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# Marine Monitoring: Historical Background, Regulatory Framework and Science–Policy Interactions

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## 1.1. Introduction

Public awareness about marine pollution and regulatory responses is relatively recent [KRA 11]. The fact that chemical products released into the sea could be hazardous only became “shocking” in the 1950s with the methyl-mercury contamination of tuna and swordfish in Minamata Bay (Japan) in 1956, which resulted in neurological syndromes in the population. Some years later, the wrecking of the Torrey Canyon oil tanker along the Cornish coast (March 1967) and the blowout of an oil platform off the Californian coast in 1969 highlighted the fragility of marine ecosystems in the case of oil spills. The number of dramatic pollution events affecting marine quality would require a full volume but what should be remembered here is that these oil spills resulted in “visible” effects, which led to reactions from the public and changes in opinion that helped create a climate in which legislation was deemed necessary and scientific activities in research and monitoring were encouraged [KRA 11]. Research into the input, transport and fate of pollutants in the marine environment developed in the 1970s, which is reflected by the first issue of the *Marine Pollution Bulletin*, published in January 1970, which aimed to “spread news of pollution” rather than publishing research results, with the objective of informing policymakers [ANO 70].

In 1977, the International Council of Scientific Union's (ICSU's) Scientific Committee on Problems of the Environment (SCOPE) defined "monitoring" as "the collection, for a predetermined purpose, of systematic, inter-comparable measurements or observations in a space–time series, of any environmental variables or attributes which provide a synoptic view or a representative sample of the environment (global, regional, national, or local). Such a sample may be used to assess existing and past states, and to predict likely future trends in environmental features" [HOL 77]. This definition of monitoring, still valid today, turns it into a systematic method of collecting data needed for environmental problem-solving, which is linked to environmental policy [KRA 11].

Monitoring is not only focused on determining concentrations of harmful substances in various compartments of the (marine) environment, e.g. water, sediment and biota. It also includes physical parameters such as salinity, turbidity and pH as well as biological effects [KRA 11]. The basic reasoning behind monitoring has evolved over the years: in the mid-1970s, the focus was on avoiding health hazards, and the knowledge about the fate of pollutants not representing a direct threat to human health was considered to be of lesser importance. Nowadays, monitoring constitutes one branch in a more holistic approach related to marine management and international conventions and regulations (see section 1.3).

Historic developments of marine monitoring (with a focus on the North and Baltic Seas) have been described by Kramer [KRA 11] and will not be repeated here. Only key milestones that have led to current regulations will be described. The first landmark in (marine) monitoring is considered to be the United Nations Conference on the Human Environment that was held in Stockholm in June 1972, which resulted in the adoption of a declaration and an action plan. Principle 7 of the declaration stated that "all possible steps shall be taken to prevent pollution of the seas by substances that are liable to create hazards to human health, to harm living resources and marine life, to damage amenities or to interfere with other legitimate uses of the sea", whereas the action plan recommended that "governments actively support, and contribute to international programs to acquire

knowledge for the assessment of pollutant sources, pathways, exposures and risks” [UNE 72], quoted by [KRA 11]. This conference strengthened the developing environmental (marine) monitoring efforts in various national and international programs, and had some effects on harmonization and structuring marine monitoring plans and activities by active international organizations in the field [KRA 11].

Today, it is well known that marine ecosystems are experiencing unprecedented environmental changes, driven by human activities [ROO 11a]. Issues such as pollution not only from land- and sea-based sources but also from fishing, marine debris, the loss and degradation of valuable habitat and invasions by non-native species are recognized worldwide. However, the initial conventions, and hence research and monitoring, were heavily focused on measurements related to the two major problems at that time: eutrophication and contamination. Furthermore, frequent sampling at sea also became a source of hydrological data in a broader sense, as contaminant data are generally supported by metadata such as salinity, temperature, dissolved oxygen and others. As said above, this has been going on since the late 1960s and early 1970s. Not surprisingly, marine chemical monitoring is presently one of the technically most advanced branches of marine environmental monitoring. Gradually, the focus shifted from pollution to a more holistic approach, often referred to as the ecosystem approach. Chemical monitoring is now only one aspect, albeit an important one, of marine environmental monitoring. Yet, new threats such as climate change and ocean acidification will certainly give a new emphasis on chemical measurements [ROO 11a].

This chapter aims at giving an overview of the existing international organizations and conventions that are central to marine monitoring and research.

## **1.2. International institutions**

Initiatives related to environmental (marine) monitoring were started much before the 1972 Stockholm Conference by a number of international institutions with a certain competition among different

monitoring activities [KRA 11], e.g. a pollution research program developed by the Organisation for Economic Co-operation and Development (OECD) in 1965, marine pollution monitoring activities developed by the International Council for the Exploration of the Sea (ICES) from 1966 onward, etc. In 1969, the UN Food and Agriculture Organization (FAO) convened a “Technical conference on marine pollution and its effects on living resources and fishing”. The same year saw the creation of a joint Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP), cosponsored by the International Maritime Organization (IMO), UNFAO, United Nations Educational, Scientific and Cultural Organization (UNESCO) and World Meteorological Organization. The purpose of this group was to advise the various agencies and UN bodies that were concerned with marine pollution. Later, the World Health Organization, International Atomic Energy Agency and United Nations Environmental Programme (UNEP) joined the initiative [WIN 91]. A strategic vision on scientific aspects of marine environmental protection was developed by this expert group [GES 05].

These developments also resulted in the creation of SCOPE by the ICSU in 1969, which published a report on “Global Environmental Monitoring” [SCO 71] as input for the Stockholm Conference (quoted by [KRA 11]). This report stressed the need for a stronger coordination between a marine pollution monitoring system and Integrated Global Ocean Station System, then under development by the Intergovernmental Oceanographic Commission (IOC) for monitoring the physical conditions of the oceans. Studies based on monitoring of water, superficial sediments and biota for selected critical substances were proposed to be undertaken in pilot areas such as the North Sea, the Baltic Sea, the Mediterranean Sea and the Puget Sound (US). This formed the basis for developing aspects of policy by the IOC and coordinating international science by the Scientific Committee on Oceanic Research (SCOR). Ideas were further developed in the action plan for a Global Environmental Monitoring System [MUN 73] and priority pollutants were defined [AND 88].

### **1.2.1. *International Council for the Exploration of the Sea***

ICES was founded in 1902. This organization is an internationally recognized player in many scientific aspects dealing with the northern Atlantic Ocean [GRI 03, KRA 11]. Originally, ICES focused mainly on fish and fisheries studies, and the issue of monitoring was hardly touched on within the first 70 years of its existence [WEN 72], which changed from 1970s onward [ROZ 02, GRI 03, KRA 11]. Initially, stimulated by an OECD program on pollution research proposed to ICES leaders in 1965, a cooperation between ICES, IOC and OECD was established, leading to the establishment of the ICES Fisheries Improvement Committee in 1966 (from which, in 1978, the Marine Environmental Quality Committee was formed), and 2 years later the ICES Working Group on Pollution of the North Sea, followed in 1971 by the ICES/SCOR joint Working Group (WG) on the Study of the Pollution of the Baltic [KRA 11].

Surveys have been carried out by ICE, which can be considered a kind of precursor to regular monitoring programs [KRA 11], examples of which are baseline studies on trace contaminants in fish and shellfish in the North Sea [ICE 74], the Baltic Sea [ICE 77a] and the northern Atlantic Ocean [ICE 77b]. Following these baseline studies, an annual North Sea Monitoring Programme was initiated in 1974 [ICE 77c], followed by the Baltic Monitoring Programme (BMP) in 1979 [KRA 11]. These studies and programs were associated with the establishment (in 1973) of the ICES Advisory Committee on Marine Pollution, which developed guidelines on sampling, sample preparation, analytical procedures and data reporting required to obtain good quality data for various objectives, such as public health and environment protection or trend monitoring. This committee produced annual reports until 1992, and then was transformed into the Advisory Committee on the Marine Environment, which produced annual reports until 2003 [KRA 11].

