound coastal planning and management)[27]
g. Regional Conventions between Member States and the EC – OSPAR/ HELCOM/ Barcelona/ Bucharest Conventions[28]
h. 6th Environmental Action Plan; in particular its Climate Change and Marine Environmental Strategy components[29]
i. Relevant existing EU Directives, such as the Water Framework Directive (WFD) in its application to coastal waters[30]
j. Habitats Directive[31]
k. Urban Waste water directive [32]
l. Common Fishery Policy

Other communications from the Commission:
m. Integrated Maritime Policy for the European Union[33]
n. Common Information Sharing Environment (CISE)[34]
o. Shared Environmental Information System (SEIS) [35]
p. EU's Maritime Policy Blue Book[36]
q. European Marine Observation and Data Network (EMODNet)[37]
r. MARPOL (International convention for the prevention of pollution from ships)
s. Aarhus convention (Convention on Access to Information, Public Participation in Decision-making and Access to Justice) in Environmental Matters

1.4 Strengths and weaknesses for the subfunction

In this respect, “strengths” refer to those factors that contribute towards the growth (e.g. technological advances, synergies with other functions, employment, revenues etc). “Weaknesses” refer to those issues that hinder growth.

Strengths:
1. Advances in observational and communicational technology[38] [39]
2. Development of tools to deal with uncertainties associated with monitoring data (e.g. DUEY-H/WQ-Data Uncertainty Estimation Tool for Hydrology and Water Quality[40])

[25] European Commision Green Paper, Towards a future Maritime Policy for the Union: A European vision for the oceans and Seas, COM(2006) 275 final
[26] Directive 2003/4/EC on public access to environmental information and repealing Council Directive 90/313/EEC
[27] Directive 2002/413/EC concerning the implementation of Integrated Coastal Zone Management in Europe
[28] European Commission, Towards a strategy to protect and conserve the marine environment, COM/2002/0539 final
[29] European Commission, On the sixth environment action programme of the European Community 'Environment 2010: Our future, Our choice', COM (2001) 31 final
[30] Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for the Community action in the field of water policy" or, in short, the EU Water Framework Directive
[31] Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora
[32] Directive 91/271/EEC concerning urban waste-water treatment
[33] European Commision, An Integrated Maritime Policy for the European Union, COM(2007) 575 final
[34] European Commission, Towards the integration of maritime surveillance: A common information sharing environment for the EU maritime domain, COM(2009)538 final
[35] European Commision, Towards a Shared Environmental Information System (SEIS), COM(2008) 46 final
[36] COM(2007) 575 final
[37] European Commission, Building a European marine knowledge infrastructure: Roadmap for a European Marine Observation and Data Network, SEC(2009) 499
[38] e.g. Veenstra and Churnside, 2011
[39] e.g. Dessi et al, 2008

3. Real-time monitoring e.g. Argo[41], water quality such using new technologies, automated mapping of the intertidal beach bathymetry from video images Coast 3D ARGUS[42]
4. Automation of monitoring instruments, e.g. biosensors[43]
5. Enhanced system knowledge and forecasting capabilities
6. Operational and real-time forecasting as data services/products[44]
7. Value-added benefit from free access to data[45]
8. Multiplier effect due to data sharing e.g. through establishment of Common Information Sharing Environment (CISE)[46]
9. Multidisciplinary, multi-sectoral approach in data collection*
10. Integrated monitoring combining in situ, space data[47] and models[48]
11. Extensive spatial and temporal coverage, in particular through combination of techniques
12. International cooperation that enhances possibilities to learn from each other through knowledge exchange e.g. GEOSS[49]

Weaknesses:

1. Inherent uncertainties in observational data[50]
2. Fragmentation of environmental monitoring. In this context, fragmentation refers to the geographically-scattered activities, at the national, regional and European level[51], the lack of coherence in format and method of data collected within same sectors as well as across sectors
3. Different policies by different MS with respect to intellectual property rights and charging[52]
4. Risk of duplication of efforts without proper coordination at each regional level[53]
5. High costs of environmental monitoring programmes (data collection, analysis and processing)[54]
6. High demand for skilled employees[55]; high costs of skilled employees*
7. Lack of standardization[56]
8. Lack of long term vision; ad hoc actions; lack of continuity in observations[57]*
9. Relative small size of the function that limits innovation*
10. Budget problems and tension between economy and ecology*
11. Slow implementation of monitoring due to bureaucracy/politics and economic downturn*
12. Lack of data sharing[58] between public and private entities (usually confidential)*

---

[40] Bende -Michl et al., 2011
[41] Argo brochure: An array of profiling floats observing the ocean in real-time. Five years of progress, decade of potential
[42] Uunk et al., 2010
[43] e.g. Diercks-Horn et al., 2011, Diercks et al, 2008
[44] e.g. http://www.myocean.eu.org/
[45] European Commission, European Marine Observation and Data Network Impact Assessment, COM(2010) 461, SEC(2010) 999
[46] European Commission, Towards the integration of maritime surveillance: A common information sharing environment for the EU maritime domain, COM(2009)538 final
[47] e.g. Brown et al., 2011
[48] Send et al. (2010)
[49] http://www.earthobservations.org/
[50]e.g. Bende -Michl et al., 2011
[51] European Commission, European Marine Observation and Data Network Impact Assessment, COM(2010) 461, SEC(2010) 999
[52] MRAG Ltd (2008), Legal Aspects of Marine Environmental Data Framework Service Contract, No. FISH/2006/09 – LOT2, final report, October 2008
[53] European Commission, Building a European marine knowledge infrastructure: Roadmap for a European Marine Observation and Data Network, SEC(2009) 499
[54] MRAG Ltd. (2009), Marine Data Infrastructure, Framework Service Contract, No. FISH/2006/09
*based on opinions of interviewees
[55] Ryder (2007), Sustainable Marine Environmental Information Services to Meet Collective European Needs
[56] European Commission, Building a European marine knowledge infrastructure: Roadmap for a European Marine Observation and Data Network, SEC(2009) 499
[57] Ryder (2007), Sustainable Marine Environmental Information Services to Meet Collective European Needs

13. Cross-border interoperability for data sharing is still in development[59]
14. Cross-border issues and cooperation are poorly addressed*
15. Less efficient monitoring programmes/devices that collect data for single purpose[60]
16. Limited intermediate and downstream services that benefit from investment in upstream technologies[61]
17. Limited intermediate level services that make data available for downstream applications
18. Lack of common standards, lack of quality control [62]
19. Implementation of science- based policies slower than environmental degradation*
20. Competition from outside markets e.g. China and India*
21. Lack of transparency in current regulations with regards to who can be involved and who can get funded for development projects*
22. Exchange of information usually through official and time consuming application protocols*
23. DRIP syndrome (Data Rich Information Poor Syndrome) [63]

---

[58] European Commission, European Marine Observation and Data Network Impact Assessment, COM(2010) 461, SEC(2010) 999

[59] Ryder (2007), Sustainable Marine Environmental Information Services to Meet Collective European Needs

[60] European Commission, Building a European marine knowledge infrastructure: Roadmap for a European Marine Observation and Data Network, SEC(2009) 499

[61] Presentation from N. Pinardi on "MyOcean- Overview, gaps and needs"

[62] MRAG Ltd (2008), Legal Aspects of Marine Environmental Data Framework Service Contract, No. FISH/2006/09 – LOT2, final report, October 2008

[63] Timmerman et al., 2010

*based on opinions of interviewees

2 Research and technology

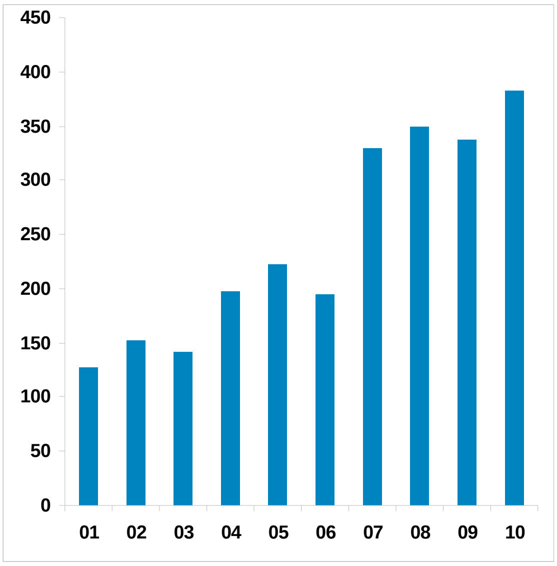
2.1 Research & technology patterns

It is difficult to estimate the amount of Research & Technology carried out in the field of Environmental Monitoring, given the wide arrange of activities it comprises and actors involved. Nevertheless, certain indicators such as the number of inventions, publications, inventions, citations, and patents can provide fair estimates of global trends in research and technology and EU's position.

