JRC Scientific and Technical Reports

MARINE STRATEGY FRAMEWORK DIRECTIVE

Task Group 10 Report

Marine litter

APRIL 2010

F. Galgani, D. Fleet, J. Van Franeker, S. Katsanevakis, T.Maes, J. Mouat, L. Oosterbaan, I. Poitou, G. Hanke, R. Thompson, E. Amato, A. Birkun & C. Janssen

Joint Report

Prepared under the Administrative Arrangement between JRC and DG ENV (no 31210 – 2009/2010), the Memorandum of Understanding between the European Commission and ICES managed by DG MARE, and JRC's own institutional funding

Editor: N. Zampoukas

EUR 24340 EN - 2010

The mission of the JRC is to provide customer-driven scientific and technical support for the conception, development, implementation and monitoring of EU policies. As a service of the European Commission, the JRC functions as a reference centre of science and technology for the Union. Close to the policy-making process, it serves the common interest of the Member States, while being independent of special interests, whether private or national.

European Commission
Joint Research Centre
Institute for Environment and Sustainability
Contact information
Address: Via Enrico Fermi 2749, 21027 Ispra (VA), Italy
E-mail: georg.hanke@jrc.ec.europa.eu
Tel.: 0039 0332 785586
Fax: 0039 0332 786351

French Research Institute
for Exploitation of the Sea
155, rue Jean-Jacques Rousseau
92138 Issy-les-Moulineaux Cedex
Tel. (33) 01 46 48 21 00
Fax (33) 01 46 48 21 21
Web site: http://www.Ifremer.fr/anglais/
Chief Executive Officer: Jean-Yves Perrot

International Council for the Exploration of the Sea
Conseil International pour l'Exploration de la Mer
General Secretary
H. C. Andersens Boulevard 44–46,
DK-1553 Copenhagen V, Denmark
Telephone (+45) 33 38 67 00
Telefax (+45) 33 93 42 15
www.ices.dk, info@ices.dk

JRC 58104
EUR 24340 EN
ISBN 978-92-79-15653-3
ISSN 1018-5593
DOI 10.2788/86941
Luxembourg: Office for Official Publications of the European Communities

Printed in Italy

PREFACE

The Marine Strategy Framework Directive (2008/56/EC) (MSFD) requires that the European Commission (by 15 July 2010) should lay down criteria and methodological standards to allow consistency in approach in evaluating the extent to which Good Environmental Status (GES) is being achieved. ICES and JRC were contracted to provide scientific support for the Commission in meeting this obligation.

A total of 10 reports have been prepared relating to the descriptors of GES listed in Annex I of the Directive. Eight reports have been prepared by groups of independent experts coordinated by JRC and ICES in response to this contract. In addition, reports for two descriptors (Contaminants in fish and other seafood and Marine Litter) were written by expert groups coordinated by DG SANCO and IFREMER respectively.

A Task Group was established for each of the qualitative Descriptors. Each Task Group consisted of selected experts providing experience related to the four marine regions (the Baltic Sea, the North-east Atlantic, the Mediterranean Sea and the Black Sea) and an appropriate scope of relevant scientific expertise. Observers from the Regional Seas Conventions were also invited to each Task Group to help ensure the inclusion of relevant work by those Conventions. A Management Group consisting of the Chairs of the Task Groups including those from DG SANCO and IFREMER and a Steering Group from JRC and ICES joined by those in the JRC responsible for the technical/scientific work for the Task Groups coordinated by JRC, coordinated the work. The conclusions in the reports of the Task Groups and Management Group are not necessarily those of the coordinating organisations.

Readers of this report are urged to also read the report of the above mentioned Management Group since it provides the proper context for the individual Task Group reports as well as a discussion of a number of important overarching issues.

Contents

Executive summary

Properties and quantities of marine litter do not cause harm to the coastal and marine environment.

1. Definition of terms descriptors and scientific understanding of key concepts associated with the descriptor.

Marine litter is any persistent, manufactured or processed solid material discarded, disposed of or abandoned in the marine and coastal environment.

Marine litter consists of items that have been made or used by people and deliberately discarded or unintentionally lost into the sea and on beaches including such materials transported into the marine environment from land by rivers, draining or sewage systems or winds. For example, marine litter consists of: plastics, wood, metals, glass, rubber, clothing, paper etc. This definition does not include semi-solid remains of for example mineral and vegetable oils, paraffin and chemicals that sometime litter sea and shores.

2. What is good environmental status

"Harm" can be divided into three general categories: Social (reduction in aesthetic value and public safety), economic (e.g. cost to tourism, damage to vessels, fishing gear and facilities, losses to fishery operations, cleaning costs) and ecological (mortality or sublethal effects on plants and animals through entanglements, captures and entanglement from ghost nets, physical damage and ingestion including uptake of microparticles (mainly microplastics) and the release of associated chemicals, facilitating the invasion of alien species, altering benthic community structure).

Definitions of the acceptable levels of harm in these categories and good environmental status must consider impacts as assessed by the amount of litter in different compartments of the marine environment (seabed, sea surface, water column, coastline), ecological effects of the litter (e.g. plastics ingested by marine organisms; entanglement rates) and problems associated with degradation of litter (microparticles) as well as social and economic aspects. Tourism is strongly negatively affected by the presence of litter. An overriding objective will be a measurable and significant decrease (e.g. 10%/year for litter on coastlines) in the total amount of litter in the environment by 2020.

3. How should scale be addressed with the descriptor

Because the litter will persist in the sea for years, decades and centuries, evaluations of sources alone will not be enough and long term monitoring in the marine environment will be required.

Working at the European scale will be possible for litter evaluation on beaches, at sea and measuring degradation processes using standard protocols. Evaluating the impact of litter on marine organisms will be done at regional or basin scale, enabling transposition of protocols to local species. Highly affected areas will be monitored locally. Temporal scales should take into account seasonal variations.

4. Key attributes of the descriptor

4.1. Description of it and subcomponents, why the attribute is important

The group recommends the overriding objective to be a measurable and significant decrease in comparison with the initial baseline in the total amount of marine litter by 2020 using the following criteria and methodologies for the evaluation of the state of good environmental status.

- Amount, source and composition of litter washed ashore and/or deposited on coastlines. The attribute will indirectly measure inputs, impacts on aesthetic values, the presence of toxic compounds and socio-economical damage.
- Amount and composition of litter in the water column - including floating and suspended litter - and accumulation on the sea floor. The attribute will measure litter dynamics and potential interactions with marine life. Accumulation areas will be located.
- Amount and composition of litter ingested by marine animals. The attribute measures time-trends and spatial variation in inputs of litter and its impact on marine life.
- Amount, distribution and composition of microparticles (mainly microplastics). The attribute will measure quantities, types, degradation processes and potential sources of contaminants.

Monitoring results combined with research on social, economic and ecological harm will lead to improved knowledge of critical thresholds.

4.2. Criteria; which subcomponent of the attribute reflect a gradient of degradation and why?

Quantities, composition and distribution of litter, including the distribution and concentrations of degradation products of litter (microparticles in sediments and the water column) as well as impact rates on organisms and the potential chemical pollution resulting from plastics are good trend indicators of degradation through marine litter and monitor direct harm in the marine environment.

Monitoring the quantities and distribution of litter in the different compartments of the marine environment will give a basis for actual and potential assessment of socio-economic and ecological impacts of litter. Impacts on organisms, distribution and concentrations of microparticles and chemical burdens monitor direct harm to the marine ecosystem.

4.3. Where appropriate, which human activities and pressures are closely linked to/reflect by the attribute or specific subcomponents:

a) Presence of point and diffuse sources of litter such as municipal landfills, untreated sewage discharges, coastal industries, tourism and specific activities such as shipping, load of litter from ships, fishing, aquaculture and various offshore activities.

b) The origin, drift and fate of litter as a consequence of rainfalls, rivers, currents, winds and geomorphological factors are important issues when evaluating effects as those will influence the distribution and abundance of litter.

4.4. What are the important classes of indicators related to the attribute to cover properties and linkages to pressures, including examples and methodological standards:

Evaluation of quantities and composition of litter (amount on the coastline, the sea floor, in the water column and on the waters surface), the amount ingested by animals and entanglement rates are the best links to pressures.

Methodological standards in Europe are currently available for the assessment of:

- Litter on coastlines: In the OSPAR, HELCOM and Black sea regions, standards for the Beach Litter Survey have been developed which could, if necessary, be adjusted, harmonized and applied to other regions.
- Litter at sea. Pilot projects indicated that litter on the sea floor could be measured along side international biological trawling surveys (e.g. IBTS) or dedicated dive or photographic transects. Impact of "ghost" nets will be considered in fishing areas. Litter in the water column can be measured by using (plankton) nets or filtered water samples. Floating litter can be assessed at large scale by aerial surveys.
- Litter in seabird stomachs: In the OSPAR system of Ecological Quality Objectives for the North Sea, amounts of plastics in Fulmar stomachs are already used as the EcoQO to assess temporal trends, regional differences and compliance with a set target for acceptable ecological quality in the North Sea area. Such monitoring can be applied in other areas by either fulmars or similar species with adjusted targets, and may also include entanglement rates of representative species.
- Particle abundance, especially microplastics can be assessed in the water column by concentrating the particles from water or by washing low-density particles from sediment samples.

5. *Methods for aggregating the indicators (indices) within the descriptor to achieve an overall assessment.*

OSPAR QSR 2010 and HELCOM based regional approaches which link pressures and activities to the quality of ecosystem components will be considered for implementation and extension to other areas.

6. *Emergent messages about monitoring and research. Final synthesis*

An initial evaluation is needed by all member states on the current state of research in their region/subregion to give a scientific and technical basis for monitoring, define knowledge gaps and priority areas for research. Harmonisation will require coordination by relevant representatives from each member state; this will lead to common and comparable monitoring approaches, recommendations and guidelines to assess GES on a regional/European scale. Research will need to include the improvement of knowledge concerning impacts on marine life, degradation processes at sea, the study of litter-related microparticles, the study of chemicals associated with litter, the factors influencing the distribution and densities of litter at sea (human factors, hydrodynamics, geomorphology etc.), the normalisation of methods and the determination of thresholds. The assessment and monitoring of socio-economic harm will also need to be addressed.

1. Initial interpretation of the descriptor

1.1. Definition of the key term 'Marine litter'

Marine litter is any persistent, manufactured or processed solid material discarded, disposed of or abandoned in the marine and coastal environment.

Marine litter consists of items that have been made or used by people and deliberately discarded or unintentionally lost into the sea or coastline including such materials transported into the marine environment from land by rivers, drainage or sewage systems or wind. For example marine litter consists of plastics, wood, metals, glass, rubber, clothing, paper etc. This definition does not include semi-solid remains of for example mineral and vegetable oils, paraffin and chemicals that sometime litter sea and shores.

1.2. What is covered by the term 'Harm to coastal and marine environment'

"Harm" can be divided into three general categories: 1) ecological (mortality or sublethal impacts to plants and animals through entanglement, physical damage and ingestion including uptake of microplastics, accumulation of chemicals from plastics, facilitating the invasion of alien species, or altering the benthic community structure); 2) economic (e.g. cost to tourism, damage to vessels, fishing gear and facilities, losses to fishery operations, cleaning costs); and 3) social (reduction in aesthetic value and public safety).