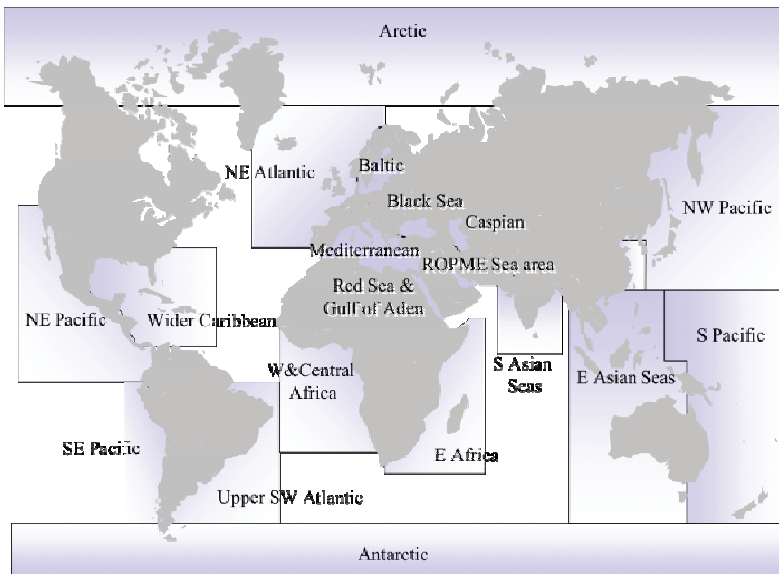
Besides monitoring activities, ICES was active in method developments and intercalibration exercises through various WGs, several of which had an influence on the design and operation of monitoring studies (e.g. WGs on marine chemistry, marine

ssediments and biological effects of contaminants). From 1984 to 1998, the data from the (Oslo and Paris, OSPAR) Joint Monitoring Programme (JMP) (see below) have been compiled and quality checked by ICES, followed by Helsinki Commission (HELCOM) data [KRA 11]. This organization has thus been, and still is, instrumental for the development of marine monitoring programs, first initiating baseline surveys and then supporting monitoring programs carried out by national organizations under the OSPAR and HELCOM umbrella.

### **1.2.2. United Nations Environment Programme**

UNEP was established by the UN General Assembly as a follow-up to the 1972 Stockholm Conference on the Human Environment (see <http://www.unep.org>) to serve as a focal point for environmental action and coordination within the UN system [KRA 11, ROO 11a]. One of the first priority areas was the assessment and control of marine pollution [BIR 74], with a focus on coastal areas and semi-enclosed seas through the Regional Seas Programme initiated in 1974; it provides a legal, administrative, substantive and financial framework for the implementation of Agenda 21 [UN 92], the Plan of Implementation of the World Summit on Sustainable Development [UN 02] and for the Bali Strategic Plan [UNE 04]. It is an action-oriented program and focuses not only on the mitigation or elimination of the consequences but also on the causes of environmental degradation (<http://www.unep.ch/regionalseas>). The action plans are usually adopted by high-level intergovernmental meetings and implemented, in most cases, within the framework of a legally-binding Regional Seas Convention and its specific protocols, under the authority of the respective contracting parties (e.g. MEDPOL, see section 1.3.6). The focus has gradually shifted from protecting the marine environment from pollution to striving towards sustainable development of the coastal and marine environment through integrated management. Currently, 17 members of the regional seas family are reflected in the Assessment of Assessment (AoA) regions (see below). Altogether more than 140 countries participate in at least one Regional Seas Action Plan or convention. In 12 of the regions, states have also adopted a legally-binding convention [ROO 11a]. Most of the regions covered by this program are located in

less developed countries, but some partner programs, e.g. the Baltic (HELCOM) and the North-East Atlantic (OSPAR), are also members. The first plan was adopted in 1975, involving 16 Mediterranean countries and the European Community to form the Mediterranean Action Plan (MAP), which is still in operation ([www.unepmap.org](http://www.unepmap.org)). The approach and strategy followed include an environmental assessment and the implementation of regional seas monitoring programs [GER 94]. Prospects for global ocean pollution monitoring were discussed in the early 1980s and were not followed up by concrete developments, owing to the low levels of contaminants, the near impossibility of identifying biological effects, logistical problems related to true open ocean monitoring and associated costs [UNE 84]. Marine regions are those identified by the UNEP Regional Seas and in the AoA [UNE 09]. An overview of the major marine regions is graphically illustrated in Figure 1.1. For most of these regions, agreements were made between the parties involved and environmental monitoring was initiated in support of these policies [ROO 11a]. An overview of prominent regional organizations is presented in Table 1.1.



**Figure 1.1.** UNEP regional seas (from [ROO 10])

| Regional commission or organization  | Website   |
|--|---|
| Permanent Commission for the South Pacific (CPPS)  | <a href="http://www.cpps-int.org">http://www.cpps-int.org</a>                       |
| South Asia Co-operative Environment Programme (SACEP)  | <a href="http://www.sacep.org">http://www.sacep.org</a>                             |
| South Pacific Regional Environment Programme (SPREP)   | <a href="http://www.sprep.org">http://www.sprep.org</a>                             |
| Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR)                               | <a href="http://www.ccamlr.org">http://www.ccamlr.org</a>                           |
| Caribbean Environment Programme (CEP)  | <a href="http://www.cep.unep.org">http://www.cep.unep.org</a>                       |
| Protection of the Arctic Marine Environment (PAME)   | <a href="http://www.pame.is">http://www.pame.is</a>                                 |
| Baltic Marine Environment Protection Commission (Helsinki Commission or HELCOM)                            | <a href="http://www.helcom.fi">http://www.helcom.fi</a>                             |
| Commission for the Protection of the Black Sea Against Pollution   | <a href="http://www.blacksea-commission.org">http://www.blacksea-commission.org</a> |
| Caspian Environment Programme (CEP)  | <a href="http://www.caspianenvironment.org">http://www.caspianenvironment.org</a>   |
| East African Coastal Database  | <a href="http://www.unep.org/eafatlas">http://www.unep.org/eafatlas</a>             |
| Mediterranean Action Plan (MAP)  | <a href="http://www.unepmap.org">http://www.unepmap.org</a>                         |
| OSPAR Commission (OSPAR)   | <a href="http://www.ospar.org">http://www.ospar.org</a>                             |
| The Regional Organization for the Conservation of the Environment of the Red Sea and Gulf of Aden (PERSGA) | <a href="http://www.persga.org">http://www.persga.org</a>                           |
| Regional Organization for the Protection of the Marine Environment (ROPME)                                 | <a href="http://www.ropme.net">http://www.ropme.net</a>                             |

**Table 1.1.** Overview of the major regional commissions or organizations and their websites (adapted from [ROO 11a])

The new Regional Seas strategy encourages the Regional Seas programs to increase monitoring and assessment activities, and to facilitate a science-based decision-making system including participation in such processes of the UN General Assembly known as the Global Assessment of the State of the Marine Environment. This concept, i.e. establishing regular marine environment assessments, was initiated in 1999 at the seventh session of the Commission on

Sustainable Development. It has led to the AoA which is described in detail in section 1.3 [ROO 11a]. UNEP is one of the lead agencies responsible for taking forward the AoA through the implementation of UN General Assembly Resolution 60/30. UNEP is also responsible for the secretariat set up to implement the 1995 Global Programme of Action for the Protection of the Marine Environment from Land-Based Activities and, one of the implementing agencies, for the Global Environment Facility (GEF). This is an independent international financing entity with the long-term goal to ensure progress toward global environmental security. The UNEP portfolio of GEF-funded activities in international waters includes global assessments, transboundary diagnostic analyses of shared water bodies, support for the implementation of strategic action programs for marine and freshwater areas, and support for integrated management of shared freshwater bodies. Because water issues play an important and increasing role in international development cooperation, GEF has designated international waters as one of its four focal areas [ROO 11a]. The Global International Waters Assessment (GIWA), led by UNEP and 50% funded by GEF, will provide the information needed for GEF's work in this particular area. The aim of GIWA is to produce a comprehensive and integrated global assessment of international waters, the ecological status of and the causes of environmental problems in 66 water areas around the world, and to focus on the key issues and problems faced by the aquatic environment in transboundary waters. The assessment is designed not merely to analyze the current problems but also to develop scenarios of the future conditions of the world's water resources and analyze policy options with a view to providing sound scientific advice to decision makers and managers concerned with water resources. In the near future, GIWA activities will be linked and coordinated with the monitoring programs described elsewhere in this section, such as OSPAR and HELCOM.

UNEP should essentially be seen as a facilitator and does not play the same role as organizations such as OSPAR and HELCOM (see sections 1.3.3 and 1.3.4). UNEP's role is to create the conditions that make marine monitoring feasible through capacity-building projects, technical and scientific advice, e.g. in the form of technical

guidelines, and by bringing organizations together that have common goals, facilitating exchange of practices and information [ROO 11a].