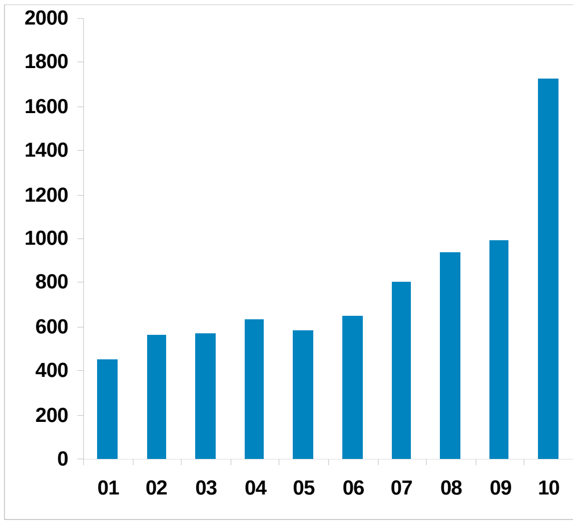
The overview shows an increase in both patents (from 127 in 2001 to 382 in 2010) and publications (from 450 in 2001 to 1724 in 2010). Inventions seem to follow a three-year cycle of slight increase and decline, however overall have increased in a 10 – years period.

Table 2.1. Total number of global inventions and publications related to Environmental Monitoring (2001 – 2010)

Inventions



Publications



Source: Thomson Reuters

The rising number of global inventions and publications in the course of the last decade gives a clear outlook of the increasing importance of Research and Technology in this function.

The table below compares EU-27 countries in terms of patents filed on their grounds, with competing countries (2001–2010). Priority country means the place where the invention was invented and filed.[64]

[64] Priority country is used in the absence of an inventor country within the patent statistics. The particular field is not present across a good amount of authorities

Table 2.2. Country score in inventions related to Environmental Monitoring

Priority countries	Total inventions (2001 - 2011)	% of global
US	1241	33%
Japan	669	18%
EU-27	576	15%
China	331	9%
South Korea	237	6%
Global	3765	

Source: Thomson Reuters

Figures above indicate that in terms of Environmental Monitoring, the US is leading in terms of inventions, with one third of global inventions in this subfunction. Japan follows with 18%, followed by the EU-27 countries ranking third.

Table 2.3. Country score in scientific citations related to Environmental Monitoring

Priority countries	Total citations (2001 - 2011)	% of global
EU-27	16796	47%
US	8114	23%
Japan	1585	4%
China	642	2%
South Korea	291	1%
Global	35956	

Source: Thomson Reuters

Table 2.4. Country score in published papers related to Environmental Monitoring

Priority countries	Total published papers (2001 - 2011	% of global
EU-27	3395	34%
US	2725	27%
China	499	5%
Japan	460	5%
South Korea	126	1%
Global	9934	

Source: Thomson Reuters

Despite the comparably strong position of the US in terms of inventions, the EU-27 is nevertheless leading in total published papers and total number of scientific citations related to them. Since published papers and scientific citations can be considered a certain indicator for future inventions, the table above can be also interpreted as a basis for future growth.

Table 2.5. Top 20 global patent assignees - organizations or individual owners of the patent's invention - are presented in the table below in Environmental Monitoring:

Top assignees	Total number of patents filed (2001- 2011)
MITSUBISHI GROUP OF COMPANIES	87
BOEING CO	84
TOYOTA JIDOSHA KK	38
JAPAN RADIO CO LTD	36
US SEC OF NAVY	25
LOCKHEED MARTIN CORP	24
HITACHI	20
THALES	20
HONEYWELL INC	19
SCHLUMBERGER TECHNOLOGY CORP	19
NEC CORP	18
TERAHOP NETWORKS INC	18
FUJITSU LTD	16
ELECTRONICS & TELECOM RES INST	15
FURUNO DENKI KK	15
GENERAL ELECTRIC CO	15
KOREA OCEAN RES&DEV INST	15
CHINESE ACADEMY OF SCIENCES	14
SONY CORP	14
GARMIN CORP	13

Source: Thomson Reuters

2.2 Overview of the main EU research projects (incl., among others, FP6 & FP7 projects)

Project Acronym	Description
Marine Data infrastructures	
EURO ARGO	Global ocean observing infrastructure- European component
SeaDataNet	Pan-European Infrastructure for ocean and marine data management
SeaDataNet II	Upgrade present SeaDataNet infrastructure into an operationally robust and state-of-the-art Pan-European infrastructure
JERICO	Towards a Joint European Research Infrastructure Network for Coastal Observatories
GEO-SEAS	Pan-european infrastructure for management of marine and ocean geological and geophysical data
NETMAR	Open service network for marine environmental data
EMSO	European multidisciplinary seafloor observation
LifeWatch	e-science and technology infrastructure for biodiversity and ecosystem research
In situ observing systems	
ACOBAR	Acoustic technology for observing the interior of the Arctic Ocean
HYPOX	In situ monitoring of oxygen depletion in hypoxic ecosystems of coastal and open seas, and land-locked water bodies
FerryBox	From on-line oceanographic measurements to environmental information
ARGOMARINE	Automatic oil-spill recognition and geopositioning integrated in a marine monitoring network
Sensor Technologies	
PROTOOL	Productivity tools: Automated tools to measure primary productivity in European seas. A new autonomous monitoring tool to measure the primary production of

	major European seas
HYDRONET	Floating sensorised networked robots for water monitoring
SHOAL	Search and monitoring of Harmful contaminants, other pollutants and leaks in vessels in port using a swarm of robotic fish
MOBESENS	Mobile water quality sensor system
EO-based observing systems	
EO2HEAVEN	Earth Observation and ENVironmental modelling for the mitigation of HEAlth risks
SIOS-PP	Svalbard Integrated Arctic Earth Observing System - Preparatory Phase
GEOSS/GMES	
GFG2	GNSS for Global Environmental Earth Observation (GEEO) and GEOSS (Global Earth Observation Systems of Systems)
GIGAS	GEOSS Inspire and GMES an action in support
GENESIS	GENeric European Sustainable Information Space for environment
MERSEA Strand1	Marine Environment and Security for the European Area builds on the current European capabilities for development, implementation and operational use of marine modelling and data assimilation systems, space-borne observations and in-situ observing networks and systems (GMES Initial)
MERSEA	Follow-up of MERSEA Strand1 to build the ocean component of GMES (GMES Demonstration)
MyOcean	Development and pre-operational validation of upgraded GMES marine core services and capabilities (GMES Implementation) See above
GMES downstream services	
BIO_SOS	BIOdiversity Multi-Source Monitoring System: from Space TO Species Research area:
MYWATER	Merging Hydrologic models and EO data for reliable information on Water Research area
SEAU	Multisensor Satellite Technologies for Oil Pollution Monitoring and Source Identification
CoBiOS	Coastal Biomass Observatory Services
AQUAMAR	Provide EO based water quality services to support European and national monitoring agencies and industries operating in coastal waters
ASIMUTH	Forecasting HABs to give advanced warning of the impending problem to the aquaculture industry
SIDARUS	Sea Ice Downstream Services for Arctic and Antarctic Users and Stakeholders
SUBCOAST	Development of a GMES-service for monitoring and forecasting subsidence hazards in coastal areas around Europe
EAMNET	Europe Africa Marine Network linking Earth Observation (EO) information providers, user networks and centers of excellence in Europe and Africa in the area of coastal and marine observations towards sustainable development in Africa.
MONARCH-A	Monitoring and Assessing Regional Climate change in High latitudes and the Arctic
Integrated Projects	
DISMAR	Data Integration System for MARine pollution and water quality
MERSEA	Development of a European system for operational monitoring and forecasting of the ocean physics, biogeochemistry, and ecosystems, on global and regional scales.
ECOOP	Building up of a sustainable pan-European capacity in providing timely, quality assured marine service (including data, information products, knowledge and scientific advices) in European coastal-shelf seas.
INCAM	Improving National Assessment and Monitoring Capacities for Integrated