Definitions of the acceptable levels of harm in these categories and good environmental status must consider impacts as assessed by the amount of litter in different compartments of the marine environment (seabed, sea surface, water column, coastline), ecological effects of the litter (e.g. plastics ingested by marine organisms; entanglement rates) and problems associated with degradation of litter (microplastics) as well as social and economic aspects. Tourism is strongly negatively affected by the presence of litter. An overriding objective for marine litter pollution will be a measurable and significant decrease in the total amount of litter in the environment by 2020.

In its ecological sense, the 'level of litter that causes effect on the environment' of course depends on the type and quantity of litter being measured and the environmental or ecosystem components being considered. Some organisms live on, or even benefit, from a waste dumpsite while others are impaired by it or can even become locally extinct. Discarded or lost fishing nets have an immediate effect through entanglement and the resulting mortality of marine mammals, turtles, birds and fishes whereas the effect of microplastic particles resulting from the degradation of those same nets, will remain for decades or centuries after, and will affect other marine species that ingest smaller items directly or involuntarily through filter feeding and may suffer from mechanical, but in particular chemical consequences from ingestion. Chemicals incorporated in, or attracted to plastics floating in seawater have a broad range of potentially toxic, carcinogenic and hormone disturbing effects (Thompson *et al*., 2009). Around 95% of Fulmars in the North Sea area has plastic in the stomach (Van Franeker *et al*., 2005) which unavoidably has mechanical and chemical consequences that affect their body condition with negative consequences for individual survival and capacity to reproduce. In the Mediterranean, sea turtles are seriously endangered, as a consequence of not only habitat loss and bycatch, but also through entanglement in, and ingestion of marine litter. Litter originating in the more populated parts of the world can reach and cause harm in remote places like the Antarctic: over 80% of chicks of Wilson's storm petrels found in the Antarctic have plastic in the stomach, fed to them by the parents that accumulated those plastics in their stomachs in their northern (up to e.g. Spain) wintering areas (van Franeker and Bell, 1988).

These examples are given to indicate that every level of litter in the marine environments causes some level of 'harm'. 'Good Environmental Status' can at best be represented by a selected type of measurement (indicator) of litter-abundance representing an overall effect level (ecological or other) considered as 'acceptable'. For an 'overall' acceptable level, one may for example look at situations in currently relatively clean reference-areas. It is important to remain aware that an indicator is not equal to the full range of environmental harm. The fact that fulmars, in spite of their plastic eating habits, are not yet extinct, does not mean that the litter abundance that they indicate is not harmful to other species, nor to economic or social aspects.

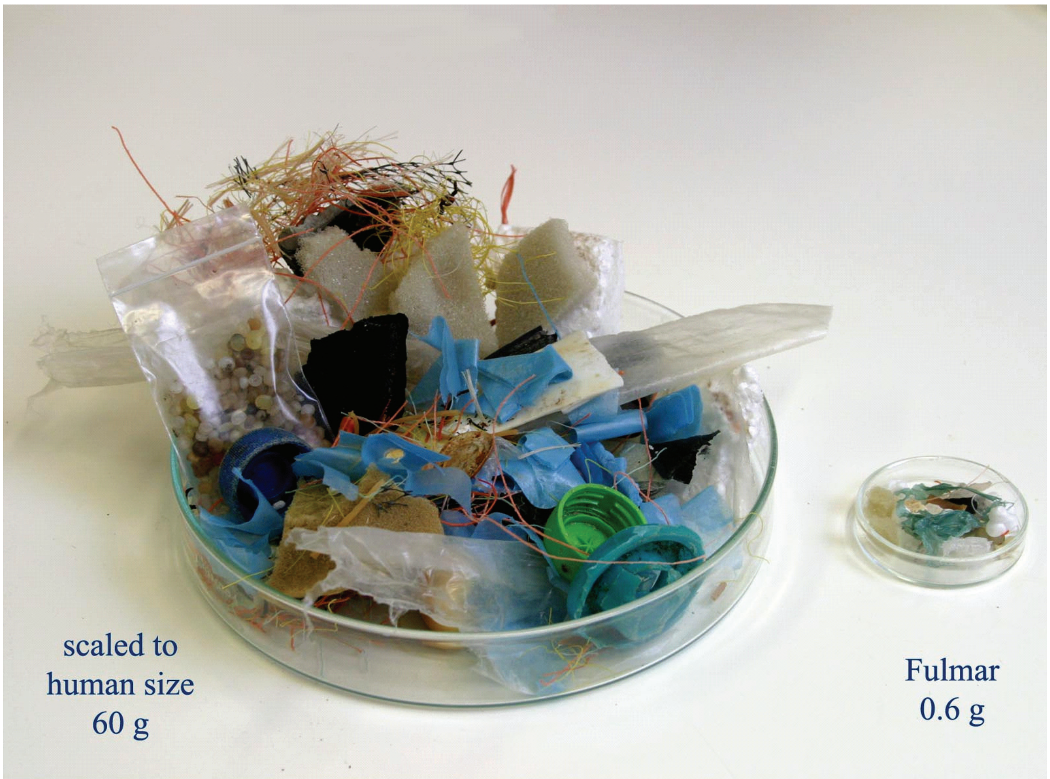

Photo: A human perspective on 'harm'

There is no doubt that the ingestion of plastic negatively affects the body condition of an animal which will reduce its chances for survival and successful reproduction. However, do current levels of marine litter affect populations at a level to be considered harmful?

In the North Sea almost every Fulmar has plastic in the stomach, with an average of around 30 pieces and 0.3 gram plastic mass per bird. Fulmars beached in the most polluted parts of the southern North Sea (See Chpt. 2.4) currently have an average of ca 0.6 gram of plastic in their stomach. Conclusive scientific evidence that such levels represent 'harm' to the Fulmar population is not possible. Such a question is maybe best approached by taking a human perspective. Imagine a Fulmar (ca. 700g) upgraded to the size of a human, about 100 times as heavy as shown on the photograph. If such a quantity of plastic was the AVERAGE amount of litter in stomachs of humans around the southern North Sea, ambient levels of litter would certainly be considered harmful and immediate action would be taken.

In the socioeconomic sense, harm can be split into the social and economic terms. Social harm includes reduction in recreational, aesthetic or education values of a particular area well as risks to human health. Economic harm includes direct costs and loss of income due to marine litter and affects a range of marine sectors including aquaculture, agriculture, fisheries, shipping (including leisure boating), power generation and industrial use, local authorities and tourism. Levels of economic "harm" have been analysed by Hall (2000) and may run into millions of Euro annually at even smaller regional scales. Economic harm should also include the cost of degradation of ecosystem goods and services caused by marine litter.

1.3. Identification of possible links and overlaps with other descriptors

The accumulation of persistent organic pollutants (POPs; Mato *et al*., 2001; Teuten *et al*., 2009), and the potential release of toxic compounds (Oehlmann *et al*., 2009; Teuten *et al*., 2009), the transportation of non-indigenous species to new locations (Barnes, 2002; Gregory, 2009), the distribution of algae associated with red tides (Masó *et al*., 2003) and the ingestion by organisms link descriptor 10 to descriptors from task groups 2 (Non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystems.), TG 4 (marine food webs) and TG 8 (Concentrations of contaminants are at levels not giving rise to pollution effects). TG 8 and 10 considered oils (mineral and non mineral) and paraffins and concluded that they are not covered adequately by the existing GES descriptors.

1.4. Identification of relevant policies and conventions related to marine Litter

1.4.1. International organisations

Conventions and agreements

- United Nations Convention on the Law of the Sea (UNCLOS) and General Assembly (GA) Resolutions: Sets out the legal framework within which all activities in the oceans and seas must be carried out. The General Assembly carries out annual reviews of the law of the sea (Resolutions), based on annual comprehensive reports prepared by the Secretary-General. (http://www.un.org/Depts/los/index.htm).

The Regional Seas programme aims to address the accelerating degradation of the world's oceans and coastal areas through the sustainable management and use of the marine and coastal environment, by engaging neighbouring countries in comprehensive and specific actions to protect their shared marine environment

- Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (UNEP, regional seas program): An intergovernmental programme which addresses the inter-linkages between freshwater and the coastal environment (http://www.gpa.unep.org/)

- International Convention for the Prevention of Pollution from Ships (MARPOL 73/78) and Annex V(http://www.imo.org/).

- London Convention 1972, Convention on the Prevention of Maritime Pollution by Dumping of Wastes and Other Matter and 1996 Protocol Thereto (http://www.imo.org/home.asp?topic_id=1488)

- Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal (http://www.basel.int/)

- Agenda 21 and the Johannesburg Plan of Implementation: Agenda 21 is a programme ran by the United Nations (UN) related to sustainable development. (http://www.un.org/esa/sustdev/)

- Convention on Biological Diversity, with the Jakarta Mandate: Ministerial Statement on the Implementation of the Convention on Biological Diversity. (http://www.oceanlaw.net/texts/jakarta.htm)

- FAO Code of Conduct for Responsible Fisheries: The Code provides a framework for national and international efforts to ensure sustainable exploitation of aquatic living resources in harmony with the environment. (http://www.fao.org/docrep/005/v9878e/v9878e00.htm)

Global activities

- Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP): GESAMP is an advisory body, established in 1969, that advises the United Nations (UN) system on the scientific aspects of marine environmental protection. (http://gesamp.net/page.php?page=1)

- International Coastal Cleanup (ICC): ICC is the largest coastal cleanup campaign. Each year tons of trash is cleared from coastlines, rivers and lakes worldwide and everything is reported.

(http://www.oceanconservancy.org/site/PageServer?pagename=press_icc)

- Clean Up the World: Clean Up the World is a community based environmental program that inspires and empowers individuals and communities to clean up, fix up and conserve their environment. (http://www.cleanuptheworld.org/en/)

1.4.2. Regional Institutions

The problem of marine litter was recognized by the UN General Assembly, which in its Resolution A/60/L.22 - Oceans and the Law of the Sea - of 29 November 2005 in articles 65-70 calls for national, regional and global actions to address the problem of marine litter. In response to the GA call, UNEP (GPA and the Regional Seas Programme), through its Global Marine Litter Initiative took an active lead in addressing the challenge, among others, by assisting 11 Regional Seas around the world in organizing and implementing regional activities on marine litter. Four of these regional seas are considered within the MSFD (North-East Atlantic Region (OSPAR Convention), Baltic Sea (HELCOM Convention), Black Sea and the Mediterranean Sea).

Taking into account the United Nations General Assembly Resolution, the Global Programme for Action framework, ongoing regional activities organised through the Regional Seas Programme of the United Nations Environment Programme and the outcome of the 2nd Intergovernmental Review of the Global Programme for Action, it has been agreed that the strategy to address the problem of marine litter at the regional level be based on the development and implementation of the Regional Action Plans for Marine Litter or Regional Strategies for the Sustainable Management of Marine Litter. It has also been agreed that the development and implementation of a Regional Strategy should pass through the following three phases:
- Phase I Assessment of the regional situation;
- Phase II Preparation of the Regional Strategy; including a regional meeting of experts and national authorities; and

- Phase III The integration of the Regional Strategy into the Programme of Work of the respective Regional Seas Programmes and the Implementation of the Regional Strategy at the national and regional level.