### **1.2.3. Intergovernmental Oceanographic Commission of UNESCO**

The Intergovernmental Oceanographic Commission (IOC) was established by UNESCO in 1960. It promotes and coordinates international cooperation and programs in marine research, services, observation systems, hazard mitigation and capacity development in order to learn more and better manage the nature and resources of the ocean and coastal areas. In addition, the Commission strives to further develop ocean governance, which necessitates strengthening the institutional capacity of member states in marine scientific research and of ocean management ([www.ioc-unesco.org](http://www.ioc-unesco.org)). In short, it is the designated UN entity for coordinating global ocean sciences [ROO 11a]. As a follow-up of the 1972 Stockholm Conference, the IOC developed the “Programme of Global Investigation of Pollution in the Marine Environment” (GIPME), cosponsored by UNEP and the IMO, the objectives of which were to provide authoritative evaluations of the state of the marine environment at both regional and global levels to identify the requirements for measures to prevent, or correct, marine pollution, and to develop/implement procedures for assessing and improving compliance and surveillance monitoring of conditions and effects in the marine environment [KRA 11]. The GIPME is based on a regionally-based marine pollution monitoring system known as MARPOLMON [KUL 1986], which constitutes a marine chemical component of Global Environmental Monitoring System [AND 88]. Important GIPME priorities are the baseline studies (status) and the standardization of methods and techniques. A great deal of emphasis has been placed on developing, testing and calibrating methodologies to ensure the quality of data for the major classes of contaminants measured in a variety of marine phases and to attempt to determine fluxes in the marine environment [DAW 88]. The day-to-day work within the GIPME is conducted by three expert scientific groups: the Group of Experts on Methods, Standards and Intercalibration in charge of the assessment and methodology for measuring levels and flux of contaminants; the Group of Experts on the Effects of

Pollutants to study the biological effects of contaminants, pollution assessment and indicators of biological and ecosystem condition on the marine environment; and the Group of Experts on Standards and Reference Materials, which deals with the assurance of data quality and comparability of measurements.

Furthermore, the IOC manages the Global Ocean Observing System, the ocean component of the Global Climate Observing System. As such, it helps to improve operational oceanography, weather and climate forecasts and monitoring and supports the sustained observing needs of the UN Framework Convention on Climate Change. The vision guiding the development of a Global Ocean Observing System is one of a world served by a unified global network providing the information needed by governments, industry, science and the public to deal with marine-related issues, including environmental issues and the influence of the ocean upon climate [ROO 11a]. The International Oceanographic Data and Information Exchange program enhances the IOC marine research and management programs by facilitating the exploitation, development and exchange of oceanographic data and information between participating member states and by meeting the needs of users for data and information products [ROO 11a].

#### **1.2.4. *European Union***

The first formal environment policy was adopted by the then named European Economic Community in 1972. As such, the European Union (EU) does not carry out monitoring activities but sets the legal framework of environment monitoring through regulations (Directives and Decisions), which have to be implemented by member states. Various legal instruments to limit the pollution of the aquatic environment have been put in place since the early 1970s, a number of which have been combined (some of them repealed) by the EU Water Framework Directive (WFD) [EUR 00] adopted in December 2000. Although the main purpose of this directive is to establish a framework for the protection of inland surface and ground waters, the WFD also covers surface “transitional waters” (such as estuaries) and coastal waters up to one nautical mile from the coastline

[FER 07]. Among other milestones (e.g. risk assessment, impact studies, programs of measures), the Directive includes obligations for member states to establish and implement monitoring of “water status” (for surface waters, ecological and chemical status) based on different criteria and parameters [QUE 11b]. The “chemical status” is linked to compliance to Environmental Quality Standards (EQS) established for 33 priority substances under the “daughter” Directive to the WFD, namely the Directive on Priority Substances [EUR 08a], which has recently been amended to include new substances. The main legal instrument concerning the marine environment is the Marine Strategy Directive, which has been described in depth by Verreet [VER 11] and is summarized in section 1.4.

### **1.3. International conventions/programs**

Combating marine pollution requires international cooperation efforts that have been orchestrated by a number of international treaties ratified over the past 30 years. Kramer [KRA 11] and Roose [ROO 11a] give a snapshot of a number of international conventions that have become instrumental in marine protection based on monitoring programs and trend studies of the marine environment. The present section gives a summary of these conventions.

#### **1.3.1. UN Convention on the Law of the Sea**

At the global level, the UN Convention on the Law of the Sea (UNCLOS) provides a legal framework and basic principles for the management of the oceans [UNE 09]. Ocean issues are considered in a comprehensive manner in the United Nations General Assembly and its processes. The international rules and standards that implement UNCLOS provisions are further developed by specialized global organizations such as FAO and IMO. The instruments can be both conventions (e.g. MARPOL 73/78, see section 1.3.5) and normative instruments (e.g. Code of Conduct for Responsible Fisheries). A large number of multilateral environmental agreements also apply to the oceans, covering themes such as climate change, hazardous substances, biodiversity and protection of species and habitats.

UNCLOS also provides the framework for regional seas collaboration. The regional level is appropriate for responding to the many problems that occur at larger than national scales. Regional organizations can bring together coastal states adjacent to the same oceans and seas, and sometimes also other states that use the areas. The most important regional seas conventions and organizations are discussed below but we should realize that in some oceans and seas there are no strong instruments or collaboration. Alternatively, in areas such as North America, bilateral cooperation can be appropriate [ROO 11a].

### **1.3.2. London Dumping Convention**

The “Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter”, in short the “London Dumping Convention” or “London Convention” (LC 72), was adopted in 1972 and enforced in 1975. This international treaty established an approach based on a “black list” (chemicals to be banned) and a “gray list” (chemicals for which dumping is to be restricted) to regulate ocean dumping. A permanent secretariat is hosted by the IMO.

### **1.3.3. OSPAR conventions**

The same year (1972), the “Convention for the Prevention of Marine Pollution by Dumping from Ships and Aircraft”, known as the “Oslo Convention”, was signed and enforced 2 years later. Its framework covered the North-East Atlantic and part of the Arctic Ocean, but excluded the Baltic Seas [KRA 11]. Similarly to LC, the Oslo Convention made a distinction between “black” and “gray” list chemicals; it was complemented by the “Convention for the Prevention of Marine Pollution from Land-Based Sources”, known as the “Paris Convention”, which was adopted in 1974 and enforced in 1978. The Oslo Commission (OSCOM) and the Paris Commission (PARCOM) shared a joint secretariat in London (OSPARCOM) [OSP 84]. This framework evolved into the “Convention for the Protection of the Marine Environment of the North-East Atlantic” or “OSPAR Convention” that was signed in 1992 (enforced in 1998), which is the current legislative instrument regulating international

cooperation on environmental protection in the North-East Atlantic [KRA 11]. It combines and updates both the above-mentioned OSPAR Conventions. Activities carried out under the Convention are managed by the OSPAR Commission. The OSPAR Convention now regulates – for its geographic region – European standards on marine biodiversity, eutrophication, the release of hazardous and radioactive substances into the seas, the offshore oil and gas industry and baseline monitoring of environmental conditions [TRO 94].

In order to examine the conditions of the sea covered by the conventions, OSCOM and PARCOM established a permanent Joint Monitoring Group (JMG), and with the guidance of ICES, a JMP in 1978 [OSP 84]. OSPARCOM adopted many of the principles of the ICES program in defining the JMP [KRA 11]. The JMG monitoring program had the following four main objectives [POR 86], i.e. the assessment of,

- 1) possible hazards to human health;
- 2) harm to living resources and marine life;
- 3) the existing levels of marine pollution (spatial distribution);
- 4) the effectiveness of measures taken for the reduction of marine pollution within the framework of the conventions (temporal trend assessment).

The JMP was based on the national programs of the contracting parties, with their national laboratories responsible for the sampling and analyses. To ensure comparability of data, calibration of methods had to be supported by participation in (e.g. ICES) interlaboratory comparison studies. The actual monitoring program started in 1979, and was initially limited to mercury and cadmium in seawater and in organisms, and polychlorinated biphenyls (PCBs) in organisms. Sampling frequencies were set according to monitoring objectives (see [KRA 11]).