	Environmental and Coastal ecosystem Management
GREENSEAS	Development of global plankton data base and model system for eco-climate early warning
FISH4KNOWLEDGE	Supporting humans in knowledge gathering and question/answering marine and environmental monitoring through analysis of multiple video streams
CORALFISH	Assessment of the interaction between corals, fish and fisheries, in order to develop monitoring and predictive modelling tools for ecosystem based management in the deep waters of Europe and beyond
Others	
LENVIS	Localised environmental and health information services for all: User-centric collaborative decision support network for water and air quality management
ESA-funded	
MarCoast	Marine and Coastal Environmental Information Services
Medspiration	Developing a European service for near real-time precise sea surface temperature
GlobColour	Developing a European service for ocean colour
Regional	
COSYNA (Germany)	Coastal Observation System for Northern and Arctic
SmartBay (Ireland)	A test and demonstration platform for the development of innovative products and services for the global maritime sector
BONUS programme	Includes a number of projects related to the Baltic Sea system into a joint and durable interdisciplinary and focused multinational programme that supports the Baltic Sea region's sustainable development
COMBINE programme	Cooperative Monitoring in the Baltic Marine Environment. Programme on how the Baltic Sea Action Plan (BSAP) will affect national monitoring of eutrophication and hazardous substances (contaminants) and their effect on the Baltic Sea
International	
AERONET	AErosol RObotic NETwork is an optical ground based aerosol monitoring network and data archive supported by NASA's Earth Observing System and expanded by federation with many non-NASA institutions. The network hardware consists of identical automatic sun-sky scanning spectral radiometers owned by national agencies and universities. Data from this collaboration provides globally distributed near real time observations of aerosol spectral optical depths, aerosol size distributions, and precipitable water in diverse aerosol regimes. Currently, two recording devices are installed in the Baltic Sea and around 250 around the world. The data can be used for European and NASA satellite optical validation (main monitoring tools for phytoplankton blooms and forest cover).

A list of key technological developments grouped under a) In situ monitoring and b) Remote Sensing is given below. The descriptions of the technological developments can be found in Annex 5.

a) In situ monitoring

- Autonomous Underwater Vehicle (AUV)
- Gliders
- Smartbuoys
- ScanFish
- FerryBoxes
- Ships of opportunity (Programme)
- Voluntary observing ships (VOSs)

b) Remote sensing

- Argos
- Platform transmitter terminals (PTTs)
- Telemetry/Satellite tagging technology
- Airborne sensors

According to *Export America Magazine*[65], the United States is the world's largest producer and consumer of environmental technologies. The U.S. environmental instrumentation revenues are estimated to be 33 % of the international environmental instrumentation market. These technologies include goods and services that promote sustainable development. U.S. companies are in this good position relative to their foreign competitors, mostly from Japan and Germany owing to their advanced analytical requirements. France, Germany and the United Kingdom are the three European countries in the top 10 markets for U.S. environmental technologies. This does not necessarily mean that there are no leading European companies in environmental technology. To mention a few: UK-based Surrey Satellite Technology[66] manufacturers of small satellites and EO technologies, Danish company EIVA[67], providers of software, products, integrated system solutions and services for application within the offshore and marine survey industry such as ScanFish, Others include Chelsea Technologies Group[68], experts in the design and manufacture of sensors and systems and SRMU Ltd.[69], developers of specialist tools to collect, access and analyse marine mammal data such as PAMBuoy[70].

On the other hand, a review of Chinese and European marine monitoring systems such as in-situ observing systems, space-borne observing systems, data integration and information management, ocean and coastal information products and services, carried out as part of FP6 Specific Support Action Dragoness[71] showed that Europe has more advanced technology on the monitoring arrangement, accuracy, data products both in quantity and quality. However, China and Europe marine observations have obvious respective geographical characteristics making them multi-compensate. Therefore collaboration between European and Chinese marine monitoring initiatives greatly contributes to GMES and GEOSS.

[65] *Export America Magazine* (2002), Global Environmental Technologies: Trends, Markets, and Prospects by the Office of Environmental Technologies Industries, Trade Development, Vol 3 No 11
[66] www.sstl.co.uk
[67] www.eiva.dk
[68] www.chelsea.co.uk
[69] www.smru.co.uk
[70] www.pambuoy.com
[71] http://dragon2.esa.int/projects?sr=5334

3 Future developments

3.1 External drivers affecting the performance of the sector

The majority of the interviewees agree that the performance of “Environmental Monitoring” is strongly determined by the **economic climate**. Budgetary restrictions by governments have a direct effect of national monitoring efforts, as countries are less inclined to invest in new technologies and tend to continue using old technologies. It may also result in an impediment to expand or introduce new monitoring programmes. According to one interviewee, the general tendency in Europe is to reduce the size of the public sector and thus potentially also the number of people involved in environmental monitoring.

Opinion of interviewee *“There is always a dilemma between knowing better in order to conduct better supervision versus the efficiency push and budget cuts. In this respect, monitoring should not be considered as a project but as an infrastructure, a continuous process. It therefore deserves structural financing….”*

Policy and the obligation of the Member States to implement directives and to demonstrate compliance are other drivers that steer the development of environmental monitoring. For example, the implementation of the WFD and the MSFD require compliance monitoring as a way to demonstrate Good Ecological/Environmental Status. However, according to one interviewee, no real growth can be observed in public expense on monitoring even though the MSFD introduced additional monitoring obligations. Besides, the Environmental Impact Assessment (EIA) is a further policy driver for growth within that subfunction.[72] Through various initiatives, such as CISE and SEIS, a progressive development towards a more integrated monitoring strategy and free access to data is supported. This, in turn, is expected to lead to more downstream services. Improving the accessibility and availability of data will increase competition to deliver value-added products. Better data not only improves the efficiency of existing services but allows for the development of new services. At this stage, however, it is notoriously difficult to assess what these new services will be. The role of policy as an external driver is confirmed by several interviewees.

Environmental problems are considered by some interviewees to be external drivers themselves for environmental monitoring. These include both environmental degradation due to increased pressures, as well as other environmental damages resulting from hazardous events, such as oil spills and other accidents, such as the recent tsunami and nuclear accidents in Fukushima. In the latter case, integrated monitoring including operational oceanographic models proved highly essential in simulating the dispersion and estimating the impact of the radioactive seawater.

Other external drivers include **innovation** that steers the continuous development and improvement of techniques. **Global drivers, such as demographic and climate change**, demand for increased monitoring to provide a solid background for management decisions and to close the underlying knowledge gaps.

[72] Further reading: http://ec.europa.eu/environment/eia/eia-legalcontext.htm

Opinion of interviewee

"Technological breakthroughs in monitoring technology through e.g. high quality and innovative space research, are themselves a driver for attracting highly skilled people to Europe. This is of very high value for the market...."

3.2 Assessment of response capacity and commercialisation potential

While budget restrictions are assumed to have a negative impact on monitoring, at the same time they can be a key driver pushing towards more efficient and cost-effective **integrated monitoring efforts.** The integration of monitoring infrastructure and data gives value-added benefits through the harmonization of multidisciplinary data sets and supports downstream services, e.g. charting/cartography, and emerging industries, e.g. marine biotechnology. As shown by the Australian IMOS project on *Integrated Marine Observing System* and US IOOS project on *Integrated Ocean Observing System*, financing data management within an integrated initiative is driven by the high anticipated economic potential. For example, the investments of €100 million in IMOS have been granted based on an expected economical application of €1 billion. Based on the United States' and Europe's own estimates of the opportunity cost of relying on a fragmented rather than an integrated marine observation infrastructure, it is estimated that the reduction in associated operational costs is worth €300 million[73]. This conservative estimate is not only the result of enhanced efficiency of existing data users but also includes benefits through new opportunities for innovation and growth.