A number of regional programmes did prepare a regional assessment (e.g. OSPAR). These Regional Assessments have been presented and analysed in "Marine Litter: a global challenge" (2009), prepared by UNEP's Regional Seas Programme.

1.4.2.1. HELCOM Convention

Lack of comparable and reliable data is a major gap in marine litter issues in the Baltic Sea. Therefore HELCOM has prepared a Recommendation for the Harmonization of methods of sampling and reporting the amount and type of marine litter on the coast within the Baltic Sea region, and a Survey form for reporting marine litter, in order to get more harmonized data from different initiatives in the future. Amendments to the HELCOM Recommendation 28/1 on Application of the no-special-fee system to ship-generated wastes in the Baltic Sea area has been prepared by the project to include the litter caught in the fishing nets to the no-special-fee system.

The amounts reported by the countries and the information provided by NGOs suggest that there is no clear descending or ascending trend in the marine litter found on coasts of the Baltic Sea. The amounts can be substantial in some specific sites near the sources of litter (e.g. shipping routes, rivers, public beaches) but generally not as important as for other areas. Yet attention should be paid to the specific points were littering is more extensive and has harmful effects on the environment, or creates a risk or economical losses to the people using or living at the coast.

The Baltic Strategy on Port Reception Facilities for Ship-generated Wastes: Already since the late 1990s the HELCOM Member States have been implementing the complex set of measures known as the Baltic Strategy on Port Reception Facilities for Ship-generated Wastes (the Baltic Strategy) to prevent illegal discharges of waste into the Baltic Sea and providing for economic incentive to deliver wastes, including garbage, onshore. The Baltic Strategy has been elaborated through a number of HELCOM Recommendations enumerated below.

-28/1 (2007) Application of the no-special-fee system to ship-generated wastes in the Baltic Sea area
-24/5 (2003) Proper handling of Waste/Landfilling
-23/1 (2002) Notification of Ship's wastes
-22/3 (2001) Unified interpretations to ensure a harmonized and effective implementation of the strategy for port reception facilities for ship-generated wastes and associated issues
-19/16 (1998) Co-operation in investigating violations or suspected violations of discharge *and* related regulations for ships, dumping and incineration regulations
-19/13 (1998) Basic Principles of Ashore Handling of Ship-Generated Wastes
-19/12 (1998) Waste Management Plans for Ports, supplemented by 22/3
-19/9 (1998) Installation of the Garbage Retention Appliances and Toilet Retention Systems and Standard Connections for Sewage on Board Fishing Vessels, Working Vessels and Pleasure Craft, supplemented by 22/1, 22/3
-14/7 (1993) Guidelines for Provisions of Facilities for the Handling, Storage and Processing of Shipboard Garbage
-13/6 (1992) Definition of Best Environmental Practice
-12/3 (1991) Definition of Best Available Technology
-10/7 (1989) General Requirements for Reception of Wastes, supplemented by 19/12

-10/5 (1989) Guidelines for the Establishment of Adequate Reception Facilities in Ports, supplemented by 19/8

1.4.2.2. OSPAR Convention

OSPAR is the mechanism by which fifteen Governments of the western coasts and catchment areas of Europe, together with the European Community, cooperate to protect the marine environment of the North-East Atlantic. OSPAR covers five subregions: Arctic, the Greater North Sea, the Celtic Seas, Bay of Biscay and Iberian Coast and the Wider Atlantic. Activities on marine litter are covered by the Biodiversity Strategy and are dealt with within the BioDiversity Committee (BDC) and the Working Group on Environmental Impact of Human Activities (EIHA). In between meetings, work is undertaken in the Intersessional Correspondence Group on Marine Litter (ICG-ML) involving experts from governments and non-governmental organizations with a particular interest in marine litter. ICG-ML actively develops OSPAR methodologies, position statements, data collection and analysis and lessons learned. It uses an electronic forum as a cost-effective means to exchange views and information. Formal meetings are held to refine assessments and strengthen the good working relationships. Some products:

The OSPAR *Pilot Project on Monitoring Marine Beach Litter 2007* was the first region-wide project in Europe to develop a standard methodology for monitoring marine litter found on beaches. The sources and quantitative trends in marine litter were identified on the beaches of nine OSPAR Contracting Parties (Belgium, Denmark, France, Germany, The Netherlands, Portugal, Spain, Sweden and the United Kingdom). The project's final report is based on a statistical analysis of marine litter from 609 surveys, using a common, standardized survey protocol on 100 meter stretches of 51 regular reference beaches monitored during the pilot project period (2001–2006), supplemented by 335 surveys of 1 kilometer stretches on 31 regular reference beaches during the same period. Beach data identified five main sources: fishing (including aquaculture), sanitary waste/sewage related waste, operational waste from shipping (including offshore activities), galley waste (non-operational waste from shipping, fisheries and offshore activities), and tourism and recreational activities.

OSPAR's *Assessment of the Marine Litter Problem in the North-East Atlantic Maritime Area and Priorities for Response (2009)* draws on previous work on marine litter in the OSPAR Area (including the above mentioned pilot project) that identified the need to develop a harmonized methodology. The result is a comprehensive analysis of quantities, composition and trends of marine litter throughout the OSPAR Maritime Area. The *Assessment* illustrates how levels of marine litter have remained high but steady between 2001 and 2006 although the spatial distribution varies. The majority of debris entering the North-East Atlantic are from sea based sources e.g. shipping, the fishing industry and offshore oil and gas installations and from land-based sources such as rivers, tourism, fly tipping, local businesses and unprotected waste disposal sites.

Notwithstanding the need to prevent litter in the first place, OSPAR has promoted 'fishing-for-litter' as a practical, simple yet effective means to remove litter from the marine environment. The project targets the fishing industry by asking fishermen to voluntarily collect marine litter caught up in their nets in large hard-wearing bags provided by the project. The amount and types of litter are recorded onshore before being disposed of in an environmentally friendly way. OSPAR published a *Background Report on Fishing-for-litter Activities in the OSPAR Region* and adopted guidelines on how to develop a 'fishing-for-litter' project. Together with large-scale, regular and targeted clean-up operations funded by government agencies, 'fishing-for-litter' has the potential to significantly reduce marine debris, thus decreasing environmental impact and economic costs to the fishing industry and society as a whole. For example in 2008 schemes run by KIMO in Scotland and the Netherlands involved 191 vessels and removed 237 tonnes of litter from the seabed.

OSPAR is in the process of preparing formal Guidelines for Monitoring Beach Litter (to be published in 2010). These Guidelines, together with quality assurance and database management procedures, will form the basis to make beach litter monitoring a formal monitoring instrument.

In the North Sea, the North Sea Ministerial Conference (2002) in Bergen, Norway commissioned OSPAR to implement a management system based on a set of Ecological Quality Objectives or EcoQO's. Among these, OSPAR has initiated the implementation of an EcoQO for marine litter (OSPAR, 2008). This EcoQO monitors the abundance of plastics in stomachs of a common seabird, the Northern Fulmar (*Fulmarus glacialis*) and uses this as an instrument to evaluate temporal trends and regional differences in the marine litter situation, and has set a target value of plastic abundance in the bird stomach considered to represent 'acceptable ecological quality'. The Fulmar-Litter-EcoQO approach probably comes closest to the intended methodology for 'Good Environmental Status' in the Marine Strategy Framework Directive and may act as an example. See section 2.4. for further details.

1.4.2.3. Black sea commission

The Black Sea does not constitute an exception from the global negative tendency towards polluting the hydrosphere with man-made debris. However, this problem is not properly addressed and managed yet on the regional and national levels. Bearing in mind that marine litter (ML) is a priority for both the Black Sea Commission (BSC) and the UNEP Regional Seas Programme, the latter organization provided support to the BSC Secretariat for the development of Regional Activity on ML in the Black Sea within the framework of the Strategic Action Plan on Rehabilitation and Protection of the Black Sea (BS SAP).

The geographical scope of the ML problem extends over the entire catchment area of the Black Sea drainage basin and includes the Black Sea satellite seas (the Sea of Azov and Marmara Sea), the Strait of Kerch and Istanbul Strait, all rivers flowing into the above maritime areas, coastal territories bordering to these maritime areas and all land drained by the rivers and their confluents.

The Black Sea states are the parties to several conventions and international agreements which are relevant to the management and mitigation of ML problem. The Convention on the Protection of the Black Sea Against Pollution (the Bucharest Convention), the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78), the Convention for the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (the London Convention), the Convention on the Transboundary Movements of Hazardous Wastes and Their Disposal (the Basel Convention), and some other instruments which have indirect relation to the control of ML problem.

All six Black Sea states are in transition process of developing and updating their national instruments aimed at combatting marine pollution including ML/ solid waste component. National policies in the Black Sea states are aimed at waste minimization, reuse, recycling and recovery of landfills. The major legislative and regulatory tools for waste management are adequately developed in the Black Sea countries, and include basic laws and regulations. Bulgaria and Romania, which were accepted to the EU in January 2007, transpose relevant EU directives and standards into their national legislation. One of the main management problems affecting most Black Sea countries consists is the imperfect ability to apply existing laws and regulations. Once declared, they should be implemented in a proper way, however, sometimes they work inadequately or do not work at all.

The 15th Regular Meeting of the BSC (Istanbul, 20-22 November 2006) considered the achieved progress in implementation of the Black Sea Regional Activity on Marine Litter and approved the BSC Workplan for the year 2006/2007.

Participants of the Special Session on ML (Istanbul, October 2006) proposed a list of high priority actions to be included in the Regional ML Action Plan. Taking into account suggestions, a Draft Strategic Action Plan for the Management and Abatement of Marine Litter in the Black Sea Region (BS-ML-SAP) (1) to improve the waste management policies, (2) to reinforce and harmonize existing legal and administrative instruments relevant to the implementation of waste management policies, (3) to strengthen intergovernmental institutional arrangements, (4) to improve national institutional mechanisms, (5) to identify financial sources and allocate essential funds for the implementation of marine litter projects, (6) to develop regional and national marine litter monitoring and assessment schemes based upon a common research approach in methodology, evaluation criteria and reporting requirements, (7) to improve, develop and implement practical measures aimed to prevent and/or reduce marine litter pollution, (8) to gain and implement the best available technologies in order to collect, process, recycle and dispose marine litter, (9) to raise public awareness and promote public education on marine litter issues, (10) to strengthen public, governmental, and private sector partnership in combating marine litter pollution, (11) to improve the professional skills and knowledge of responsible authorities involved in the management of marine litter issues, (12) to stimulate information exchange on marine litter issues amongst the Black Sea countries.