In 2003, the Ministerial Meeting of the OSPAR Commission adopted a strategy for the Joint Assessment and Monitoring

Programme (JAMP), a combination of the national monitoring programs of the contracting parties. This provided a framework for work to prepare and produce a series of thematic assessments (quality status report, QSR). Thus, OSPAR is coordinating repeated measurement and assessment of the marine environment over a decadal time frame [KRA 11]. The organizational structure of OSPAR changed in 1995. Monitoring and assessment became a task of the Assessment and Monitoring Committee of OSPAR (ASMO). Monitoring has since been split into several domains in several working groups under ASMO, such as the Working Group on Concentrations, Trends and Effects of Substances in the Marine Environment (SIME), WG INPUT, dealing with atmospheric inputs (via the Comprehensive Atmospheric Monitoring Programme) and riverine inputs and discharges (via the Comprehensive Study of Riverine Inputs and Direct Discharges), and WG MON, e.g. via the Co-ordinated Environmental Monitoring Programme (CEMP) [DE 06].

The QSR 2000 [OSP 00] was based on the combined efforts of JMP and JAMP. The geographic coverage was expanded to a larger area, the North-East Atlantic (the OSPAR convention area) which was subdivided into five regions (Arctic waters, Greater North Sea, Celtic Seas, Bay of Biscay and Iberian Coast and Wider Atlantic). For each region, a separate report was prepared as well as a holistic synthesis report for the entire area. The most recent QSR 2010 was launched at the occasion of the Ministerial Meeting of the OSPAR Commission in Bergen (2010). Again a regional approach was followed in a printed and electronically available version (<http://qsr2010.ospar.org>), albeit in one volume [OSP 10].

OSPAR has taken, with its assessment tools, the next step in data assessment by using novel statistical approaches to test against set reference values such as background assessment concentrations and environmental assessment criteria. OSPAR also has well-defined statistical tools for temporal trend analysis that takes the quality of the data used into account. This has resulted in innovative and high-quality assessments that appear at regular intervals describing, e.g.,

the spatial distribution and trends of contaminants in the OSPAR area. Like HELCOM, OSPAR has developed ecological quality objectives (EcoQOs) for the implementation of the ecosystem approach but there are also no legal sanctions if contracting parties do not meet their obligations, resulting in gaps in the datasets [ROO 11a].

#### **1.3.4. Helsinki Convention**

International cooperation in the study of the Baltic Sea environment can be traced back to the establishment of ICES in 1902, which is mentioned earlier [ROO 11a]. This led to the development of a parallel framework to the OSPAR Convention in the Baltic Sea, resulting in the adoption of the Convention on the Protection of the Baltic Sea Area in 1974, known as the “Helsinki Convention” (enforced in 1980), which is governed by the HELCOM (or Baltic Marine Environment Protection Commission). The main goal of HELCOM is to protect the marine environment of the Baltic Sea from all sources of pollution, and to restore and safeguard its ecological balance. The present contracting parties to HELCOM are Germany, Denmark, Estonia, Finland, Latvia, Lithuania, Poland, Russia and Sweden. The setup is very similar to that of OSPAR (see below), and many of the principles – such as the “best environmental practices”, “best available technologies” and “the polluter pays” – are adopted and applied by HELCOM [ROO 11a]. Following a review of its first 20 years of existence [HEL 94], this convention was updated in 1992 by a new framework enforced in 2000, which now covers the whole of the Baltic Sea area, including inland waters as well as the water of the sea itself and the seabed. Measures were also taken in the whole catchment area of the Baltic Sea to reduce land-based pollution. All these conventions have aimed at the regulation of inputs to carry out baseline studies (present status), monitor for trends and carry out intercalibrations between contracting parties to warrant quality data [KRA 11].

Under the Helsinki Convention, monitoring of physical, chemical and biological variables of the open sea started in 1979 (radioactive

substances in 1984) but was considered a national obligation. It was called BMP and revised several times. The first pilot period covered 1979–1983; the second phase (1984–1988) had a larger coverage. The third stage started in 1989. For political reasons, the coastal areas of the sea were only poorly covered by the BMP, and the program focused on the open sea. The aim of the BMP was to monitor the long-term changes in selected indicators in the Baltic ecosystem, details of which are given by Kramer [KRA 11]. The Cooperative Monitoring in the Baltic Marine Environment (COMBINE) was instituted in 1992 with the aim of quantifying the state, impacts and changes in the various compartments (water, biota and sediment). The “ecosystem approach” adopted by the Joint HELCOM/OSPAR Ministerial Meeting in 2003 (including EcoQOs and related indicators) led to a different type of assessment focused on the pressures of human activities as well as the resulting impacts on, and state of, the marine environment.

### **1.3.5. MARPOL**

Recognizing the threat of pollution of the seas by oil from shipping, the International Convention for the Prevention of Pollution of the Sea by Oil, or the “OILPOL Convention”, was adopted in 1954 (enforced in 1958), primarily addressing pollution resulting from routine tanker operations. Later, the Intergovernmental Maritime Consultative Organisation (IMCO, since 1982 called IMO) organized the International Conference on Marine Pollution in London in 1973, which led to the International Convention for the Prevention of Pollution from Ships, known as MARPOL [KRA 11]. This convention was revised by the MARPOL protocol, the combination of which led to the MARPOL 73/78 Treaty adopted in 1978 and enforced in 1983. Its worldwide objective was to preserve the marine environment through the complete elimination of pollution by oil and other harmful substances and the minimization of accidental discharge of such substances. The initial focus on oil was expanded in later years with the inclusion of other substances: noxious liquid substances

carried in bulk; harmful substances carried in packaged form; sewage, garbage and air pollution [KRA 11].

### **1.3.6. Mediterranean Sea: Barcelona Convention**

In 1976, the Mediterranean countries and the EU adopted the Barcelona Convention for the Protection of the Mediterranean Sea Against Pollution (see [ROO 11a]), overarching the MAP, approved the year before (see <http://www.unepmap.org/>). This framework convention includes the preparation of technical protocols, such as the protocols for the protection against pollution from land-based sources [BAR 80] and from hazardous waste disposal [BAR 96]. As the environmental assessment component of MAP and the associated protocols, the Programme for the Assessment and Control of Pollution in the Mediterranean region (MEDPOL) was established. When started in 1975, its main aim was the establishment of a network of institutions undertaking marine pollution work and the collection of information regarding the level of pollution in the Mediterranean Sea. The monitoring activities covered heavy metals in marine biota (mainly mercury and cadmium), halogenated hydrocarbons in marine biota (mainly PCBs and dichlorodiphenyltrichlorethane (DDTs)) and petroleum hydrocarbons in seawater. The development and maintenance of these national monitoring programs were the aim of the second phase (1981), whereas more recently (1996) the emphasis has shifted from pollution assessment to pollution control. In parallel, MEDPOL provides assistance in the formulation and implementation of regional and national action plans addressing pollution from land-based sources and activities. It also formulates and carries out capacity-building programs related to the analysis of contaminants and treatment of data and to technical and management training [ROO 11a]. Although monitoring of the Mediterranean environment is firmly in place for several countries, a coordinated and well-developed monitoring program has not been realized, as is the case for HELCOM and OSPAR. Emphasis has been mainly on capacity-building and setting up the conditions that will eventually result in a sustainable monitoring program for the Mediterranean. For instance, guidelines have been developed covering various aspects of

monitoring and efforts have been made to enhance the quality of the processes [ROO 11a].

### **1.3.7. Bonn Agreement**

Another international framework (cited by [KRA 11]) on discharges of oil and other substances into the North Sea region under the Agreement for Cooperation in Dealing with Pollution of the North Sea by Oil, or the “Bonn Agreement”, was adopted and enforced in 1969 and later superseded by the Agreement for Cooperation in Dealing with Pollution of the North Sea by Oil and other harmful substances (1983, Bonn Agreement; in force 1989). Now parties were required to jointly develop and establish guidelines for joint action and to provide information on pollution incidents. Developments were discussed on the occasion of its 40th anniversary (Bonn Agreement, 2009). One of the implementation instruments of the Bonn Agreement is the on-going aerial surveillance program, which started in 1986, to monitor and assess trends in levels of oil input into the marine environment [CAR 07].