Increased commercialization potential is also expected from data that is made **publicly available**. There is evidence that data sharing and making data available to the public domain have resulted in significant revenue returns in the US[74], where the development of new products is relatively easier. This appears to be much less the case in Europe, where as confirmed by one interviewee, it takes a lot effort to assemble a pan-European map due to non-harmonized data, for instance. This assumption can not be entirely supported since efforts to achieve harmonized data are already underway through, for example, the INSPIRE directive. Further efforts at EU level are provided within the CleanSeaNet project which provides a near-real-time satellite-based oil spill and vessel monitoring service. The service provides a range of different products to the Commission and to EU Member States. [75]

A questionnaire distributed to EU Member States as part of a recent survey by Milieu Ltd. (2011)[76] on **the use of offshore industrial monitoring data for MSFD monitoring purposes**, shows that the majority of the countries believe that further use of industrial data could be beneficial, despite a number of concerns over re-use. The use of industrial monitoring data for MSFD reporting could be best optimized if the indicators of the 11 MSFD descriptors are included as required data for baseline EIA studies. Indeed, this approach has already been recently adopted by Spain. Some of the mentioned limitations include dataset longevity, infrequent monitoring or limited number of parameters, as well as issues related to data ownership and commercial sensitivity. Also, the current approaches for data collection within the scope of EIAs/SEAs vary from country to country and are subject to historical agreements. For most countries, it would be an expensive and time-

[73] European Commission, European Marine Observation and Data Network Impact Assessment, COM(2010) 461, SEC(2010) 999

[74] European Commission, Building a European marine knowledge infrastructure: Roadmap for a European Marine Observation and Data Network, SEC(2009) 499

[75] Further reading: http://emsa.europa.eu/operations/cleanseanet.html

[76] Milieu Ltd. (2011), Use of industrial monitoring data for MSFD reporting purposes, Service Contract No. 070307/2010/579390/SER/D2 – Task W

consuming process to review/renegotiate historical agreements over data ownership/use. Stakeholders would have to be consulted prior to any proposed legislation/ policy. Nevertheless, approximately half of the responding countries considered that there was greater potential for collaboration between public (governmental) and private (owners/operators and contractors) organizations in undertaking monitoring. This collaboration could also be in the form of sharing staff and resources (ships, sampling and analytical equipment). If, as the survey suggests, most countries are willing to explore the further use of industrial monitoring data, a first step would be to make a preliminary assessment of whether such re-use of industrial data for MSFD reporting obligations outweighs the potential efforts required to reach agreement on use. Another proposal for reducing the financial burden of MSFD monitoring purposes is through the financial contribution of offshore industry via license fees or additional levies in line with the **polluter pays principle**.

The increased demand for **cheaper technology, more efficient monitoring**, such as automatic cleaning ferry boxes, reduced labour costs and new sensor technologies will reduce costs of monitoring. At the same time, this will encourage free public access to data and enhance the export potential of both data and monitoring equipment. The combination of more efficient data collection, innovative equipment and increased export potential is key for increasing the commercialization potential.

> Opinion of interviewee
>
> *"USA leads the state of the monitoring "market", in particular in the fields of physical oceanography. Access to data is free in USA, putting USA in a much better position as compared to Europe. Although European counter data services now do exist, such as data products from MyOcean, the European private sector is not always aware of that and still revolts to US services. Efforts should be put in creating awareness, trust and demonstrating the applicability of European data products. One way would be to integrate these core services in the business plans of private companies. With respect to global ocean operational modelling, Europe through MyOcean can be regarded both as a competitor, by trying to achieve better forecasts, as well as collaborator, e.g. through datasharing, with USA...."*

In line with the future movements towards integrated monitoring, cost-effective options such as **multipurpose and multisectoral** (e.g. voluntary observing ships) are now being considered. Such developments will present new opportunities for commercial companies and SMEs manufacturers of sensors and other instruments. There is a similar movement to make more efficient use of the ship time of a research vessel by sharing it with different knowledge institutes. Although such vessels are currently restricted to national spaces, integrating these ideas at the European scale could benefit all. As mentioned by one interviewee, in general it can be stated that most profitable and affordable improvements are the result of *unconventional* applications, such as the environmental monitoring of the ocean by recreational sailing vessels (Volvo Ocean Race) and the application of downstream services for leisure market (wind, wave surfing, fishing). Generally data is gathered for primary uses. However, in line with multi-purpose philosophy of data collection, secondary complementary purposes should be also developed in order to maximize added-value for the same costs and efforts. Data on, for example, marine biodiversity may be more difficult to collect than data related to physical state. In such cases, multisectoral data integration may be comprised by the quality/depth of data.

Improved monitoring infrastructure also contributes towards **reduction of uncertainties**. If we assume that a better monitoring infrastructure reduces the uncertainty in sea-level rise by 25%, then €100 million of direct savings in coastal defence infrastructure are likely[77]. A study[78] suggests

[77] European Commission, European Marine Observation and Data Network Impact Assessment, COM(2010) 461, SEC(2010) 999

that an expenditure of €70 million on mapping Irish waters would reduce uncertainty to industry, leading to an increase in benefits of €450 million to fisheries, aquaculture, biodiversity, renewable energy and other related industries. Better seasonal forecasts and better fish stock assessments will also result in even greater savings but more work is necessary to determine whether better data alone can deliver these benefits.

To assess the response capacity and commercialisation potential, it is important to be able to **anticipate the drivers**, such as offshore wind parks and their impact on ecosystem. Renewable energy is for sure one of the most potential sectors. According to one interviewee, in UK alone 1 € billion are spent annually on data collection related to renewable resources, although the implementation of such monitoring programmes stimulated by emerging drivers is usually a slow process (10 to 20 years minimum).

There is still potential for the growth of **commercial downstream applications** envisaged for the next of 5-10 years. Yet given the small size of this function with most SME's active in the field, the resulting employment increase will be marginal. The commercialization potential is limited by the size, which also hinders the pace of innovation.

In general the highest growth potential is still envisaged for the private sector, followed by research and public monitoring. One of the ultimate functions of monitoring is to bring the different communities together next to the policy-making and scientific interface

[78] Price Waterhouse Cooper (2008), INFOMAR Marine Mapping Survey Options Appraisal Report

Monitoring for Coastal Protection purposes

As elaborated in the subfunction profile on *Coastal Protection,* coastal protection against flooding and erosion starts with data collection to assess the risk for flooding, erosion and submerging shores, followed by the design and ultimately the implementation of coastal protection measures. After construction, monitoring and maintenance is a requisite to guarantee the required protection level.

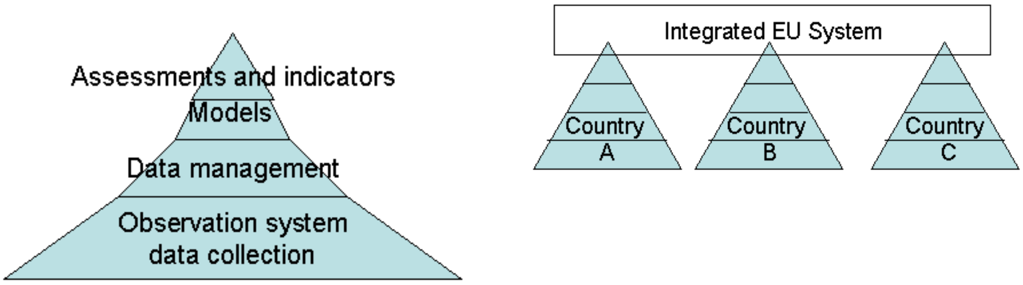
Monitoring morphological change is useful in designing maintenance operations, but does not allow for improved forward planning of coastal management. Additional meteorological and sea state information is required to understand the processes leading to change. This is because coastal dynamics are driven by multiple processes that are active over different time scales, ranging from very long time scales, such as changes in relative sea level, changes in the total volume of sand available to the coast or changes in climate, as well as short time-scale, including tides, storm surges, winds and waves. Effective decision making thus demands for the availability of detailed coastal state information with sufficiently high resolution both in time and space.

The integration of multiple methods, such as *in situ* data collection, video-based coastal imaging system and numerical modelling provides a powerful combination for monitoring coastal erosion. The application of coastal monitoring systems can be also extended to other issues that are part of coastal zone management. For instance, a video imagery technique primarily installed for the quantification of shoreline evolution can have other multi-purpose and multi-sectoral applications, ranging from ecological (e.g. spatial quantification of areas covered by vegetation), socio-economic (e.g. quantification of beach users), safety and surveillance (monitoring of the development of rip currents that pose a serious threat for swimmer safety) and recreational (quantification of wave parameters for recreational activities) purposes.

Forward planning based on robust marine data e.g. on climate change, meteorology and other physical data enables planners, engineers and policy makers to incorporate improved risk and uncertainly analysis in planning and analysis of risks associated with the marine environment. The consideration of improved risk and uncertainty data in business planning, project financial and economic analysis will ultimately lead to cost reductions, enhancing the commercialization potential of such techniques.

3.3 Most likely future developments (the Micro-future)

Currently the monitoring value chain can be described as having a hierarchical structure (left) with “observation systems and data collection” at the bottom rising towards “assessments and indicators” on a country-to-country basis. As a result of the proposed cohesion and integration strategies, such as through the Marine Strategy Framework Directive as a foresight activity to the unified goal, a more horizontal structure (right) is expected. The integrated structure will ensure continuity which will result in a competitive advantage of the EU in relation to the USA. This cohesion demands for quality and standardization with relation to metadata and terminology. The plan of establishing the European Centre for Ocean Monitoring and Forecasting (ECOMF) is a step in this direction.