1.4.2.4. Barcelona convention/MEDPOL

Marine litter has been an issue of concern in the Mediterranean since the 1970s. The Mediterranean countries adopted the Convention for the Protection of the Mediterranean Sea against Pollution (the Barcelona Convention) in 1976. Within the framework of this Convention, the Mediterranean countries adopted in 1980 a Protocol for the Protection of the Mediterranean Sea against Pollution from Land-Based Sources. The Protocol Annex I defines as one of the categories of substances "Litter as any persistent manufactured or processed solid material which is discarded, disposed of, or abandoned in the marine and coastal environment".

The Mediterranean was designated a Special Area for the purposes of Annex V of the MARPOL 73/78 Convention. However, only very recently did the Mediterranean coastal States Parties to the MARPOL Annex V present a joint submission to the IMO’s MEPC, notifying that adequate reception facilities for garbage were provided in their respective ports.

UNEP/MAP, jointly with IOC and FAO, organised in 1988 a survey with five participating countries (Cyprus, Israel, Italy, Spain and Turkey), considered as a landmark activity for the assessment of coastal and marine litter in the Mediterranean. The secretariat was asked in 1999 to begin actions on coastal and marine litter and to prepare a relevant assessment including a budget line for the assessment of pollution of the Mediterranean Sea by litter.

A general Questionnaire about Litter Management in Coastal Zones of the Mediterranean was sent to Mediterranean countries. The result indicates that it is the inadequate management of coastal solid waste that is responsible for the presence of litter on the beaches, floating in the water and on the sea bed. In addition, almost all the Mediterranean countries have poor policies for the management of coastal solid waste and only few countries have policies related specifically to marine litter.

Based on these facts, MEDPOL built up a strategy to assist coastal local authorities to improve the management of coastal solid waste and prevent the introduction of litter into the marine environment. Along this line, MEDPOL implemented in 2004-2005, with the cooperation of RAMOGE and UNADEP, a pilot project at the Municipality of Tripoli, Lebanon in which direct technical and legal assistance has been provided together with a public awareness campaign.

In 2003, UNEP/MAP, in cooperation with WHO, prepared Guidelines for Management of Coastal Litter for the Mediterranean Region (MAP, 2003). The Mediterranean Action Plan of UNEP with the support of the Regional Seas Programme of UNEP in 2006 developed a medium-term public awareness and education campaign on the management of marine litter in the Mediterranean with the overall objective to contribute to the protection of the environment and the sustainable development of the Mediterranean. UNEP/MAP opted to work with partner NGOs of the region (MIO-ECSDE, HELMEPA, and Clean Up Greece) in a project entitled "Keep the Mediterranean Litter-free Campaign" carried out by the three partner organizations with the support of UNEP/MAP. The outcomes were a series of awareness events, brochures and clean-ups.

Numerous international organisations and NGOs have conducted surveys and beach cleanup campaigns yielding data and information on marine and coastal litter pollution of the Mediterranean Sea. These efforts, which continue to present, are considered as a reliable source of data and information.

In 2008 an assessment of Marine Litter in the Mediterranean was prepared relied on the information collected from completed questionnaires of fourteen Mediterranean countries, analysis of beach clean-up data mainly from the period 2002-2006, the monitoring and recording of litter floating on the sea surface for the duration of the study by an NGO (HELMEPA) member companies with ships traveling in or transiting the Mediterranean, existing literature and initiatives and the direct contacts with local authorities, non-governmental organizations and associations, as well as scientists and individuals, who could provide reliable data on marine litter (recorded or unrecorded).

The main findings of the assessment include useful data on marine litter in the region (types, quantities, etc.) however they are inconsistent and geographically restricted mainly to parts of the North Mediterranean. Previous deductions confirmed that most of the Mediterranean marine litter originates from land-based sources, rather than ships, .

Marine litter on beaches in the Mediterranean originates from shoreline and recreational activities and is composed mainly of plastics (bottles, bags, caps/lids etc.), aluminium (cans, pull tabs) and glass (bottles) (52% - based on item counts). Marine litter from smoking related activities accounts for 40% (collected items) which is considerably higher than the global average. In terms of marine litter floating in the sea (number of items observed), plastics account for about 83.0%, while all other major categories (textiles, paper, metal and wood) account for about 17% (UNEP, 2009).

1.4.3. EU Directives addressing Marine Litter Issues

The EU Directive on the landfill of waste (Directive1999/31/EC) to prevent or negative effects on the environment from the landfilling of waste, including the pollution of surface water. The Directive is applicable to litter from landfills entering the seas and becoming marine litter.

The EU Directive on port reception facilities for ship-generated waste and cargo residues (Directive 2000/ 59/EC, December 2002) focuses on ship operations in Community ports and addresses in detail the legal, financial and practical responsibilities of the different operators involved in delivery of waste and residues in ports. The Dutch government uses the OSPAR Fulmar Litter EcoQO (Chapter 2.4) to monitor effects of implementation of this EU Directive.

The EU Directive on waste (Directive 2006/12/EC) that prohibit the abandonment, the rejection and the uncontrolled elimination of waste; they must promote the prevention, the recycling and the transformation of waste in order to re-use them.

The EU Directive on packaging and packaging waste (Directive 2004/12/EC) to encourage packaging re-use and recycling.

The EU Directive on the conservation of natural habitats and of wild fauna and flora (DIRECTIVE 92/43/EEC) of 21 May 1992 to promote the maintenance of biodiversity by requiring Member States to take measures to maintain or restore natural habitats and wild species at a favourable conservation status, introducing robust protection for those habitats and species of European importance.

*The Water Framework Directive (Directive 2000/60/EC) for the protection of inland surface waters (rivers and lakes), transitional waters (estuaries), coastal waters and groundwater***.** It will ensure all aquatic ecosystems and, with regard to their water needs, terrestrial ecosystems and wetlands meet 'good status' by 2015. The Directive requires Member States to establish river basin districts and for each of these a river basin management plan. The Directive envisages a cyclical process where river basin management plans are prepared, implemented and reviewed every six years. There are four distinct elements to the river basin planning cycle: characterisation and assessment of impacts on river basin districts; environmental monitoring; the setting of environmental objectives; and the design and implementation of the programme of measures needed to achieve them.

The EU Directive concerning the management of bathing water quality (Directive 2006/7/EC*)*.

1.4.4. National legislations and policies

There is no national legislation addressing marine litter in the European countries. There are general statutory orders, regulations, bylaws and acts governing mainly waste handling and port reception facilities. Some countries have municipalities acting on collection of litter from beaches. There might be problems when the issue of marine litter is covered and implemented by several authorities (e.g. maritime authorities, environmental authorities). Coordination of enforcement is therefore essential. Many countries reported the general legislations to be insufficient and some of the present regulations to be too vague or difficult to understand for the people working with marine litter in practice. To have a marine litter policy, in most of the countries, it is necessary, to compile all the texts relative to the water pollution, to the waste and to the protection of habitats and species. The difficulty lies in the fact that the public policies relative to the waste are often separated from that relative to the water pollution. The marine litter is situated at cross these two sectoral policies. An evolution is actually observed that is taking into account the marine litter in the French statutory texts within the framework of Grenelle of the environment.

2. Scientific literature and existing methods

There have been many drastic changes in the last half-century, but one of the most instantly observable is the ubiquity and abundance of debris in the marine evironment. It is a growing problem and will persist for centuries. The occurrence of large gyres accumulating floating litter in open oceans has been demonstrated (Moore *et al*., 2001). From what started as an aesthetic problem of littering, the number of potentially harmful implications of debris that have been identified has escalated and include the transport of persistent organic pollutants (POPs; Mato *et al*., 2001), the release of toxic compounds, including medicines, the assistance of alien invasions (Barnes, 2002), the distribution of algae associated with red tides (Masó *et al*., 2003), the entanglement of larger marine organisms and the mortality of many marine species, including marine mammals, sea birds and turtles after ingestion of litter (for a review see Katsanevakis, 2008), altering the structure of benthic communities (Katsanevakis *et al*., 2007), and socioeconomic impacts such as the threat of floating debris to navigation, reduction of the recreational value of beaches, the lost of income to the tourism industry and damages to fishing gear.

The first important compilation of existing knowledge on the sources and impacts of marine litter was published in a book edited by Coe and Rogers (1997). An important compilation of up to date knowledge on environmental aspects of plastic including marine pollution, human health risks and research methods, was recently published in a 200 page special issue of the Phil. Transactions of the Royal Society (Thompson *et al.*, 2009), with a chapter on existing survey methods to monitor the abundance of marine litter (Ryan *et al*., 2009).

In recent years OSPAR and UNEP have published a number of reports on litter pollution in different regions (e.g. Lozano & Mouat 2009 for the NE Atlantic) and on litter related topics e.g. Abandoned, lost or otherwise discarded fishing gear (Macfadyen 2009**).** UNEP/IOC published Guidelines on Survey and Monitoring of Marine Litter in 2009 (Cheshire et. al. 2009).

2.1. Coastline

Litter washed ashore on the coastline is one of the most obvious signs of marine litter pollution. The sight of litter on the tide line sensitizes people generally to the marine litter problem. Litter found on the coastline can be from land- or sea-based sources. Major land-based sources include tourism, recreation, illegal dumping, waste disposal sites, input from rivers, sewage and storm water outflows. Major sea-based sources are commercial shipping, fisheries activities and pleasure craft.

Surveys of litter stranded on the coastline are a primary tool for monitoring the load of litter in the marine environment and have been used world-wide to quantify and describe marine litter pollution. They can be used to measure the effectiveness of management or mitigation measures, the sources and activities leading to litter pollution and threats to marine biota and ecosystems (Cheshire *et al*., 2009).

Up-to-date overviews of the results of litter surveys on the coastline are included in the Global Marine Overview (UNEP, 2009). This includes the results of the reviews by Lozano & Mouat (OSPAR/KIMO/UNEP 2009) for the N-East Atlantic region, Helsinki Commission (2007) for the Baltic region, BSC (2007) for the Black Sea region and information for the Mediterranean Sea.

Tudor and Williams (2001) verified that the use of volunteers to conduct litter surveys is a reliable method, with no statistical difference between the results of data gathered by inexperienced and experienced surveyors.

Assessment of litter on the coastline can supply the following information:

1. Changes in the composition of litter present in the marine environment
    a. Indications on activities as the source of litter
    b. A limited indication of the geographical origin of litter
    c. Changes in the abundance of litter items and then reflecting to the evolution of sectors of economic activities and on waste reduction policies
    d. Input of new litter items or changes in behavior of the human population
2. Changes in amounts of litter present in the marine environment
    a. Number of items
    b. Weight of litter
    c. Volume of litter
    d. Size of litter items
3. Potential threats to marine biota and ecosystems
    a. Types, sizes and composition of litter, potential for transport and release of toxic chemicals

As litter found on the coastline can originate from numerous sources, measures to combat litter pollution need to target these different origins. Monitoring of litter pollution thus also needs to be able to estimate the input from the different sources in order to be able to implement appropriate management and mitigation measures. The measurement of temporal changes in the amount of litter found on the coast is necessary to assess the effectiveness of those measures. In order to do this it is necessary to identify and assess the amount of the different litter items recorded on the coastline in detail.