### **1.3.8. Arctic Ocean: Arctic Monitoring and Assessment Programme**

For the Arctic Ocean, data are gathered and assessed through the Arctic Monitoring and Assessment Programme (AMAP) [ROO 11a]. AMAP was established in 1991 to implement certain parts of the Arctic Environmental Protection Strategy, primarily “providing reliable and sufficient information on the status of, and threats to, the Arctic environment, and providing scientific advice on actions to be taken in order to support Arctic governments in their efforts to take remedial and preventive actions relating to contaminants” (see <http://www.amap.no>). The Arctic Council, established in 1996 by the eight Arctic countries (Canada, Denmark, Finland, Iceland, Norway, Russia, Sweden and the United States), coordinates AMAP activities. AMAP was conceived as a program that integrates both monitoring and assessment activities in relation to pollution issues and provides information and reports on the state of the Arctic environment. The

AMAP Trends and Effects Monitoring Programme [AMA 00] is designed to monitor the levels of pollutants and their effects in all compartments of the Arctic environment [ROO 11a]. The program includes both monitoring and research components, and special studies that yield information that is vital for the valid interpretation of monitoring data. AMAP has produced comprehensive and scientifically sound assessments of contaminants in the Arctic environment, discussing their levels, trends, and effects (both based on comparison with current literature and the observation of biological effects as such) [AMA 02]. An AMAP assessment should therefore not be considered as a formal environmental risk assessment [ROO 11a]. Rather, it constitutes a compilation of current knowledge. The emphasis is very much on science as the basis for relevant policy and the program has no regulatory purpose as such. The setup is therefore much like a scientific program and there seem to be no legally-binding obligations or a strict set of guidelines as, for instance, there are for the OSPAR CEMP (see further). Specific for this program is the assessment of human health through the study of dietary intake and body burdens [AMA 09].

### **1.3.9. North East Pacific Ocean**

There are extensive chemical data series that cover the North East Pacific region's biophysical environment during much of the past 50 years, particularly off the coasts of the United States and Canada [ROS 09]. These data are, amongst others, the result of directed research and monitoring efforts of governments and academia that cover both ocean physics and chemistry. There is also a well-developed science program for the region. However, there is no formal convention and accompanying monitoring program covering the entire region, as is the case for, the North East Atlantic for example [ROO 11a]. For the northern part of the North East Pacific region, periodic monitoring and assessments are conducted by the Fisheries and Oceans and Environment Canada (DFO), the US National Oceanic and Atmospheric Administration (NOAA), the US Environmental Protection Agency (US-EPA) and their counterparts. A good example is the NOAA's National Status and Trends monitoring program that has been going on since 1986 and covers the Atlantic,

Pacific and Gulf coasts of the United States. Canada, Mexico and the United States also have formal scientific advisory bodies that conduct assessments and provide advice to the respective governments on policy and management [ROS 09]. For the remainder of the region, a UNEP Regional Seas Programme is based on the Convention for Cooperation in the Protection and Sustainable Development of the Marine and Coastal Environment of the Northeast Pacific (Antigua/Guatemala Convention), and was signed in 2002 [ROS 09].

### **1.3.10. North West Atlantic Ocean**

As the North West Atlantic Ocean region is only bordered by the shores of three countries (Canada, Denmark (Greenland) and the United States), no regional convention and accompanying monitoring and assessment program have been set up [ROO 11a]. Nevertheless, there are extensive data series covering most of the past 50 years on the biophysical environment and there is a well-developed science program for the region, including cooperative Canada–US studies on various topics [RIC 09]. Very extensive data collection systems are operating in both countries, including research surveys operating year-round and newly-developed ocean observing systems, which are coming on stream. As for the previous region, a substantial body of assessment work is being carried by the responsible national institutions (DFO, NOAA, US-EPA) or in collaboration with regional organizations. This is particularly the case for the northern part of the region that is also covered by AMAP. There are also strong links with European efforts through ICES (see section 1.2.1). Still, despite its size, the region is mostly approached on a national level. It is therefore not surprising that there has been no overall synthesis of the information on the North West Atlantic Ocean region ecosystems [ROO 11a]. This does not mean that there are no major assessments for the ecosystems along the coast under the auspices of government agencies. For instance, there are Canadian series on the state of the oceans or the United States Coastal Condition Report. Synthesis studies such as the latter give a broader overview of the entire coast but at much lower resolution. Integrated ecosystem assessments are in progress in both countries.

### **1.3.11. North Sea conferences**

The baseline studies, other surveys and surveillance programs, and serious concern at the political level, led to a series of North Sea conferences from 1984 onward [SKJ 06], which were supported by QSR providing an integrated assessment of the cumulative and relative impact of all human pressures on the marine environment, identifying where action needed to be taken [KRA 11]. One of the outcomes of the QSR 1987 was the recognition that despite the large number of contaminants measured, the spatial coverage of the North Sea was rather limited. As a result, the North Sea Task Force (NSTF) was set up, cosponsored by OSPARCOM and ICES, the objectives of which included advice on research and on the implementation of a quality-assured monitoring program [HOO 91]. The aims of the NSTF Monitoring Master Plan were to enhance scientific knowledge and understanding of the North Sea environment, and to overcome shortcomings in data on the distribution of contaminants [REI 90]. The NSTF was active from 1988 to 1994 and its approach was then incorporated into ASMO. Worth noting is that it contributed to the launching of the QUASIMEME proficiency testing scheme [WELL 97], which is described in Chapter 2.

### **1.3.12. Other conventions**

Besides the Barcelona Convention (see section 1.3.6), the concept of the OSPAR Conventions was used as a basis for developing a framework for the protection of other (European) sea areas, such as the Convention on the Protection of the Black Sea against Pollution, the “Bucharest Convention” (adopted in 1992; enforced in 1994).

## **1.4. The EU marine strategy**

Protection of water is a long-standing part of the European Community’s environmental policy<sup>1</sup> [VER 11]. Like the international

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<sup>1</sup> With the entry into force of the Lisbon Treaty, the EU is the successor of the European Community. An overview of the current body of EU legislation in the field of water protection is given at [http://europa.eu/legislation\\_summaries/environment/water\\_protection\\_management/index\\_en.htm](http://europa.eu/legislation_summaries/environment/water_protection_management/index_en.htm).

legal framework generally, the European Community's policy regarding the protection of the marine environment has grown in a relatively piecemeal fashion over the years. Quality standards for different types of water use (e.g. shellfish water and bathing water) or seafood were set in a first wave of EC directives on water quality. It was also attempted at the EC level to elaborate common discharge standards for point sources of listed substances on land (Directive 76/464/EC). Over the period 1975–1993, the EC had become, as a regional economic integration organization, a party to the regional sea conventions in three of the four main sea basins around Europe<sup>2</sup>, with discussions regarding membership of the convention dealing with the pollution of the Black Sea (Bucharest Convention) progressing only slowly since the EU membership of Romania and Bulgaria in 2007 [VER 11]. Environmental policy is a shared competence between the EU and its Member States. In contrast, the Conservation of Marine Biological Resources under the Common Fisheries Policy (Treaty on the Functioning of the European Union, Art. 3 (1)(d)) has been an exclusive community policy since the early 1980s, following international developments on access to fisheries resources during the 1970s when coastal states started to declare their exclusive economic zones under UNCLOS (see section 1.3.1). EU Member States agreed that the management of the fisheries stocks in their exclusive economic zone could be better managed in a common European regime.

An important milestone and precedent for a comprehensive approach to the protection of the marine environment was the adoption of the Water Framework Directive 2000/60/EC (WFD) [EUR 00] whose objective is to establish a framework for the protection of inland surface waters, transitional waters, coastal waters and groundwater. This regulation contributes to the achievement of the objectives of international agreements described in section 1.3. Its geographical limit of application (as defined by the

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<sup>2</sup> In the Baltic: the EC became a party to the 1992 Helsinki Convention in 1993. In the North-East Atlantic Ocean: the EC became a party to the 1974 Paris Convention in 1975; this Convention preceded the 1992 OSPAR Convention currently in force. In the Mediterranean Sea, the EC became a party to the 1976 Barcelona Convention in 1977.

term “surface waters”) at the seaward side extends fully to the coastal waters (with a limit of 1 nautical mile from the baseline) and to the territorial waters only with regard to “chemical status” (most often these cover waters up to 12 nautical miles from the coast).

Even after the adoption of the WFD, EU environmental policy makers considered there was a lack of strategy underpinning the policies to protect the marine environment. A commitment to formulate such a strategy was included by the European Parliament and the Council in the sixth Environmental Action Programme adopted in July 2002 and applicable for the period 2002–2012 [EUR 02a]. The European Marine Strategy developed over the period 2002–2005 [EUR 06a] and resulted in the adoption of the Marine Strategy Framework Directive (Directive 2008/56/EC). Marine environmental and maritime policy are, however, not the only relevant policy frameworks for chemical monitoring of the seas. Prevention of pollution by chemicals is also addressed by extensive legislation on production, marketing and use of substances, such as the REACH Regulation [EUR 06b]. An analysis within the framework of the OSPAR Commission concluded in 2008 that most of the EU chemicals legislation seemed to adequately address the possible risk to the marine environment, although this judgment was not fully reached for substances used as veterinary medicines and pesticides [OSP 08].