The future developments are highly dependent on the political field. One interviewee suggests that the development of environmental monitoring could go in two ways:

- **Top down**: The EU will create preconditions by ensuring a level-playing field. Furthermore, the EU will oblige the Member States to have comparable methods. ICES currently is preparing guidelines on this issue
- **Bottom up**: the parties in the sector are motivated themselves and see the need to tune to each other's methods

However, other general scenario's are also suggested:

- **Environmental monitoring will boost**, because of the introduction of the MSFD leading to the generation of a valuable monitoring industry in 2025
- **Environmental monitoring will stagnate** due to fragmentation in policies between Member States, resulting in lack of standardization, integration and commitment to environmental issues. Minimizing efforts also means that compliance monitoring will prevail

In general, according to the opinion of the interviewees, well-funded countries may go to full implementation of adaptive management systems, adopt the DPSIR elements and integrate all important stakeholders in the value chain of the ecosystem services delivery. Other regions/countries may adopt a more compliance-oriented monitoring approach (thresholds, targets, checking towards a decision support system).

The following future perspectives are proposed during the interviews:

<u>Governance and policy:</u>

- better access to data as a result of increased global cooperation
- open and free data policy
- open circulation of skills, data, information as a key factor for innovation, societal benefits and sustainability (ambition of MyOcean for coming decade)
- monitoring of new parameters in the open sea motivated by MSFD, possibly prompting new fields of monitoring. Nevertheless, this would only be stimulated if the EU would provide the necessary funds
- harmonization of policies (See Section 4)

<u>In situ monitoring:</u>

- use of automated instruments in open sea; Euro Argo floats and gliders development
- technological development to extend the power supply of moorings, to improve data transmission, durability and cost-effectiveness of platforms
- addition of sensors (e.g. prototype sensors for oxygen, rainfall and bio-optical variables, carbon and pH sensors) to existing networks of Lagrangian buoys (drifting buoys, profiling floats, gliders)
- extension of monitored parameter suite to new carbon (DIC and total alkalinity) and pH sensors on moorings to help constrain ocean carbon changes

- extension of monitoring equipment of mooring by acoustic sensors for measuring biological variables
- observations of photosynthetically active radiation, bio-optical variables and ocean colour can along with the use of acoustic sensors for various applications, such as surface precipitation and biological measurements.
- pilot project deployment of new sensors to help develop observing platforms to their full potential
- use of commercial ships, ferries and cruise boats to collect data and provide sustained observations, as well as analyse samples on board (TNO and NIOZ in The Netherlands already have different technologies that enable such field monitoring)
- use of VOSs. This, however, will require improved sensors and systems (higher quality, long-term stability, improved data transmission)
- network of VOSs in coastal regions expected in increased to improve for example the spatial coverage
- strong monitoring network in open sea; extension of current ESOnet pole network
- extension of existing global network of moorings for long-term timeseries (OceanSITES-type)
- underwater networks of observatories to provide infrastructure on sea floor, including power and communication to individual applications
- participation of gliders in the global ocean observing system
- biogeochemical sensors, payload capacity, battery duration, and ease-of-use of EGO gliders

- simultaneous use of a fleet of gliders. *A rough estimate of resources required is about 13 million $/euro for ~20+ gliders permanently at sea during five years in the world oceans, based on present scientific infrastructures*[79]

> *"We really are about to enter into a new era in oceanography with gliders providing many contributions to sustained ocean observations in the coming decade. We are mainly limited by our imagination and available funding…."*
>
> Testor et al., *Glider White Pape*r 2010

Remote sensing technologies: The establishment of satellite series for sustainable service availability leads to significantly lower production costs compared to the optimization of the specifications and design for any one particular satellite and its instruments. The latter leads to expensive, non-renewable satellites

- increased importance of hyper-spectral technology to increase the number of biogeochemical and ecosystems variables that can be monitored
- increased space-time resolution of individual satellite missions and sensors
- increased space-time sampling emerging from constellations of satellites
- increased use of SAR and ALT technology to improve information about sea ice
- elaborate intercalibation procedures between satellite missions and old/new technology
- new communication technologies coupled with GPS navigation to remove the present restrictions on data transmission in Argo
- focus on strengthening EO monitoring applications through environmental projects (Research Infrastructures)[80] by European Forum Strategy for Research Infrastructure[81] in the next 20/25 years

---

[79] Testor et al. (2010)
[80] List of ESFRI Research Infrastructures in the next 20/25 years
1) COPAL – Heavy payload long endurance tropospheric aircraft
2) EISCAT3D – The next generation European incoherent scatter radar system
3) EMSO – European multidisciplinary seafloor observatory
4) EPOS – European plate observing system
5) Euro-ARGO – Research infrastructure for ocean science and observations

Because of the global scale and complexity of environmental research, and the high costs of environmental Research Infrastructures, international collaboration is essential. Natural partners of pan-European Research Infrastructures are global research and monitoring programmes launched by international organisations. Some Research Infrastructures, in particular SIOS, EISCAT_3D and EPOS have participating organisations from outside Europe. Others, such as ICOS, EURO-ARGO and Lifewatch have activities with international research programmes. Currently discussions are on-going with NSF (National Science Foundation) and NOAA (National Oceanic and Atmospheric Administration) to establish closer cooperation between ESFRI and these organisations.

Other:

- development of appropriate technologies to move from single-purpose to multipurpose data
- collection and use
- emphasis on detection and forecasting of algal blooms
- developments in data transfer/ data communication technology. For example, environmental monitoring for offshore sector is expensive. New developments by European companies in offshore connections that include wireless technology are needed. (Currently only American companies such as Intel, Cisco have such products in the testing phase)
- better capacities to deal with large databases, including data storage, database design
- infrastructure for data sharing, such as the initiative by CarbonTrust (UK)[82] as a broker of data from 12 companies involved in the construction of wind parks

The envisaged strategy is **data assimilation** of in situ measurements, remote sensing in oceanographic models. The strength lies in a combined package, which would generate the most benefit and optimize the validation. This falls within the objective of the follow-up of MyOcean (2009-2012), MyOcean2 (2012-2014) *to continue, develop, improve the GMES Marine service for ocean monitoring and forecasting and prepare transition to GMES operational phase.* Other aspects for integration include the reinforcement of the link to EuroGOOS, pan-European technical coordination and user training.

Currently satellite images do not always provide the necessary information and therefore when combined with ecosystem modelling, better understanding would be reached on marine phenomena in the sea: nutrient cycles, nitrification processes, the degree of transparency. The focus will be on monitoring blooms and on finding mechanisms to mitigate and reduce nutrient inputs. After 2025, there would be a joint network for Europe where all near real time systems and activities will combined together. This will provide search databases, which are connected directly to the network. A request would be handled by a centralized database system, which would provide flexibility. A requirement for this to happen is the further development of cross border activities.

One interviewee mentioned that social media will play a major role in the future, allowing for the direct involvement of the general public. There are already some examples of contribution from the public to environmental monitoring, e.g. SYKE (Finland) is developing a system through which the general public can send observations of phytoplankton blooms in the form of georeferenced pictures that can be used to determine the degree of damage. This kind of feedback is envisaged to become more common. However, it is not exactly known how the participation of private citizens to

6) IAGOS-ERI – In-service aircraft for a global observing system
7) ICOS – Integrated carbon observation system
8) LIFEWATCH – Science and technology infrastructure for biodiversity data and observatories
9) SIOS – Svalboard integrated Arctic Earth observing system

[81]ESFRI (2011) Strategy Report on Research Infrastructures Roadmap 2010

[82] www.carbontrust.co.uk

data information would affect monitoring. Until recently only environmental actors and policy makers had the right to decide on environmental issues. However, if society becomes more open to information, it might evoke unforeseen expectations for environmental monitoring. It will also force politicians to act quicker on environmental issues.

3.4 Impacts, synergies and tensions

Environmental monitoring provides synergies and benefits for a wide range of maritime functions and sub-functions: from algae growing and blue biotechnology to all energy sub-functions as well as leisure and tourism functions. Synergistic interactions exist between subfunction 6.3 Environmental Monitoring and functions 1 to 4[83], as the sustainable development of latter sectors contributes towards the growth of environmental monitoring. For instance, the development of offshore windparks will demand for new developments in monitoring, such as new measuring set-ups, new constructions, new traffic to database, extra database services and data validation needs that will in turn generate new employment and economic **opportunities**. In relation to the energy sectors, environmental monitoring is not only necessary for the optimization of exploration and production activities but also for better management and minimization of the negative environmental impacts. Environmental monitoring services can also be used in junction with coastal protection purposes. On the other hand, the risk for erosion and flooding may result in increased efforts in environmental monitoring.