The composition of the litter recorded provides good information on places were debris is accumulating and some information on the sources of the litter involved. Regular surveys of the amount of litter recorded on a known length or area of coastline give information on the load and changes in load over time. An emerging area of concern is the accumulation of microplastic fragments in intertidal sediments as well as in subtidal sediments (Thompson *et al*., 2004). Fragments of common polymers (including polyester, nylon, polyethylene, polypropylene) less than 20µm have been recorded in intertidal sediments worldwide (Thompson *et al*., 2004; *Barnes et al*., 2009).

In order to have information on the geographic origins of waste and thus to have a basis for the implementation of actions aimed at reducing litter pollution, it is necessary to make regular litter surveys and analyze the results in relation to local weather conditions and geography, such as the washing out of litter from the land into the sea after torrential rain on the Mediterranean coasts. in the Mediterranean zones with intensive tourist activities, the beaches are cleaned most of the time by the local authorities. The OSPAR methods of assessment apply to sandy beaches of up to 1 km coastline. This type of beach is not very frequent in the eastern part of the Mediterranean, and if such beaches are present they are used intensively by tourists. Small litter polluted inlets or bays are identifiable, however, that could be used for surveying litter on the coastline. The methods applied will have to be adapted to regional differences type of coastline.

UNEP produced guidelines on surveying litter on coastlines in 2009 which deal comprehensively with the methods available to assess litter on the coast (Cheshire *et al*., 2009). The UNEP Guidelines are being considered for application in the Black Sea region. Recommendations for monitoring litter on the coastline in the Baltic Sea region were adopted in March 2008 (HELCOM RECOMMENDATION 29/2,march 2008), which are based on the UNEP Guidelines. HELCOM advise to update this Recommendation according to international developments on this issue to ensure harmonized approach on a global scale. An OSPAR Beach Litter Monitoring Program has been running in the Northeast Atlantic region since 2001 (OSPAR, 2007a, 2009), which is compatible to the UNEP guidelines.

2.2. Floating litter

The abundance of floating debris at sea can be estimated either by direct observation of large debris items, by net trawls for smaller items or by aerial surveys (Ryan *et al*., 2009; Herr, 2009).

Direct observations rely on competent, motivated observers. Studies comparing detection ability show marked differences among observers (e.g. Ryan and Cooper, 1989), which needs to be addressed if multiple observers are used to monitor debris at sea. Counts of litter at sea can be used to provide an index of abundance (number of items per unit distance) or an estimate of abundance based on fixed-width or line transects. Fixed-width transects assume that all debris is detected, which is unlikely unless transects are very narrow. For line transects (Buckland *et al*., 2001), the perpendicular distance to each item has to be estimated to compensate for decreasing detection rate with distance from the observer. This method assumes that the probability of detection on the transect line is 1, and there are problems with sea state, light conditions and the size, colour and height above water of plastic objects. Observations should be conducted only on the side of the ship with the best viewing conditions. Separate detection curves should be estimated for different sea states, and studies should state the smallest size of items recorded. Most surveys are conducted from ships or small boats.

Net-based surveys are less subjective than direct observations but are limited regarding the area that can be sampled (net apertures and ships speed). This is the only approach when considering debris in the water column. The debris sampled is also determined by net mesh size. Floating debris is typically sampled with a neuston or manta trawl net lined with 0.33 mm mesh. Given the very high level of spatial clumping in marine litter, large numbers of net tows are required to adequately characterize the average abundance of litter at sea. Long-term changes in plastic meso-litter have been reported using surface net tows however caution is needed in interpreting such findings, because of the problems of extreme spatial heterogeneity, and the need to compare samples from equivalent water masses. To date, most studies have sampled floating debris, but some plastics are denser than seawater, making it important to sample mid-water and bottom loads of plastic debris. Suspended debris can be sampled with bongo nets with a 0.33 mm mesh. All surface and subsurface net tows should be deployed with a flowmeter to assess the volume of water sampled. Microplastic particles have been monitored in the water column using the continuous plankton recorder (CPR) indicating an increase in abundance since the 1960s (Figure 2). However the CPR samples at approximately 10m depth and so will not sample floating debris.

Aerial surveys near the sea surface supply information on the distribution and density of floating litter. These in turn supply information on the origin of the litter involved (e.g. correlation with shipping traffic or other sources; modeling of the route of drift), of its potential detrimental effect on the marine environment at the moment of the survey (e.g. correlation with distribution of species and habitats) and, through the prediction of its future drift, on future effects it might have on marine or coastal species and habitats as well as facilities and equipment. Methods have been developed by Herr (2009) based on Line-transect distance sampling (Buckland *et al.*, 2001), which could be applied in other regions. Aerial monitoring of floating litter has been carried out during Harbour Porpoise monitoring flights in the German Exclusive Economic Zone (EEC) since 2002.

2.3. Sea floor

2.3.1. Shallow waters

In shallow coastal areas (< 40 m depth), the abundance of marine debris is generally much greater than on the continental shelf or on the deep seafloor, with the exception of some accumulation zones in the open sea (Katsanevakis, 2008). Greater abundance of marine debris has been found in bays than in open coastal areas, which is a result of the influence of hydrodynamics (Hess *et al.*, 1999; Katsanevakis and Katsarou, 2004). In bays, it is more difficult for litter disposed locally to be transported away from the point of disposal, due to weaker currents, and thus it is more likely to accumulate on the bottom. Furthermore, in open coasts, wave action may transfer a large portion of the marine debris from shallow areas to the shore. This wave-induced cleaning of the seafloor is of less importance in small bays, where usually there is much less intensity in wave action. Among the variety of human activities that contribute to the pattern of marine debris in shallow coastal areas, fishing activities of the coastal fleet seem to be of great importance (Katsanevakis and Katsarou, 2004).

The most commonly used method to estimate marine debris density in shallow coastal areas is to conduct underwater visual surveys with SCUBA (Chiappone et al., 2002; Boland and Donohue, 2003; Katsanevakis and Katsarou, 2004; Machado, 2006; Abu-Hilal and Al-Najjar, 2009), although snorkeling or manta tow have also been applied for very shallow waters (usually < 10 m depth) (Spengler and Costa, 2008). These surveys were mostly based on plot sampling and especially strip transects. In strip transects, the plots are long, narrow strips and the diver-observer travels along the center line searching marine debris and counting all items within the strip. Other data such as type and size of debris may also be recorded.

In plot sampling, the critical assumption is that all items present in the surveyed areas A_c are detected. However, this assumption cannot be tested using the survey data, and to ensure that it holds to a good approximation in all habitats and environmental conditions, it may be necessary to use narrow strips, which is problematic for low debris densities and increases the variance of density estimators (Burnham and Anderson, 1984; Buckland *et al*., 2001). If the assumption that all items present in the surveyed areas are detected is not met, there is underestimation of abundance. This is overcome by applying distance sampling, which is a group of methods for estimating abundance and/or population density (Buckland et al., 2001). In distance sampling surveys, it is acceptable that we fail to detect some of the items that are in the covered region, as detectability is actually estimated and used to 'correct' abundance estimations. The extra effort in a line transect survey is to record the perpendicular distance of each item from the line. This set of distances is used to estimate detection probability (Buckland *et al*., 2001; Katsanevakis, 2009). The most commonly used Distance Sampling method for underwater surveys is line transect sampling.

Preliminary sampling of microplastics has also been undertaken in shallow water subtidal sediments near Plymouth, UK and at this location microscopic fragments were more abundant in the shallow subtidal than in nearby intertidal habitats (Thompson *et al*., 2004) Figure 2.

2.3.2. Continental shelf

Surveys of macro-debris loads on the seabed have been conducted with submersibles, remotely operated vehicles and trawl surveys. The use of sonar is less informative when compared with results from trawling, since sonar does not enable discrimination of different types of debris (Ryan *et al*., 2009). Trawling (e.g. using Agassiz) is probably the most adequate method to date, particularly when mesh size and opening width can be manipulated (Goldberg 1994, 1995; Galgani and Andral, 1998). Such nets are only semi-quantitative and because of their design for collecting epibenthos, probably underestimate the quantities of debris present. Therefore, beam trawling, with a constant mouth width, which works deeper in sediments, is considered the best approach. To date all off-shelf trawl data have used this methodology. General strategies to investigate seabed debris are similar to methodology for benthic ecology and place more emphasis on the abundance and nature (e.g. bags, bottles, pieces of plastics) of items rather than their mass. Interpretation of trends is made difficult because the ageing of plastics at depth is not well researched and the accumulation of plastics on the seabed began long before specific scientific investigations started in the 1990s. Perhaps somewhat surprisingly, plastics dominate macro-debris on the sea floor to an extent similar to which they dominate floating litter and beach debris. Just like stranded debris, plastic on the seabed aggregates locally in response to local sources and bottom topography (Galgani *et al*., 2000). "Fishing for Litter" initiatives have been implemented to remove litter from the seabed as part of normal fishing activity (OSPAR, 2007b). To date, most studies have measured standing stocks of macro-debris, but some accumulation data have been obtained following cleanups. There has been little attention to the abundance of meso- and micro-debris on the seabed. Epibenthic trawls have found substantial plastic loads just above the seabed in shallow coastal waters off southern California. Bottom sediments in deeper waters can be sampled with a Van Veen grab or similar device.