#### **1.4.1. The notion of “good environmental status”**

The objectives of the Marine Strategy Framework Directive (MSFD) are clearly to achieve a certain desired degree of environmental quality through the achievement of a “good environmental status”, which marks an important shift toward a more proactive and forward-looking marine environmental protection regime [VER 11]. It embodies an important aspect of the ecosystem-based approach. The environmental management will be geared to achieving explicit objectives rather than being driven only by the principles and concepts of the past, such as “prevention of pollution”. It can be argued that these past concepts were in themselves

insufficient to secure the maintenance of healthy, clean and productive seas. This shift is not without its own challenges: it hinges on the ability to ensure that the objectives are well formulated and that they provide the correct drivers for management action. Being able to measure and monitor the right variables is a key consideration underlying environmental objective formulation. Details about definitions and qualitative descriptors of “good environmental status” are provided by Verreut [VER 11] and will not be repeated here. Implementation of good environmental status objectives closely relies on the development of operational “criteria and methodological standards”, which is subject to a Commission decision [EUR 10]. This framework provides further guidance on adequate methods by which Member States can ensure that the normative aspects of “good” are correctly applied in their concrete, operational, expression of what “good environmental status” means for their marine waters. The incorporation, under EU law, of these components of the ecosystem-based approach creates a significant driver for the further development and application of quality assessment techniques, which were hitherto only applied in a “soft law” context, such as the EcoQOs promoted earlier in the frameworks of the North Sea Conferences, OSPAR and their equivalents under HELCOM (see section 1.3). The “determination” of good environmental status by the Member States will be accompanied by the setting of targets and associated indicators, which will have to be designed so as to guide the selection of necessary management measures. It is good practice to formulate policy objectives and indicators together, so that there is a clear understanding of how success or failure will be evaluated [VER 11].

#### ***1.4.2. Marine strategies of the Member States***

The initial assessment, the determination of “good environmental status” and the setting of associated targets and indicators are an extensive prelude to the real substance of the Member States’ marine strategies, which should be their program of measures that are necessary to achieve the environmental objectives. The different steps

have been described by Verreet [VER 11] and are summarized in Table 1.2.

| Marine strategy element   | First version ready   |
|---|---|
| – A description and assessment of current environmental status, including the environmental impact of human activities  | By 15 July 2012   |
| – The determination of good environmental status  | By 15 July 2012   |
| – The establishment of environmental targets and associated indicators  | By 15 July 2012   |
| – The establishment and implementation of a monitoring programme for ongoing assessment and regular updating of targets | By 15 July 2014, except where otherwise specified in the relevant community legislation |
| – The programme of measures toward good environmental status  | Established by 2015; entry into operation by 2016                                       |

**Table 1.2.** Documents that together form a “marine strategy” (adapted from [VER 11])

Similarly to the EU WFD [EUR 00], the Marine Strategy Directive follows an “adaptive management” approach, which takes account of the progress in available knowledge and changing challenges and circumstances, through a 6-yearly review cycle of each of the marine strategy elements [VER 11]. In view of the synergies between Member States’ activities under the regional sea conventions and the MSFD implementation, joint actions are now currently undertaken and programed at EU subregional and national levels in close cooperation (regarding exchanges of data, information and best practices) among the different organizations.

#### 1.4.3. Monitoring in the MSFD policy context

During the development of the EU Marine Strategy, many stakeholders and the European Commission emphasized the need for an “evidence-based policy” and a “knowledge-based approach” [EUR 05], requiring *inter alia* a strong basis in science for all elements of marine strategies. An adequate science–policy interface is

needed so that science continuously informs policy (this is discussed in section 1.5). Only then can the information value derived from observation and monitoring be maximized.

Within the MSFD, monitoring is related to the “on-going assessment of the environmental status of [...] marine waters”, which is based to an important degree on indicators updated on a regular basis [VER 11]. In this context, an environmental indicator is defined by the OECD as “a parameter, or a value derived from parameters, that points to, provides information about and/or describes the state of the environment, and has a significance extending beyond that directly associated with any given parametric value. The term may encompass indicators of environmental pressures, conditions and responses” (OECD online glossary of statistical terms). Indicators are closely linked to the DPSIR (drivers, pressures, state, impact, response) model, i.e. used for risk assessment, pressure analyses, status assessment and responses. A matrix showing the combination of MSFD requirements and the functional relation to elements of the DPSIR framework is given in Table 1.3. “State” is the central component on which MSFD effectiveness should ultimately be assessed [VER 11].

| MSFD Article   | Additional requirement                                      | Driving forces   | Pressures           | State           | Impact              | Response    |
|--|---|--|---------------------|-----------------|---------------------|-------------|
| Art. 8: (Initial) assessment                             | on basis mainly of Annex III                                | Descriptive  | Descriptive         | Descriptive (*) | Descriptive         | Descriptive |
| Art. 9: Good Environmental Status                        | on basis of EU common criteria and methodological standards | (unlikely)   | “Take into account” | Normative       | “Take into account” | (unlikely)  |
| Art. 10: Environmental targets and associated indicators | on basis of Art. 8 and 9 output (**)                        | Potentially all, they are “established so as to (...) guide progress towards achieving good environmental status”. |                     |                 |                     |             |

\* Likely to be progressively adapted to reflect a normative approach following implementation of Article 9

\*\* Taking account of needs of the program of measure

**Table 1.3.** MSFD articles and additional requirements as a basis for indicators across the DPSIR spectrum (adapted from [VER 11])

Unlike the WFD, the MSFD regulatory framework does not include a specific aggregation algorithm for a compound judgment of overall environmental quality. So far, few methodologies exist to integrate all the elements into a single evaluation of a water body [BOR 08]. A model representation of ecosystem structure, functioning and processes seems to be necessary as a background canvas to allow a systemic approach to such integration [VER 11].

In the marine environmental policy context, the notion of an “ecosystem approach” is synonymous with “ecosystem approach to the management of human activities”, stressing that it is the latter that are being managed, not the environment as such. Against this background and of MSFD information needs, monitoring and assessment play a vital role. In this context, monitoring programs are embedded in Member States’ marine strategies, linking in with the cycle of monitoring and assessment activities (which are often managed regionally) and that of policy making and effectiveness evaluation [VER 11]. With a strong focus on environmental status defined by the MSFD, the monitoring programs will go beyond environmental monitoring to the extent that indicators require other types of data such as socioeconomic data. As a framework directive, and according to the subsidiarity principle, the MSFD does not automatically “force” the Member States to monitor any given substance or compound. There is no straightforward “European obligation” for any of the monitoring parameters.

The MSFD coverage of chemical water quality cannot be completely dissociated from that of the WFD, even if the latter concerns surface waters that extend to 1 mile of the coast. In proposing the MSFD, the European Commission had stressed the possible synergies of surface water management under the two regimes. The WFD approach to chemical quality is based on reaching water quality objectives based on EQS for a common list of priority substances and of priority hazardous substances [EUR 03, EUR 09b]. The MSFD further complements it by an approach based on the identification, as an element of environmental status, of a risk of possible “pollution effects” by substances in Member States wider

marine waters [VER 11]. In other words, “good environmental status” is linked with the absence of pollution effects as defined by the MSFD. Another emphasis is put on ensuring that all biota that we harvest as seafood are safe to eat. In a first phase, considering that the WFD implementation is more advanced in time (as it started in 2008) than that of the MSFD, Member States cover the management of most of the risks related to chemical substances – most of which originate from land-based sources – under the WFD river basin management plans (which include coastal waters, if not the territorial waters of the sea), and complement this with a review of any additional needs based on elements of information derived from their initial assessment of the environmental status (including risks and threats) of their marine waters [VER 11]. Novel elements regarding chemical quality are the inclusion, in MSFD Annex III, of parameters reflecting ocean acidification (pH, pCO<sub>2</sub>), which is likely to be a basin-wide phenomenon best addressed at that level.

## **1.5. Science–policy interactions**

### **1.5.1. *Scientific foundation of environmental policies: where do we stand?***

The need to strengthen links among scientific outputs and policy-making activities is subject to on-going debates and specific discussions in the water and marine sectors have examined concrete developments [QUE 10]. They tend to show that a conceptual framework for a science–policy interface among scientists, policymakers and stakeholders is required *inter alia* in the water and marine sectors. This section takes over general considerations about science and policy interfacing needs (after [QUE 07]). In a first instance, let us recall that key steps of the “environmental (including marine) policy chain” related to protection against pollution are based upon a scientific foundation and basic technical knowledge; these steps can be summarized as follows:

- describe what you want to protect;
- measure or describe status;

- define the level of protection according to well-defined objectives;
- identify pressures;
- quantify the relationship between pressure and environmental response;
- quantify the relationship between social and economic cost and pressure;
- identify the least-cost pathway;
- define the policy instrument;
- implement the policy instrument and assess response;
- take appropriate measures (control, remediation);
- review policy on the basis of scientific/technological progress.