The **strength** lies in the combination of the three aspects of observations (namely remote sensing, in situ observations and modelling) and the integration of monitoring strategies at a European scale. Together this will generate new powerful insight and forecasts, and coherence. The implementation of integrated monitoring systems will not only benefit the producers of instruments and services, but also provide added-value societal benefits. Monitoring can then generate a large macro-economic effect.

However, the major **threat** to defragmentation and integration at the European scale is the nationalistic behaviour of countries. As expressed by one interviewee, *'The Dutch will not readily use a French instrument'.* Each country looks at its own environment implying that reinventing the wheel in unavoidable. The official national institutes have primary national duties, which might differ from the other countries. This hinders the standardization and the European goal of a unified monitoring system. Further, the exchange of information is another significant threat.

A matrix table relating impact indicators to the medium-term and longer-term developments in the European seas[84] is given in Annex 6. The selected indicators describe economic, employment, environmental and other impacts.

[83] Function 1 to 4 refer to 1) Maritime transport and shipbuilding, 2) Food, nutrition, health and eco-system services, 3) Energy and raw materials and 4) Leisure, working and living, respectively.
[84] The European Regional Seas include the Baltic Sea, North Sea, Mediterranean Sea, Black Sea, Atlantic Sea, Arctic Sea and Outermost seas.

4 Role of policy

4.1 Policy and political relevance

An overview of relevant policies at the EU-level related to Environmental Monitoring is provided in Section 1.2. So far, the policies of the EU were mostly focusing on coasts and inland waterways. However, with the implementation of MSFD, more authority will be obtained in open seas which should be used as an impulse to enlarge the coherence in the monitoring sector. The MSFD gives an opportunity to fill the gaps in the current monitoring practices and to create a stimulus for innovation. This can be achieved by assuring commitment and imposing strict demands through the MSFD. The MSFD also demands for an ecosystem-based approach, built on scientific knowledge of the marine environment. This is seen as “environmental” pillar of the maritime policy, which establishes a framework within which the Member States are required to take the necessary measures to achieve or maintain good environmental status in the marine environment by the year 2020 at the latest. The MSFD presents a tool to tackle cross border pressures and impacts. However, governance at the EU level is needed for implementation since there is no one fit-for-all model that can serve all the Member States and sea basins.

Environmental monitoring brings together different stakeholders with different interests. From the EU side, this overlaps with the interests of DG Energy, DG Env, DG Mare, DG Research, DG Enterprise and Industry as well as regional development interests. Due to the complex interaction between the functions, advanced analysis is needed to make long-term predictions on a long time scale and the answer questions like: *Is it possible to predict the behaviour of the North Sea in 2020, based on our observations today? Is it possible to run scenarios (alternative plans) with the data at hand to find better ways forward?*

4.2 Domains for EU policy

The Marine Knowledge 2020 initiative aims to unlock and assemble marine data from different sources and facilitate their use for purposes other than those for which they were originally intended. It outlines the case for a more coordinated approach to marine data collection and assembly and proposes an action plan to bring together contributions from different EU policy initiatives. This initiative will result in better alignment of policies and monitoring strategies. As an example, currently the assessments of the North Sea take place on a period of 5 years. This frequency coincides with timing of political cycles. Therefore one improvement would be to increase the frequency of such environmental assessments and to focus the assessments on “20” important parameters that can be monitored in real time. This so-called *dashboard* of parameters can best be arranged in a cluster in which institutions can participate. Such clusters would also be responsible for a specific sea basin.

Proposed changes in EU policy take in account the gap created by the lack of funds for environmental monitoring and ways for optimization though operationalization and automation of all kinds of monitoring that would lower the need for funding. An alternative way is to look for other sources of financing. Another potential role of the EU is to stimulate or enforce increased cooperation between Member States and enhancing the awareness of the benefits of a harmonised approach.

One interviewee suggested the introduction of a levy for the use of the sea, which can be reduced as a compensation for collected data. In this perspective, there are lessons to be learnt from the Common Fishery Policy. The fishery sector receives remuneration for the data it provides on fish. Alternatively industries can be obliged to provide information (e.g. by oil and gas and shipping) and make the data accessible to European databases.

Other suggestions by interviewees on the possible role of the EU are:

- steer towards further standardisation of methods, data processing, reporting etc.
- related to above mentioned, impose obligation to supply data and give an impulse to companies for collecting data. For example, installation of FerryBoxes on all kind of logistics to achieve an integrated monitoring system should be supported. It would be helpful if there would be a common recommendation that during shipbuilding, integration of devices should be taken into account. In the building stage (of ships, ferries etc) integration devices would hardly provide extra costs, but the added-benefit would be significant
- improve the connections between SMEs working in the same field
- increase the involvement of private sector to share data
- stimulate the development of downstream services by making data available for free
- evaluate the introduction of sea-use tax to finance monitoring
- adopt the GMES "business model" in which the downstream services drive the upstream technological development and determine the quality of the service
- involve the public; stimulate public participation in monitoring of for e.g. marine litter, by NGOs or interested citizens

4.3 Recommendations for the study

Based on this assessment, the key findings are:

- Environmental monitoring driven by: a) policy and supervision, b) research and c) commercial/industrial activities
- Environmental monitoring is historically a "fragmented" subfunction at various levels: a) methodologically, b) geographically and c) across sectors
- Significant technological developments, for example, automation of instruments took place in recent years
- Monitoring for commercial purposes is usually confidential with limited scope for data sharing, although spending and turnover by industries greatly exceeds public spending
- Estimate of spending by private companies still remains highly uncertain
- Relatively small size of function, with numerous SMEs and niche market for monitoring equipment
- Performance of subfunction is primarily determined by economic climate
- Data assimilation of in situ measurements, remote sensing data in oceanographic models to provide powerful insight of state and predictions
- Data sharing and re-use will require cooperation, cross border data intercompatibility with the benefits of increased competition, reduced operational costs and less restricted practices
- There is now movement to integrate monitoring efforts across sectors (multisectorial, multipurpose, use industrial data collected within the scope of EIAs for MSFD reporting obligations, as is already the case in Spain) and across countries, partly driven by reducing costs
- There is now movement towards free access to data that will stimulate value-added products
- Adoption of business models, such as the one followed in GMES MyOcean where the use of downstream products sustains upstream developments. This is based on integration of different monitoring methods (in situ, remote sensing and modelling) offering value-added data products

- Growth potential in monitoring related to renewable energy sector is very promising
- Yet given the small size of this function, the resulting employment increase is expected to be marginal

List of key recommendations:

- Conduct a preliminary assessment to evaluate whether re-use of industrial data for MSFD reporting obligations outweighs the efforts required to reach agreement on use and adapt historical agreements
- Reduction of the financial burden of MSFD monitoring purposes through the introduction of license fees or additional levies for industries in line with the polluter pays principle
- Promote free access to data, data re-use, e.g. by facilitating private-public data sharing and export of data outside the EU
- Invest in new technological developments that improve the efficiency and capacity of monitoring instruments
- Invest in technological breakthroughs, such as automated monitoring systems, and innovative research, such as the development and optimization of multiplatform-type monitoring systems
- Assess the role of social media and voluntary monitoring through public participation, including implementation of measures to ensure appropriate data quality assurance