2.3.3. Deep sea floor

Change in the nature, presence or abundance of anthropogenic debris on the deep sea floor is much less widely investigated than surface or continental shelves patterns. Studies that investigate seabed debris typically focus on continental shelves, and research into the deeper seabed, which forms about half the planet's surface, is restricted by sampling difficulties and cost. Large-scale evaluations of deep seabed debris distribution and densities anywhere are scarce (Galgani *et al*., 2000) but macro-debris is more important in northern ocean (Barnes *et al*., 2009). Assessments of abundance clearly demonstrate the domination of this debris by plastics, because at more than half the study sites plastics constituted 50 per cent of debris. Of the areas investigated along European coasts to date (Galgani *et al*., 2000), Mediterranean sites tend to show the greatest densities owing to the combination of a densely populated coastline, shipping in coastal waters and a lack of dispersion of plastics because of limited tidal flow or water circulation. In general, bottom debris tends to become trapped in areas of low circulation and high sediment accumulation in contrast to floating debris, which accumulates in frontal areas. Debris that reaches the seabed may already have been transported considerable distance, only sinking when weighed down by fouling. The consequence is an accumulation of plastics debris in bays and canyons rather than the open sea (Galgani *et al*.,1996; Hess *et al*., 1999; Stefatos *et al*., 1999; Katsanevakis and Katsarou, 2004). Some accumulation zones in the Atlantic Sea and the Mediterranean Sea have very high debris densities despite being far from coasts. These densities relate to the consequence of large-scale residual ocean circulation patterns. There are higher densities in particular areas such as around rocks and wrecks or in depressions or channels (Galgani *et al*., 1996). In the North Sea, accumulation of plastics 320 km offshore from Denmark (Galgani *et al*., 2000) is a consequence of several factors. These include the eddying and long-term circulation of waters. In some regions, large rivers are responsible for substantial inputs of debris to the sea bed. They can transport waste out to sea because of their high flow rate and the strength of bottom currents. Deep submarine extensions of coastal rivers also influence the distribution of seabed debris. In some areas, local water movements transport plastics away from the coast to accumulate in zones of high sedimentation. Under these conditions, the distal deltas of rivers can fan out in deeper waters, creating areas of high accumulation. Continental shelves have locally lower concentrations of debris since most of the anthropogenic debris in the outer shelf originates from coasts to shelves that are washed offshore by currents associated with river plumes. The accumulation of plastics in coastal canyons may also be related to strong currents occurring in the upper part of canyons, which decrease rapidly in deeper areas resulting from increased confinement. Accordingly, debris distribution seems to be more temporally stable. An inevitable effect of this is the presence of greater amounts of debris in deeper shelf waters than in coastal waters (Galgani *et al*., 1996, 2000). Investigations using submersibles at depths beyond the continental shelf have revealed substantial quantities of debris. Besides the high densities found in coastal canyons (up to 112 items per kilometre and 70% plastics), plastics and other anthropogenic debris were found widely dispersed at slope and abyssal depths (Galgani *et al*., 2000). Deployment of a remotely operated vehicle submarine in the Fram Strait (Arctic) (Galgani and Lecornu 2004) revealed 0.2–0.9 pieces of plastic per linear kilometre at Hausgarten (2500 m). On dives between 5500 and 6770 m, 15 items of debris were observed, of which 13 were plastic, probably carried there by the Norwegian current in the North Atlantic. At such latitude and bathymetry, there is negligible human activity, suggesting long-distance transport of debris. Finally, most polymers are highly persistent in the marine environment and only degrade slowly via photo-catalysis when exposed to UV radiation. Estimates for the longevity of plastics are variable but are believed to be in the range of hundreds or even thousands of years depending on the physical and chemical properties of the polymer, but this is likely to be greatly increased at depth, where oxygen concentrations are low and light is absent. We know little about trends in accumulation of debris in the deep sea as studies are rare, but the data we have indicate considerable variability. Abundance remained stable in the Gulf of Lion, France during a 15 years period (1994-2009). However, in some areas around Greece, the abundance of debris at depth has increased over the last 8 years (Koutsodendris *et al*., 2008). To date examination of plastics in the deep sea has focused on larger items and there is a need to assess the accumulation of microplastic fragments which are now widespread in the intertidal and present some shallow subtidal habitats (Barnes *et al*., 2009; Thompson *et al*., 2004).

2.4. Ingestion, Entangled and beach stranded species, affected organisms

The entanglement of marine species in marine litter, often as a result of their normal behavior patterns, has been frequently described as a serious mortality factor. Among the most problematic marine litter is derelict or discarded fishing gear, which may continue to fish for years, a process that has been termed 'ghost' fishing. Entangled animals may get killed by drowning, suffocation, or strangulation. Even if they manage to survive, entangled animals may suffer restricted efficiency of movement , and thus an impaired ability to catch food and avoid predators, whilst their demand for food may increase significantly due to elevated energetic costs (Feldkamp *et al*., 1989). Entanglement could cause lacerations and infections from the abrasive or cutting action of attached debris. In addition, entangled animals may exhibit altered behavior patterns that place them at a survival disadvantage (Laist, 1987). Entanglement in marine debris has been reported for at least 20 pinniped species, i.e. 61% of existing species worldwide, at least 14 cetaceans: six species of baleen whales and eight species of toothed whales, all seven species of marine turtles, and more than 56 species of marine and coastal birds (Katsanevakis, 2008).

The effect of marine debris on marine populations is difficult to quantify as unknown number of marine animals die at sea and decompose without being recorded. Many species vulnerable to entanglement are oceanic or migratory and are scattered across wide ocean areas. Animals that become entangled and die may quickly sink or be consumed by predators at sea, eliminating them from potential detection (Laist, 1997). Some endangered species may be very rare and their detection quite difficult, so that evidence of entanglement incidents with marine debris is generally scarce and difficult to detect, even with intense sampling efforts. For these reasons, the estimated mortality rates and the effects on the population dynamics of many affected species are probably underestimated.

Nevertheless, the assessment of dead birds found on the coastline, Beached Bird Surveys (BBS), can supply information on mortality due to a number of causes. BBS have been used for decades to measure the effects of oil pollution on birds. The percentage of birds with oiled feathers in the total of all birds found on a given coastline, the co-called oil rate, is used as an index of the pollution levels of adjacent waters. Oil rates in Guillemots are used by OSPAR to monitor for the Ecological Quality Objective (EcoQO) for oil pollution in the North Sea. If appropriate elements are added to the survey protocols, BBS could also be used to assess the percentage of dead birds found entangled with litter items. Notes of BBS observers on entanglement have been used in initial surveys of entanglement rates among birds on the North Sea coasts of Germany and the Netherlands (Camphuysen, 2008; Fleet *et al*., 2010). The entanglement rate would indicate the levels of litter pollution with certain litter items in adjacent waters and the effect of litter on pelagic and coastal birds. Entanglement occurs mainly with fishing lines and nets but also balloon ribbons and similar items, and classically with other objects such as 6-pack rings. A detailed manual exists for BBS as part of the OSPAR Oiled-Guillemot-EcoQO (Camphuysen, 2005), that could be adapted for the assessment of entangled birds.

Many marine species such as marine mammals, seabirds, marine turtles, fish and invertebrates have been reported to ingest marine debris especially plastics. Ingestion of marine debris may occur either because of misidentification of debris items as natural prey or accidentally during feeding and normal behaviour (Gregory, 2009). Serious effects of ingested debris are the blockage of the digestive tract and internal injuries by sharp objects, which may be a cause of mortality. Other harmful effects from marine debris ingestion include blockage of gastric enzyme production, diminished feeding stimulus, nutrient dilution, reduced growth rates, lowered steroid hormone levels, delayed ovulation and reproductive failure, and absorption of toxins have also been suggested (Azzarello and Van-Vleet, 1987; Ryan, 1988; Van Franeker and Bell, 1988; Sievert and Sileo, 1993; Auman *et al*., 1997; McCauley and Bjorndal, 1999; Derraik, 2002; Thompson *et al*., 2009, Teuten *et al*., 2007; Teuten *et al*., 2009). At least 32 species of cetaceans (43% of existing species worldwide), all species of marine turtles, more than 111 species of seabirds (or approximately 36% of the world's seabird species), and many species of fish have been reported to ingest marine debris (Katsanevakis, 2008).

There is increasing concern that ingested plastics may transport potentially harmful chemicals to organisms. Two routes have been suggested (i) the release of potentially harmful substances that are incorporated into plastics during manufacture and (ii) the sorbtion and subsequent release of persistent organic pollutants (POPs).

(i) If ingested plastics may release chemical such as nonylphenols (NP), polybrominated diphenyl ethers (PBDE), phtalates, and bisphenol A (BPA) that are incorporated during manufacture either as plasticizers or to give desirable properties like flexibility, durability, high heat and electrical resistance, and UV resistance. There is growing evidence from studies on humans and animals in laboratory settings that these chemicals can be released to food and drink and subsequently may accumulate in body tissues (Koch and Calafat, 2009; Oehlmann *et al*., 2009; Talsness *et al*., 2009) and it therefore seems likely that these chemicals could be transferred to organisms in that eat plastics in the natural environment.

(ii) Plastics also have the potential to sorb hydrophobic pollutants including PCBs and DDT from seawater (Carpenter *et al*., 1972; Mato *et al*., 2001) and there is concern about the possible transfer of these chemicals to marine organisms and subsequent adverse effects (Ryan *et al*., 1988; Mato *et al*., 2001; Derraik, 2002; Teuten *et al*., 2007; Teuten *et al*., 2009). Ryan *et al*. (1988) found a positive correlation between the mass of ingested plastics and PCB concentrations in the fat tissue of Great Shearwaters *Puffinus gravis*, and presented the first indication that marine organisms can assimilate toxic chemicals from ingested plastics. There is evidence that even small quantities of plastic could facilitate the transfer of persistent organic pollutants to marine invertebrates (Teuten *et al*., 2007; Teuten *et al*., 2009) and it seems likely that as plastics fragment into smaller pieces the potential for such transfer will increase because both the abundance of fragments and their surface area will increase (Thompson *et al*., 2009). Small and microscopic plastic particles occur both in sediments and the surface waters of the oceans (Moore *et al*., 2001; 2002; Thompson *et al*., 2004) Fig 2. These fragments are likely to result from diverse sources however as plastics age they become brittle and undergo mechanical fragmentation, leading to small and microscopic particles of 'plastic dust'. Laboratory experiment have shown that such fragments may be ingested by a variety of small marine organisms (both suspension-feeders and deposit-feeders) such as amphipods, lugworms, bivalves, barnacles and mussels. The impact of microscopic plastic particles on marine fauna and the marine food web is still insufficiently known, but recent studies give reason for concern (Thompson *et al*., 2009, Teuten *et al*., 2009)

Other known impacts of marine debris include altering the structure of benthic communities (Katsanevakis *et al*., 2007), causing damage to coral reefs and coral facies (Donohue *et al*., 2001; Chiappone *et al*. 2002), and assisting invasions of alien species (Winston, 1982; Barnes, 2002; Barnes and Milner, 2005).

The OSPAR Fulmar-Litter-EcoQO:

The methodology closest to that intended in the approach to Good Environmental Status (GES) in the MSFD is the Ecological Quality Objective (EcoQO) approach of OSPAR for the

North Sea. For the EcoQO on marine litter, OSPAR uses abundance of plastics in the stomach of a seabird, the Northern Fulmar. Initiated by studies in the Netherland, amounts of plastics ingested by beached Fulmars have developed into a North Sea wide standard to evaluate temporal trends and regional differences in the litter situation. The EcoQO approach includes a target value ('ecological quality objective') considered to represent an acceptable level of litter in the marine environment (OSPAR, 2008).

In a pilot project for the EcoQO, Van Franeker and Meijboom (2002) evaluated the feasibility of using stomach contents of beached Northern Fulmars to measure changes in the litter situation in an ecological context. Samples of Fulmars available for the feasibility study mainly originated from the periods 1982 to 1987 and 1996 to 2000. Reasons for selection of the Fulmar out of a list of potential monitoring species are of a practical nature:

- Fulmars are abundant in the North Sea area (and elsewhere in the North Atlantic) and are regularly found in beached bird surveys, which guarantees supply of adequate samples for research.
- Fulmars are known to consume a wide variety of marine litter items, and over 90% of Fulmars from the North Sea has one or more items of plastic in the stomach).
- Fulmars forage exclusively at sea and never on land.
- Fulmars do not normally regurgitate indigestible items, but accumulate these in the stomach where digestion and mechanical wear reduces particles to a size that can pass into the gut to be excreted.