The reliability of the overall chain will depend upon the effectiveness of the integration of scientific and technological knowledge in a timely fashion at each step of policy development, implementation and review. The knowledge of “environmental interfaces”, e.g. sediment–water interactions, and pollutant pathways at this interface (mobility, bioavailability, etc.) represents a basic feature for understanding the impacts of anthropogenic pressures on various (marine) environmental compartments. Hence, it has a direct impact on the way policy and related monitoring are designed, developed and implemented. This knowledge should, in principle, be tackled in a “holistic” fashion. In other words, it is difficult to understand the overall impact of a specific pressure on the environment by looking at only one compartment [QUE 07]. The different pollution pathways depend upon the nature of the pollutants (type and origin of chemical substances) and a high variety of environmental factors, such as the climate, hydrology (water flows and related sedimentation rates), geology, hydromorphology, physicochemical conditions (e.g. pH and redox potential) and biological interactions. In this respect, it is hard to understand a given pathway by looking at a single environmental compartment and through one discipline only.

To date, the knowledge of environmental interfaces is still limited by the lack of sufficient multidisciplinary studies. The progress is ongoing but the scientific foundation is not considered to be sufficiently developed to be able to effectively assess the effectiveness of environmental policies in a holistic context. It is worth mentioning that, among research projects and related on-going activities, gathering of an increasing number of monitoring data (linked to EU policies and/or international programs such as the European Environment Agency's State-of-the-Environment program) and the development of models now provide a much better vision of the problems to be tackled and of the way to approach them. On the medium term (5-year horizon), it will be possible to establish a much better "holistic" evaluation of environmental interfaces and related pollution pathways. This will obviously have a direct effect on the implementation and review of related EU policies. In the longer term (10–15 years), the increasing number (and quality) of environmental databases, models and other monitoring facilities (e.g. Global Monitoring for Environment and Security) should enable us to look at the environment as a single entity instead of series of separate compartments.

### ***1.5.2. EU scientific framework in support of water and marine policies***

The treaty establishing the EU indicates that research framework programmes have to serve two main strategic objectives. First, to provide a scientific and technological basis for industry and encourage its international competitiveness. And second, to promote research activities in support of other EU policies. To this end, framework programmes (FPs) are designed to help solve problems and respond to major socioeconomic challenges faced by society. The research framework programme is the main instrument of EU for funding research and development. In this context, the European Commission has been supporting water and marine research through its successive FPs for research and technological development (RTD). The FP aims to foster scientific excellence, competitiveness and innovation through the promotion of better cooperation and coordination. It also aims to produce advances in knowledge and understanding, and to support the

implementation of related European policies. The FP is implemented through open “calls for proposals” and successful projects are selected after an evaluation procedure carried out with the help of external independent experts.

The Seventh Framework Programme covered priority areas reflecting EU research needs in sectors such as health, food and agriculture, information and communication technologies, nanosciences, energy, transport, socioeconomic sciences, space and security. Environment and climate change was one of these 10 priorities. It focused on knowledge of the interactions between the biosphere, ecosystems and human activities, and the development of new technologies, tools and services, with emphasis on the following issues:

- improved understanding and prediction of climate, earth and ocean systems changes;
- tools for monitoring, prevention and mitigation of environmental pressures and risks;
- management and conservation of natural resources.

More specifically, the research areas addressed pressures on environment and climate, impacts and feedback, environment and health, conservation and sustainable management of natural resources (including groundwater), evolution of marine environments, environmental technologies, understanding and prevention of natural hazards, forecasting methods and assessment tools, and earth observation.

Horizon 2020 has succeeded to the 7th Framework Programme; it is the biggest EU research program ever with some €79 billion of funding available over 7 years (2014–2020). By coupling research and innovation, the program seeks to help achieve excellent science, industrial leadership and tackle societal challenges. EU research funding has already brought together scientists and industry in Europe and from around the world to find solutions to a huge array of challenges, including environment protection.

### 1.5.3. Identification of research needs in the water policy sectors

It is not always possible to clearly establish the border between “basic” and “applied” research. Also the timing aspect (short-, medium- and long-term) is intimately linked to the way research instruments are being operated. The identification of research needs is of course fed by advances in scientific knowledge, but is also directly influenced by the evolution and requirements of policies. The needs for ensuring coincidence of research and policy agendas may depend upon the stage of development of the policy in a given thematic area. In this respect, one may distinguish three different categories of needs in the water policy sector, depending on timing considerations:

– *Short-term* (~1–2 years): Needs are basically concerning accessibility of research knowledge required for the development of policies on a short-term basis. Timing is not adapted to develop new types of research (unless very specific needs are identified, which may be sorted out in a 6–12 month period). Policy development also requires efficient and user-friendly access to background scientific information and archives; a typical example is the thematic strategies covered by the 6th Environment Action Programme (EAP). In this context, the time needed for the design, approval and operation of *ad hoc* calls for proposals makes it difficult to respond to short-term research needs, i.e. a specific research need expressed at a given time will rarely be met through a project selected under a call for proposals the year after. Therefore, to date such needs may only be tackled through Joint Research Centre (JRC) action lines (see section 2.2.3) that are identified in their annual work program and agreed by Environment Directorate-General, as well as through possible national research programs; successful examples exist in the sector of water policies. In the future, short-term needs could also be partially fulfilled through a coordination of national research calls for proposals (European Research Area-Network (ERA-NET) scheme).

– *Medium-term* (~2–5 years): The timing of medium-term research is adapted to responses to needs expressed in relation to the implementation agenda of well-defined policies (representing a

“stable platform” for building strong partnerships among policy implementers, the scientific community and various stakeholders). This is the case of the WFD, in support of which research activities have been carried out since the time of its adoption (2000) in response to needs linked to, for example analysis of pressures and impacts, characterization of water bodies (2004–2005) and economic analysis (2005). For the forthcoming milestones, the formulation of medium-term research needs will have to take into account, for example monitoring (2006) and the preparation phases (2007–2008) of the first river basin management plan to be published in 2009. The SSP mechanism (research in support of policies) within FP6 was well adapted to respond to such identified needs, i.e. a detailed description of research needs by policymakers and the follow-up of projects in close coordination with the scientific community represent key elements for achieving successful use and application of research to the policy making process. RTD projects running over a 2–3-year period may also fulfill medium-term research needs.

– *Long-term* (~5–10 years): Scientific progress in this respect supports either policy milestones, which are clearly identified at the 10-year horizon, or the legislation review process. In the case of the WFD, long-term research needs may be linked to the development of the program of measures, which has to be operational in 2012. It may also concern the review process of the technical requirements detailed in the relevant annexes of the directive, which should be known at the time of the Second River Basin Management Plan in 2015. It is expected that research activities, as they are developed under integrated projects (funded under FP6 or FP7), may respond to either well-defined milestones of the thematic policies or legislation review.

#### **1.5.4. Interactions with the scientific community**

At the start of projects which have been identified as relevant to water policies, there is certainly a need to clarify policy issues by describing the aims, milestones, and technical challenges to the RTD

project coordinators so that they understand the policy expectations over the duration of their project. These exchanges of information/knowledge rarely occur, which may lead to divergent directions being taken by the projects in comparison to policy orientations.

#### 1.5.4.1. *Synthesis needs*

At the end of the projects, the most critical issue is the way the scientific information is “digested” so that it may be efficiently disseminated to policy endusers and possibly applied. This integration phase is certainly the weakest link in the science–policy chain. Indeed, only a small percentage of RTD projects are known to policy implementers, which illustrates the need to improve awareness about RTD outputs and also to encourage policy actors to reflect on research needs linked to their portfolios. This may be translated into needs to carry out synthesis works in the form of “policy digests” (addressed to the scientific community from the policy implementer’s side) and “science digests” (prepared by the scientific community for the policy implementers).

#### 1.5.4.2. *Exchange platforms*

As a follow-up to RTD or financial instrument for the environment (LIFE) projects, useful interactions may occur at the occasion of yearly meetings. Participation by policy officers in all project meetings may not be practicable due to a lack of resources but efforts are needed to organize regular joint meetings focusing on specific themes. This is already taking place in the WFD sector [QUE 05] and should be systematized.