Annex 1: Bibliography

- Argo brochure: An array of profiling floats observing the ocean in real-time. Five years of progress, decade of potential
- Bende-Michl et al. (2011), Monitoring strategies and scale-appropriate hydrologic and biogeochemical modelling for natural resource management: Conclusions and recommendations from a session held at the iEMSs 2008
- Brown et al. (2011), Benthic habitat mapping: A review of progress towards improved understanding of the spatial ecology of the seafloor using acoustic techniques, Estuarine, Coastal and Shelf Science 92, 502-520
- Dessi et al. (2008), Modis data processing for coastal and marine environment monitoring: A study on anomaly detection and evolution in Gulf of Cagliari (Sardinia-Italy). The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences. Vol. XXXVII. Part B8. Beijing 2008
- Diercks-Horn et al. (2011), The ALGADEC device: A semi-automated rRNA biosensor for the detection of toxic algae, Harmful Algae 10, 395–401
- Diercks et al. (2008), Development and adaptation of a multiprobe biosensor for the use in a semi-automated device for the detection of toxic algae, Biosensors and Bioelectronics, 23, 1527–1533
- European Commission, Towards a strategy to protect and conserve the marine environment, COM/2002/0539 final
- European Commission, On the sixth environment action programme of the European Community 'Environment 2010: Our future, Our choice', COM (2001) 31 final, 24 January 2001
- European Commission Green Paper, Towards a future Maritime Policy for the Union: A European vision for the oceans and Seas, COM(2006) 275 final, 7 June 2006
- European Commission, Towards a Shared Environmental Information System (SEIS)", COM(2008) 46 final, 1 February 2008
- European Commission, Building a European marine knowledge infrastructure: Roadmap for a European Marine Observation and Data Network, SEC(2009) 499, 7 April 2009
- European Commission, Towards the integration of maritime surveillance: A common information sharing environment for the EU maritime domain, COM(2009)538 final, 15 October 2009
- European Commission, European Marine Observation and Data Network Impact Assessment, COM(2010) 461, SEC(2010) 999, 8 September 2010
- European Commission, Marine Knowledge 2020 marine data and observation from smart and sustainable growth, SEC(2010) 461, 8 September 2010
- European Commission, Draft Roadmap towards establishing the Common Information Sharing Environment for the surveillance of the EU maritime domain, COM(2010) 584, 20 October 2010
- EUROSTAT and Flemming (2007), SEPRISE – Socio – Economic Analysis Scoping Report
- ESFRI (2011), Strategy Report on Research Infrastructures Roadmap 2010
- Export America Magazine (2002), Global Environmental Technologies: Trends, Markets, and Prospects by the Office of Environmental Technologies Industries, Trade Development, Vol 3 No 11

- Fisher et al. (2010), Ocean Information for society: sustaining the benefits, realizing the potential, OceanObs'09 (21-25 September 2009, Venice, Italy) conference statement
- Milieu Ltd. (2011), Use of industrial monitoring data for MSFD reporting purposes, Service Contract No. 070307/2010/579390/SER/D2 – Task W
- MRAG Ltd (2008), Legal Aspects of Marine Environmental Data Framework Service Contract, No. FISH/2006/09
- MRAG Ltd. (2009), Marine Data Infrastructure, Framework Service Contract, No. FISH/2006/09
- Pira International Ltd., University of East Anglia and Knowledge View Ltd. (2000), Commercial exploitation of Europe's public sector information
- Price Waterhouse Cooper (2008), INFOMAR Marine Mapping Survey Options Appraisal Report
- Ryder (2007), Sustainable Marine Environmental Information Services to Meet Collective European Needs, EuroGOOS publication No. 26
- Uunk et al. (2010), Automated mapping of the intertidal beach bathymetry from video images. Coastal Engineering 57, 461-469
- Veenstra T.S. and Churnside, J.H. (2011), Airborne sensors for detecting large marine debris at sea. Mar. Pollut. Bull. doi:10.1016/j.marpolbul.2010.11.018
- Science (2008), FerryBoxes Begin To Make Waves, Vol 322
- Send et al. (2010) Towards an integrated observing system: In situ Observation, OceasnObs'09 (21-25 September 2009, Venice, Italy)
- SMRU Ltd (2010), Approaches to marine mammal monitoring at marine renewable energy developments Final Report MERA 0309 TCE
- Testor et al. (2010), Glider White Paper: Gliders as a component of future observing systems
- Timmerman et al. (2010), Analyzing the data-rich-but-information-poor syndrome in Dutch water management in historical perspective. Environ Manage. 45, 1231-42

Annex 2: List of interviewed stakeholders

Interviewee	Organization	City/ Country	Specific theme	Face-to-face/ phone	Comments
Trine Christensen	EEA/EioNET	Copenhagen Denmark	EEA Marine assessments	face-2-face	1.
Franciscus Colijn	MODEG	-	FerryBox	phone	2.
Pierre Bahurel	Mercator Ocean	France	MyOcean	phone	3.
Dick Schaap	MARIS	Netherlands	SeaDataNet	face-2-face	4.
Seppo Kaitala	SYKE	Finland	Operational monitoring	phone	5.
Stephen Hodgson	MRAG Ltd	Belgium	Costs of monitoring	face-2-face	6.
John Shaw	Mainstream Renewable Power (Energies)	Dublin	Data user	phone	7.
Iain Sheperd	European Commission	-	EMODNet		8.

Annex 3: Economic sectors on which marine data will have economic impacts

GDP category	Impact Components	Economic Impacts
Agriculture, hunting and fishing	Agricultural production in coastal areas; coastal flooding; data on marine, Chemistry, physics	Meteorological services, coastal weather events, flooding and other storm events and their impact on agricultural and fish production; impacts on marine fish and fish products
Mineral extraction	Impacts on the coastal environment.	Better management of mineral extraction with less negative impacts on the coastal environment.
Industry including energy	Impact of weather and flooding events; Equipment sales	Coastal industries; offshore energy production from wind, tidal, wave and current energy; Contribution to value added, employment, revenue generation. Increased information on the risk factors for industry and the energy sector.
Building and Construction	Port and harbour construction; coastal settlements including housing	Construction and flood defence criteria; potential impacts of climate change; data on erosion, accretion and coastal currents; more effective risk analysis.
Trade, transport and communication	Meteorological data and marine oceanic data	Potential impacts on maritime transport, including risk factors
Financial services and business activities	Includes engineering, environmental and management consultancy, insurance, banking and finance	More effective engineering, financial and management consultancy using marine data; Cost savings in planning and design; More effective risk assessment for insurance and re-insurance services.
Other services	Include tourism and recreation and other coastal economic development; applied research; climate forecasting, certification; applied research (public sector research establishments and universities); military and defence	Contribution to better planning and location of tourism and other infrastructure. Contribution to value added generation and employment.

Source: MRAG Ltd. (2009)

Annex 4: Upscaling of costs of to EU-22

The survey by MRAG Ltd (2009) was based on the spending of public and private bodies in 5 EU countries, namely of France, Netherlands, UK, Sweden and Spain. Note that the data from Spain was excluded in the extrapolation due to insufficient data. The data gathered for these countries was upscaled to the EU-22 Member States that have a coastline, proportional to GDP (€), population (number of persons), EEZ (km^2) and length of coastline (km).

- The minimum spend, calculated as total spends/GDP, was found to be 0.00612% based on the data collected from France, Netherlands, UK and Sweden. By applying this calculated average minimum spend per GDP to the other MS the total spend on marine data was found to be €726 million.
- Based on the population of each country, the average minimum spend per person (Euro/yr) was found to be €2.04. When applied to all EU-22, the total spend on marine data was found to be €945 million.
- When normalized by coastline, the total spend was then €1212 million. Note that due to the fractal nature of coastline data these extrapolations should be treated with caution. (Coastline is found not to be a good factor for extrapolation since it leads to over-estimations for countries with large coastlines like Finland and Sweden and under-estimates for those with small coasts such as the Netherlands).

The estimates of marine data spendings varied-between €726 and €1226 million, depending on the extrapolation factor as explained above.

Assumptions:
-GDP and population figures are from year 2008
-the public sector data holders list included in the study is not exhaustive. Therefore the results of the extrapolation are under-estimated
- the spending at EU-level, for instance of ESA or DG MARE are not included
-this therefore only indicates a conservation minimum estimate

Annex 5: Description of key technological developments

Autonomous Underwater Vehicle (AUV)

An autonomous underwater vehicle (AUV) is a robot which travels underwater without requiring input from an operator. The oil and gas industry uses AUVs to make detailed maps of the seafloor before building subsea infrastructure aiming at the most cost effective installation and minimizing environmental impacts. **AUVs allow survey companies to conduct precise surveys or areas where traditional bathymetric surveys would be less effective or too costly.** Scientists use AUVs to study the ocean, and the ocean floor. A variety of sensors can be affixed to AUVs to measure the concentration of various substances and the presence of microscopic life.

Gliders

Small autonomous underwater vehicles which were developed to carry out in-situ observations of the upper 1km of the ocean filling the gaps left by the existing observing systems. At the moment there are 3 groups in the USA who have developed operational gliders:

- Seaglider by University of Washington
- Slocum by Webb Research Corp ;
- Spray by Scripps Institution of Oceanography

It has been now demonstrated that gliders are able to carry out high resolution measurements of not only **physical** (temperature and salinity as well as average velocities over a dive, and velocity profiles) but also **biogeochemical** parameters like dissolved oxygen and fluorescence/optical backscattering at various angles/wavelengths (Chla, CDOM, phycoerythrin, turbidity, …). An overview of new developments in glider technology is given in the Glider White Paper [85].