Because of these characteristics, stomach contents of Fulmars are representative for litter pollution in the offshore environment, averaging pollution levels over a foraging space and time span that avoids bias from local pollution incidents. Other North Sea species that ingest litter either do not accumulate plastics (they regurgitate indigestible remains); are coastal only and/or find part of their food on land (e.g. *Larus* gulls); ingest litter only incidentally (e.g. North Sea alcids) or are too infrequent in beached bird surveys for the required sample size or spatial coverage (e.g. other tubenoses or Kittiwake *Rissa tridactyla*).

At dissection of birds, their sex, age, origin, condition, likely cause of death and a range of other potentially relevant parameters are determined. Standardized dissection procedures for EcoQO monitoring have been described in detail in a manual (Van Franeker 2004). Stomach contents are sorted into main categories of plastics (industrial and user-plastics), non-plastic rubbish, pollutants, natural food remains and natural non food-remains. Each of these categories has a number of subcategories of specific items. For each individual bird and litter category, data are recorded on presence or absence ("incidence"), the number of items, and the mass of items (see methods).

The pilot study undertook extensive analyses to check whether time-related changes in litter abundance were susceptible to error caused by bias from variables such as sex, age, origin, condition, cause of death, or season of death. If any of these would substantially affect quantities of ingested litter, changes in sample composition over the years could hamper or bias the detection of time-related trends.

A very important finding of the pilot study was that no statistical difference was found in litter in the stomach between birds that had slowly starved to death and 'healthy' birds that had died instantly (e.g. because of collision or drowning). This means that our results, which are largely based on beached starved birds, are representative for the 'average' healthy Fulmar living in the southern North Sea. Only age was found to have an effect on average quantities of ingested litter, adults having less plastic in their stomachs than younger birds. Possibly, adults lose some of the plastics accumulated in their stomach when they feed chicks or spit stomach-oil during defence of nest-sites. Another factor could be that foraging experience may increase with age. Although age affects absolute quantities of litter in stomach contents, changes over time follow the same pattern in adults or non-adults. So, as long as no directional change in age composition of samples is observed, trends may be analyzed for the combined age groups.

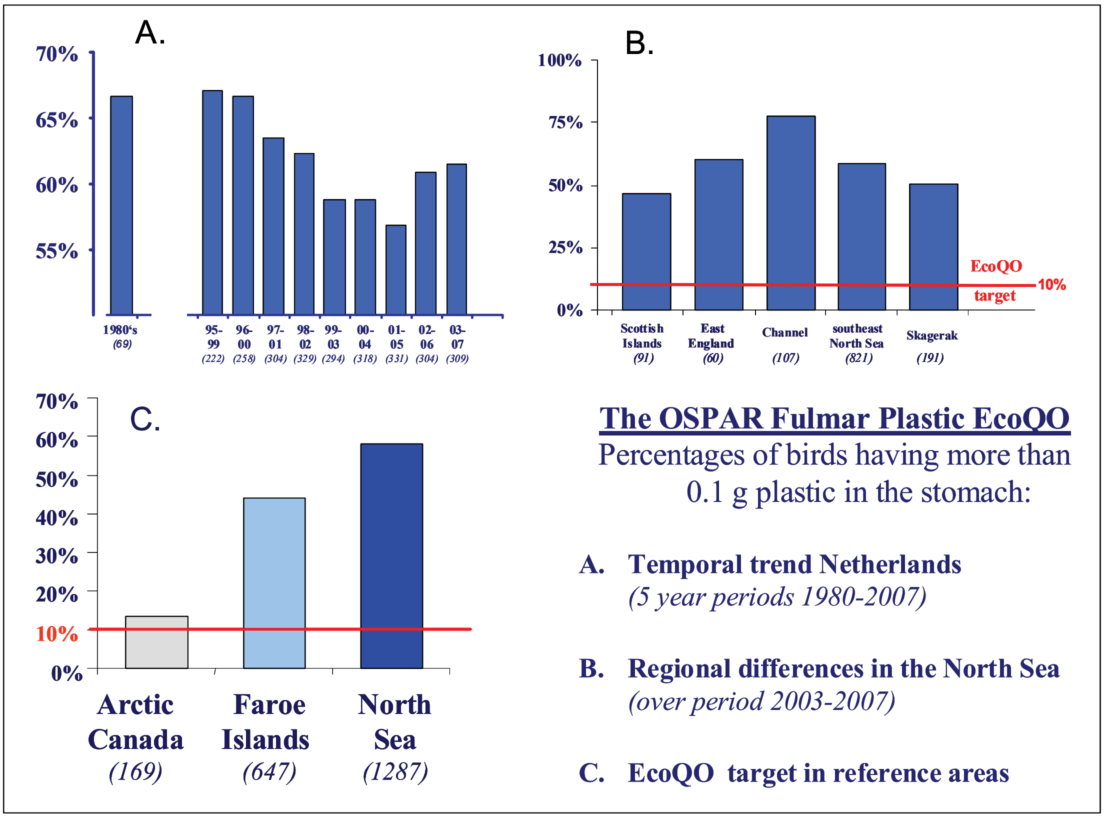

Figure 1: The OSPAR fulmar EcoQO

In a number of reports (see refs in Van Franeker et al. 2009; all available at www.zeevogelgroep.nl under downloads) the Fulmar EcoQO has shown to be able to provide valuable information on temporal changes and spatial patterns in abundance of marine litter, to detect differences between trends of industrial and user plastics, and to identify source areas and activities.

OSPAR has provisionally defined it's objective for acceptable Ecological Quality concerning litter in the North Sea as *"There should be less than 10% of Northern Fulmars having 0.1 gram or more plastic in the stomach in samples of 50-100 beachwashed fulmars from each of 5 different regions of the North Sea over a period of at least 5 years"*.

Currently, the 'cleanest' North Sea region in the north has about 45% of birds exceeding the 0.1g critical level, whereas this percentage is near 80% the most polluted part in the Channel (graph B). The current level in the Netherlands is about 60% of birds in excess of the critical level, in which a gradual reduction since the mid-1990's appears to have stopped or even slightly reversed (graph A). Nowhere in the North Sea is the litter situation at the EcoQO target, which is only reached in clean arctic locations (Graph C; Arctic Canada data from Provencher *et al*. (2009) and Provencher, Mallory and Gaston, pers com).

Setting an EcoQO or GES target level for marine litter is largely an arbitrary choice. In the case of the Fulmar EcoQO, the OSPAR target resembles the litter situation in a reference area where the pollution level is considered to be acceptable in terms of environmental quality, e.g. the Canadian Arctic (Fig.1.c). However, the OSPAR target has no solid implementation data, and an MSFD GES threshold for year 2020 could be formulated differently. An erroneous question often asked, is whether the 10% and 0.1 g EcoQO level means there is no longer effect on Fulmars. However, the Fulmar in this case is just a monitoring tool, a " thermometer" of the environment. As indicated before there may be species happily living on rubbish dumps where others become extinct. The EcoQO level is a subjective decision attempting to include all elements of the ecosystem, not just the Fulmar.

The Fulmar EcoQO approach is now implemented in the North Sea and the Faroe Islands, but can be applied over most of the North Atlantic, as Fulmars occur abundantly over the whole area into the high arctic. For "non-fulmar-regions' the Fulmar project has also initiated pilot studies into the suitability of another seabird species (Cory's Shearwater *Calonectris diomedea*) for similar monitoring. Plastic commonly occurs in this species but its value for monitoring temporal or spatial patterns needs to be assessed. Currently there a bird species with a similar function in the Baltic or Black Sea has not been identified, however, pilot studies for bio-monitoring should also consider other species, including e.g. marine turtles, fishes or even zooplankton or shellfish.

2.5. Microparticles

Debris are progressively fragmenting in the environment (Colton *et al*., 1974; Thompson *et al*., 2004). Microparticles are defined as fragments of litter smaller than 5mm as stated in the NOAA workshop (Arthur *et al*., 2009).

There is considerable concern about the accumulation of microscopic pieces of plastic (microplastic) due to their high prevalence and slow rate of chemical and biological degradation. Plastics are progressively fragmenting in the environment and are also transported as pellets (<5mm) and powders (<1mm) prior to manufacture into everyday items. Numerous reports of spillage of these pre-production plastics exist (Ryan *et al*., 2009). In addition, the use of granules as abrasives in skin cleaning products and in a range of commercial applications such as shot blasting has increased considerably in recent years. There is no accepted "lower bound" in size, however plastic particles as small as 1.6µm have been detected in the marine environment. Monitoring techniques are currently limited by our ability to collect and identify very small particles. However it seems likely that items of debris exist into the nanoparticle scale.

Microplastic particles have been monitored in the water column using the continuous plankton recorder (CPR) indicates an increase in abundance since the 1960s. However the CPR samples at approximately 10m depth and so will not sample floating debris (See fig. 2).

The prevalence of small pieces and granules (<5mm in diameter) varies considerably among habitats. At most locations quantities appear to be relatively low at present. However quantities of plastic microparticles in excess of 100,000 items m^{-2} (e.g. Gregory 1978 or see Thompson *et al*. 2009 for a recent review) or 1250 items $250g^{-1}$ of natural material (Zubris and Richards, 2005) have been reported, while in intertidal habitats near Plymouth around

10% small (<5mm) plastic pieces by weight have been reported (Browne *et al*., 2007). As well as these small pieces, in 2004, Thompson et al. reported on the accumulation of microscopic plastic fragments (≥ 20µm diameter) on shorelines and in the water column around the UK (Thompson *et al*., 2004: Fig 2). Similar debris has been reported in India (Reddy et al. 2006) and Singapore (Ng and Obbard, 2006) and a recently completed global survey confirmed that polyethylene, polyvinyl chloride and polypropylene fragments are now present on shorelines worldwide (Barnes *et al*., 2009). Production of plastic is increasing rapidly and since conventional plastics will not biodegrade it is inevitable that the abundance of small fragments like these will increase over the next few decades. Such fragments have a considerably larger surface area to volume ratio and hence a greater potential to transport and release contaminants than larger items. In addition, because of their size they are available to a wide range of organisms including deposit feeders, filter feeders and detritivores (Thompson *et al*., 2004: Fig 2). Ingestion of microplastic material therefore presents a route by which chemicals could pass from plastics to the food chain (see 2.4 and 2.6 of this report). Accumulation of microplastic particles in organisms could also present a physical hazard as has been shown for larger litter fragments in 2.4. More research is needed to establish the full environmental relevance and potential impact of these microparticles.