#### 1.5.4.3. *Toward a “science–policy interface”*

As discussed in section 4.2, at the present stage efforts to present results and demonstrate projects are lacking in a form that policymakers may easily use, e.g. “science-digested” policy briefs. On the reverse side, the consideration of research results by the policy making community is not straightforward, mainly for political reasons and due to difficulties integrating the latest research developments in

legislation. The difficulty is enhanced by the fact that the policy making community is probably not defining its role as “client” sufficiently well. In other words, the dialogue and communication are far from being what one would hope to ensure an efficient flow of information. In this respect, improvements could be achieved through the development of a “science–policy interface” based on a coordination of relevant programs/projects with direct relevance to the WFD implementation [QUE 05]. In other words, strategies should identify needs for short-, medium- and long-term scientific developments and should establish an interface so that R&D results are synthesized in a way that can efficiently feed the implementation and further reviews of the policies. This interface should include the following:

- A screening phase evaluating which type of research is needed (background information or tailor-made research and demonstration) in accordance with the policy step of concern (e.g. development of the daughter directives covered by the WFD, implementation issues, reviewing). This is already happening through regular contact within commission services and with the scientific community.

- A mechanism to ensure that the most promising research projects in support of the policies are “validated” through demonstration activities, disseminated efficiently, and applied at the appropriate level (regional, national or EU). This is not yet or is rarely the case, but there are increasing examples of RTD projects that include a demonstration phase.

- A management scheme involving both scientists and policy makers to discuss the corresponding research and policy agendas from the very beginning in order to ensure a more structured communication at all appropriate levels of policy formulation, development, implementation and review. This is hardly operational to date.

More than dissemination and application, the interface should establish strong links between the different funding mechanisms existing at the EU level and the thematic policies. This should enable us to promote pilot projects combining the implementation of the results of successfully completed EU-funded RTD or demonstration

projects with the implementation of related policies. This would allow the formation of new and innovative partnerships by combining various EU (RTD, LIFE, Cooperation in Science and Technology (COST), structural and cohesion funds (Interreg projects), agricultural funds, etc.) and regional/national funding mechanisms, and the establishment of a collaborative partnership involving scientists, policy makers, managers and other stakeholders for the effective integration of scientific outputs in policy and management decisions. At present, however, such coordination is not operational.

### ***1.5.5. Science-based development of an integrated environmental policy***

In the first instance, we may ask the basic question: is our scientific (multidisciplinary) knowledge sufficient to develop a more integrated policy? The on-going discussions show that the scientific base is likely still not sufficiently consolidated at this stage but that a tight coordination mechanism and tailor-made developments in FP7 could lead to the establishment of an operational science–policy interfacing mechanism on the 2015–2020 horizon.

Noteworthy is the consideration about scientific uncertainty for which awareness is raising. Such considerations seek to invoke the standard of evidence that “guilt” must be demonstrated “beyond a reasonable doubt”. However, given the complexity of environmental pollution pathways, this would mean that the reality of environmental risks would not be accepted until something had actually happened. This is against the prevention principle and is not acceptable. In the light of the precautionary principle, however, where there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures aimed at preventing environmental degradation.

The WFD is a good example of such an evolution tending to better policy integration. This is illustrated in Figure 1.2, showing a progressive integration of existing directives that will be repealed under the WFD.

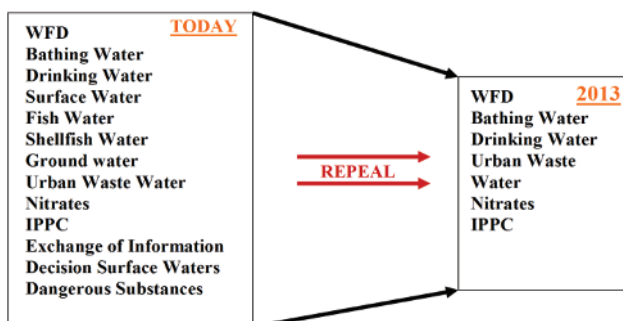


Figure 1.2. Policy integration trends under the WFD

In the context of WFD requirements, the following observations can be made:

- Monitoring and data reporting of environmental status and trends need to be coordinated at EU level in the framework of a common mechanism. This is the goal of the Water Information System for Europe (WISE [DEU 06]), which allowed a considerable step forward at the 2008–2009 horizon. Coordinated reporting and data sharing should constitute the core basis for water policy implementation and review within the next decade. In the light of increasing considerations about climate change (and its impact on water management), we may wonder whether data sharing should not be expanded at a global scale in the form of a global WISE to be closely linked to Global Monitoring for Environment and Security developments.

- Building up environmental databases, such as the one to be developed under the WFD monitoring programs, should enable us to test/validate existing models and develop new models better able to evaluate environmental risks linked to pollution pathways, and thus better evaluate the efficiency of policy responses. This is closely linked to the knowledge-based considerations stated in this chapter.

- Risk assessments and programs of measures need to be coordinated in the light of effective implementation of directives in force (namely all directives listed in Annex VI, part A, of the WFD).

The consequence of better integration of scientific knowledge and policies might result in a few pieces of framework legislation in the long-term. In Figure 1.2, RTD projects studying “environmental interfaces” are closely interlinked to specific policies. The overall cycle, however, could be conceived in one single environmental circle. In this context, a better – knowledge-based – appraisal of risks in the context of concerted planning (e.g. at river basin level) would facilitate the design of monitoring programs (avoiding duplication, focusing on specific features) and the elaboration of programs of measures. The way framework directives are being developed opens the door for increasing integration, which should be pursued and linked to a sound and validated scientific foundation.

## 1.6. Conclusions

In this chapter, we may be puzzled by the high number of international organizations, national, international, regional and sometimes global conventions, which all deal with the study (primarily the monitoring) of chemicals in the marine environment [KRA 01, ROO 10, ROO 11]. Some of these programs have been running for many years or even decades, principally within the industrialized northern hemisphere. The output of these programs has been used to identify areas or regions of concern, estimate the hazards caused by chemicals to human beings and the marine environment and assess the effectiveness of the measures taken. Over the past 40 years, the objectives of monitoring harmful substances in fish and shellfish as potential hazards to human health have changed into an ecosystem approach where – in Europe under the WFD and MSFD – good environmental status will be reached. Monitoring is one of the management tools used for assessing the quality status and the temporal trends, i.e. as a policy tool. These long-term monitoring programs are expected and able to demonstrate changes in the levels of chemicals in the marine environment resulting from policy actions [ROO 11a]. Despite this, the present situation is far from ideal. Collecting and reporting of the data is often incomplete, which hampers the assessment process, and this particular aspect deserves special attention at all the levels. Clearly, it is one thing to

conceive a monitoring program, it is quite another to implement it. This requires time and effort spent by all parties involved and we should not forget that monitoring of the marine environment is a time-consuming and expensive process [ROO 11a]. A further fundamental difficulty for an efficient interface between research and policy arises from the fact that research and policy have different and varying agendas [ROO 11b]. Although policy tends to focus on the short-term perspective, science envisages a long-term perspective. Moreover, while policy tries to involve the development of acceptable compromises, the scientific community aims to work toward the collection of objective scientific facts and the development of reasonable theories. This ambiguity is also present in the current monitoring programs. There is a clear need for more data, both in terms of quantity (e.g. spatial and temporal distribution of data points) and quality (e.g. number of chemicals determined) if we are to understand the status of the marine environment. Given the natural variability, fewer data are often disastrous for a proper assessment, whereas more data imply more resources, which inevitably meet restraints. Nevertheless, we can wonder if the potential consequences of limited data sets outweigh the costs of obtaining the right information [ROO 11].

An important aspect is that there is a general awareness that the data, which are produced and stored, should be of high and, specifically, well-defined quality. The emphasis on the awareness of quality assurance and quality control (QA/QC) is one of the major achievements of chemical monitoring to date. Successful intercomparison exercises and programs such as QUASIMEME ([TOP 97, WEL 00, WEL 06]; [www.quasimeme.org](http://www.quasimeme.org)) have highlighted the need for rigorous QA/QC in chemical monitoring. QA/QC is now omnipresent and an essential element of all well-defined monitoring programs. Among other things, this implies the obligation of laboratories to participate in international intercomparison exercises or proficiency testing schemes and to have documented QA/QC procedures if not outright accreditation. This is a part of the overall metrological framework of this book, which is discussed in Chapter 2.