Smartbuoys

These autonomous devices are moored, "intelligent", automated, multi-parameter recording platforms used to collect marine environmental data. The data they collect aids or provides:

- improved understanding of environmental variability
- early warning and flood forecasting
- monitoring change in marine biodiversity/new insights into ecosystem function
- improved model validation and testing

ScanFish

A towed undulating vehicle system, the Scanfish MK II (EIVA), designed for collecting profile data of the water column in oceanographic, environmental monitoring and bathymetric applications. It is equipped with CTD sensors, optical devices to study the distribution and content of phytoplankton and suspended solids. Employed within COSYNA to conduct scientific studies of the position of the chlorophyll maximum in the German Bight or the relevance of the vertical density distributions for the data assimilation in regional operational observation systems.

FerryBoxes

FerryBoxes are automated instrument packages on ships of opportunities. They are already in use since many years, starting from the simple "Continuous Plankton Recorder (CPR)" with single purpose of collecting plankton samples during regular ship cruises up to the most recent

---

[85] Testor et al. (2010)

sophisticated FerryBoxes with an ensemble of different sensors and biogeochemical analysers. **For automated ocean observing it soon became clear that monitoring of surface waters using buoys, piles and platforms with in- situ sensors is very expensive mainly due to not-yet-solved bio-fouling of the sensors.** This requires frequent manual cleaning depending on the region (water temperature and eutrophic status of the waters). Each FerryBox system has four core sensors in addition to other sensors that are considered applicable to specific routes. Within the European funded *FerryBox* project, Chelsea Technologies Group is responsible for the supply and support of instrumentation. Chelsea Technologies Group also supplies complete FerryBox systems throughout the world, including sensors contained in a flow through system.

Ships of opportunity (Programme)
The primary goal of the Ship-of-Opportunity Programme (SOOP) is to fulfil upper ocean data requirements which have been established by GOOS and GCOS, and which can be met at present by measurements from ships of opportunity (SOO). The SOOP is directed primarily towards the continued operational maintenance and co-ordination of the XBT (*Expendable Bathythermograph* probe used to obtain information on the temperature structure of the ocean to depths of up to 1500 meters) ship of opportunity network but other types of measurements are being made (e.g. CTD, pCO2, phytoplankton concentration etc). This network in itself supports many other operational needs (such as for fisheries, shipping, defense, etc.) through the provision of upper ocean data for data assimilation in models and for various other ocean analysis schemes**. One of the continuing challenges is to optimally combine upper ocean thermal data collected by XBTs from the SOO with data collected from other sources such as the Argo, and satellites (eg. AVHRR, altimeter, etc.).**

Voluntary observing ships (VOSs)
Commercial ships serve as platforms to obtain routine observations near the surface in the ocean along selected commercial shipping routes. VOSs are presently being used to measure a small number of physical parameters (surface temperature, salinity..) although the resulting data quality can be inferior to those collected in research vessels (RV). **The problem of VOS of continuously changing shipping route is hindering an increased use of commercial shipping fleet as part of the global observation system. Measurements have to be autonomous and the maintenance and calibration of sensors of VOS is not as simple as it is on RVs.**

b) Remote sensing

Argos
Satellite-based system which collects environmental data from autonomous platforms and delivers it to users worldwide. Oceanographers and meteorologists use Argos to gather in situ observations for operational oceanography and meteorology. Argos buoys, floats and fixed stations collect data for operational programs such as World Weather Watch (WWW). Over 70 percent of Argos data are exchanged on a global and voluntary basis for insertion into numerical ocean and weather prediction models via Global Telecommunication System (GTS). Furthermore, Argos offers ocean data telemetry services for a broad spectrum of applications including ocean modeling, moored buoy monitoring and more.

Platform transmitter terminals (PTTs) as one component of Argos systems. **New technology allows for the integration of additional sensors (i.e. water temperature, dive depth, dive duration) into the PTT.**

Telemetry/Satellite tagging technology

Telemetry is a technology that allows remote measurement and reporting of information. **Satellite tagging technology is used for tagging wildlife**, such as whales and marine turtles. SMRU Ltd (2010) present a cost-benefit analysis of using such techniques for compliance monitoring of marine mammals around renewable energy developments. ARGOS CLS is only earth-orbiting satellite system which provides daily global location data for monitoring transmitters attached to wildlife.

<u>Airborne sensors</u> grouped as passive (most common using the energy reflected or emitted by objects) or active (provides its own source of energy to illuminate objects and includes lidar and radar). The passive sensors include are all imaging systems, and include video cameras, multispectral and hyperspectral cameras and thermal imagers. Used for **detecting large marine debris at sea** and have variable potential for operation on unmanned aircraft systems (Veenstra and Chrunside, 2011)

Annex 6: Matrix table showing impact of the medium-term and longer-term developments

Function	Indicators	Bal-tic	North Sea	Medi-terr.	Black Sea	Atlan-tic	Arc-tic	Outer most
1. Economic impacts	Demography change	-	-	-	+	0	0	+
	Spatial planning	+	++	+	++	0	++	+
	Service and distribution	+	+	+	+	+	++	+
	Property values	+	0	+	+	0	+	+
2. Employment impacts	Depopulation rural	-	0	+	+	0	0	+
	Relocation people	0	0	+	+	0	0	+
	Change Life style	+	-	-	+	0	0	0
	mobility	+	+	+	0	0	0	0
	Human Poverty	0	0	+	+	0	0	0
3. Environmental impacts	Human Health	+	++	++	+	0	+	0
	Security, Hazard, safety issues	0	--	-	-	0	--	0
	Env, quality (air, water, soil)	+	++	+	+	+	++	+
	Benefits, HDI, opportunities	+	0	0	++	0	-	0
	Waste management	++	+	++	++	+	++	+
4. Other impacts	Decrease Social Resilience	0	--	-	-	0	-	
	Leisure	+	0	0	+	-	--	0
	Satisfaction	+	+	+	+	0	+	0
	Community involvement	0	++	+	-	0	+	0
	Monitoring intensity	0	-	0	+	+	+	0

HDI: Human Development Index

++ = Strong positive impact expected

+ = Considerable positive impact expected

0 = Negligible impact expected

- = Considerable negative impact expected

-- = Strong negative impact expected

Annex 7: Case study

A Why this Case is important

Example of emerging, innovative and automated technology

Key description of the case

High-tech Robot Glider fleet surveying Atlantic (March 2010)[86]

Europe’s largest fleet of gliders was set to explore the oceans like sailplanes up to a depth of 1000 meters. In doing so, they only consume as much energy as a bike light. Up to 10 of these high-tech instruments take measurements to better understand many processes in the oceans. The new robots represent an important supplement to previous marine sensor platforms. The IFM-GEOMAR in Kiel, Germany has been the first institute in Europe to be committed to the new technology. A glider can carry out autonomous missions for weeks, or even months. Every glider is equipped with instruments to measure temperature, salinity, oxygen and chlorophyll content, as well as the turbidity of the sea water. This technology enable the observation of the upper layers of the ocean much more effectively and, thus, much less expensive than previously.

For the first time, the scientists in Kiel prepared a whole fleet of gliders for a concerted mission. The robots were released mid-March 2010 at about 60 nautical miles north-east of the Cape Verde Island of Sao Vicente. For two months, they investigated physical and biogeochemical quantities of the Atlantic Ocean around the oceanographic long-term observatory TENATSO.

Within the context of a special investment, IFM-GEOMAR was able to obtain six new gliders adding to a total of nine altogether, which is the biggest fleet of that kind in Europe. Teledyne Webb Research in the USA is the manufacturer of the IFM-GEOMAR-gliders.

This highly successful program has one major disadvantage: the pathways of the drifters cannot be controlled and have no direct motor. With their small wings, they move forward like sailplanes under water in a zigzag movement, cycling between a maximum depth of 1000 meters and the sea surface. “*By telephone we can ’talk’ to the glider and upload a new course every time it comes up...”*

[86] Source: http://www.sciencedaily.com/releases/2010/01/100114162345.htm

P.O. Box 4175
3006 AD Rotterdam
The Netherlands

Watermanweg 44
3067 GG Rotterdam
The Netherlands

T +31 (0)10 453 88 00
F +31 (0)10 453 07 68
E netherlands@ecorys.com

W www.ecorys.nl

Sound analysis, inspiring ideas