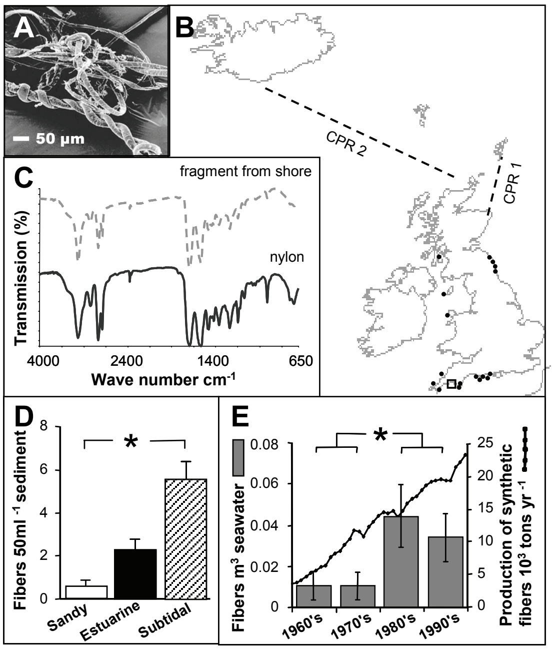

Figure 2. *(**A**) Fragment of microscopic plastic from shoreline. (**B**) Sampling locations in North-East Atlantic, showing Routes (CPR 1 and 2) sampled by Continuous Plankton Recorder (CPR) since 1960 and used to assess changes in the abundance of microplastics in the water column (see Fig. 1E). Shores around the UK where similar fragments were found (●) and the location of sites near Plymouth (□) used to compare the abundance of microscopic plastic among habitats (see Fig. 1D). (**C**) Example showing how FT-IR spectroscopy was used to identify fragments from the shoreline and the water column. Here an unknown fragment is identified as nylon. (**D**) There were significant differences in abundance of microplastics between sandy beaches and subtidal habitats (ANOVA on log10(x + 1) transformed data, $F_{2,3} = 13.26$, $P < 0.05$, * = $P < 0.01$), but abundance was consistent among sites within habitat type. (E) Accumulation of microscopic plastic in CPR samples revealed a significant increase in abundance when comparing the 1960's and 1970's to the 1980's and 1990's (ANOVA on log10(x + 1) transformed data, $F_{3,3} = 14.42$, $P < 0.05$, * = $P < 0.05$). Approximate figures for global production of synthetic fibres overlain for comparison. Microplastics were also less abundant along the oceanic route CPR 2 than CPR 1 ($F_{1,24} = 5.18$, $P < 0.5$). Reproduced from Thompson et al. (2004), with permission.*

2.6. Litter related chemicals

A range of potentially toxic chemicals, including flame retardants, plasticizers and antimicrobials are frequently added during the production of plastics (Eagon *et al.*, 1994; IEH, 1995, 1999). These additives have well documented toxic effects. For example, brominated flame retardants cause neurotoxicity, immunotoxicity and reduced thyroid hormone levels (de Wit, 2002; Welshons *et al.*, 2006), and phthalate plasticizer concentrations have been correlated with impaired genital development in humans (Swan, 2005). Some debris (Plastic, tissues, metals) are also known to adsorb hydrophobic persistent organic pollutants (POPs) such as PCBs, DDE, nonylphenols and phenanthrene from contaminated seawater. These pollutants have well recognised endocrine disrupting, carcinogenic and immunotoxic effects, (Endo *et al.*, 2005; Rios *et al.*, 2007) and can become 5 to 6 orders of magnitude more concentrated on plastics than in the surrounding seawater. Further work has confirmed that these plastics additives and sorbed contaminants were present on the surface of polypropylene debris collected in various marine habitats in Japan, Europe and the USA (Endo *et al.*, 2005; Mato *et al.*, 2001; Rios *et al.*, 2007). These studies clearly demonstrate the capacity for plastic to sorb toxic contaminants, but provide little information about the potential for plastics to subsequently release sorbed contaminants or toxic additives to marine organisms. The evidence we have, however, suggests that these chemicals could be released to organisms that ingest plastics and that in some habitats relatively small quantities of plastic (parts per million) could increase the transport of persistent organic pollutants. Ryan *et al.* (1988) found a positive correlation between the mass of ingested plastics and PCB concentrations in the fat tissue of Great Shearwaters *Puffinus gravis*, and presented the first indication that marine organisms can assimilate toxic chemicals from ingested plastics. Recent evidence indicates that even small quantities of plastic could facilitate the transfer of persistent organic pollutants to marine invertebrates (Teuten *et al.*, 2007; Teuten *et al.*, 2009) and it seems likely that as plastics fragment into smaller pieces the potential for such transfer will increase because both the abundance of fragments and their surface area will increase (Thompson *et al.*, 2009).

2.7. Socio- economic impacts

Marine litter can have significant socio-economic impacts and can affect a range of marine sectors including aquaculture, agriculture, fisheries, shipping (including leisure boating), power generation and industrial use, local authorities and tourism.

Marine litter is a serious affront to the visual and other aesthetic sensitivities of tourists and local visitors to beaches, especially sanitary, sewage related and medical waste which may also cause injuries and/or be a risk to human health (Gregory, 1999; Ivar do Sul and Costa, 2007).

Cigarettes butts and plastic fragments that frequently appear in large quantities on beaches are potentially dangerous to small children as they may be ingested. For these reasons, tourists tend to avoid beaches with high marine debris concentration. Destinations where no beach cleanup is regularly conducted acquire a bad reputation and are avoided by tourists and tourist operators, with important consequences on the local economy. Apart from beaches, high marine debris concentration on the seabed and on coral reefs may have serious impacts in the diving industry, as heavily debris-polluted diving sites will be avoided by divers. However, studies that quantify the tourism-related economic losses because of marine debris contamination on coastal areas are rare, although such information is valuable. Balance *et al.*

(2000) evaluated the income from beach tourism, on selected beaches, in the Cape Peninsula region of South Africa, using the travel cost method, at 0.3 - 2.2 million Euros but highlighted that an increase of litter to 10 pieces of litter per m^2 would deter 40 % of foreign tourists and 60% of domestic tourists from returning to these beaches.

Obvious costs include the removal of marine litter from beaches and the removal of litter from harbour areas. However, there are other less obvious cost such as the costs to agriculture, of litter blowing ashore, and search and rescue cost for aiding shipping with fouled propellers or blocked intakes. Such physical damage may occur in all types of vessels and imposes repair and delay costs on their owners. Takehama (1990) estimated that the annual frequency of accidents caused in insured fishing vessels in Japan due to drifting marine debris remained steady at about 10% between 1982 and 1985, and was more than twice the frequency attributable to all other causes. Wallace (1990) reported that in the eastern US, over 45% of the commercial fishermen had their propellers caught, over 30% had their gear fouled, and over 35% had their engine's cooling system clogged by plastic debris. Repair costs and lost fishing days may be quite significant, especially for uninsured small-scale fishing operations.

Studies undertaken so far, such as that by KIMO International (Hall, 2000), have focused on evaluating direct costs to these marine and coastal sectors using survey-based techniques to gather data. The report used the Shetland Islands as a case study and highlighted that in a worst case scenario the Islands, with a population of 22,000, could be paying up to €7 million per year due to marine litter.

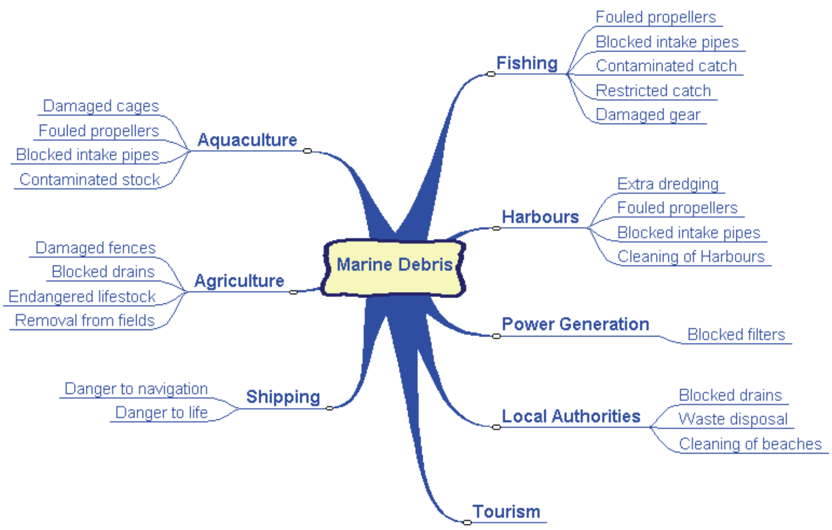

Figure 3: A summary of socio-economic impacts of litter at sea

Whilst this gives a good indication of the economic burden of litter on marine sectors it can be lacking in spatial coverage as it relies on voluntary responses. Another of the difficulties in collecting direct costs using survey-based methods is that there is generally little national collection of data and individual companies or organisations very often don't specifically record the financial costs of litter or record it in different formats. Also where it is recorded it tends to be underestimated as hidden cost such as staff salaries and contract management are not usually included (Fanshawe and Everard, 2002).

This method also only gives you the financial cost of marine litter on these sectors and does not account for the social costs. These might include reductions in the existence, recreational or educational value of a particular region due to high volumes of litter and while these can be measured using economic methods, such as travel costs for recreation, land/property values, willingness to pay for improvements, etc, it is more difficult (Turner *et al*., 2009).

If the full cost of degradation of ecosystem goods and services by marine litter is to be assessed more research on the ecological impact of marine litter needs to be undertaken. Combined with existing work on the use and non-use values of marine ecosystems already undertaken this would give a greater understanding of the impact of litter on the total economic value (TEV) of the marine and coastal environment. These costs will be essential along with evaluation of the direct costs when assessing policy options for mitigation through frameworks such as the DPSIR (Driver, Pressure, State, Impact, Response) approach (Borja *et al*., 2006).

In relation to the descriptor and what constitutes harm in a socio-economic sense this has yet to be defined for marine litter however for land-based litter socially acceptable levels have been enshrined in law. In the UK for example the Environmental Protection Act 1990 requires duty bodies to keep land clear of litter and the code of practice outlines a graduated scheme (levels A-D) of cleanliness which set outs what is socially acceptable and where remedial action is required. A similar scheme could be developed for the marine environment. There is no consensus on what is an acceptable level of economic harm from marine litter.

2.8. Summary of approaches

Table 1 : Summary of approaches for assessing GES with regards to marine Litter

COMPARTMENT	APPROACHES	POSITIVE ASPECTS	POORLY COVERED & NEGATIVE ASPECTS
Coastline	Counts of the amount of litter items on known stretches of coast	Allows for assessment of composition, amounts, sources (geographic and activities), trends, social harm (aesthetic, economic)	Very small items and microparticles in sediments are not quantified. Not all coasts are accessible or appropriate.
Sea surface	Ship observers	Precise evaluation at local scale,	Depending on weather, Not at large scale , small debris not considered, strong temporal variation
Sea surface and water column	Trawling and water filtration	Precise evaluation at local scale, consider smaller debris	Costs, strong temporal variation
Sea surface	Aerial counts of the number of litter items floating on the sea surface along transects	Assessment of densities of litter on water surface over large areas possible - correlation with possible sources in the offshore area such as shipping or fisheries activities	Smaller items not covered. Only counts of items from TetraPak size upwards are possible.
Sea floor shallow	Visual survey with divers	All substrate types (rocky, sandy, muddy, seagrass beds etc), replicability, feasible to account for detectability (Distance Sampling)	Depth limitation (<40 m)
Sea floor , Deep sea litter	Trawling (beam and agassiz)	Replicability, possible standardisation	Only where trawling is possible
Sea floor , Deep sea litter	Submersibles and Remote operated vehicles	All sites accessible	Only small areas, costs
Entanglement rates of marine organisms	Assessment of entanglement rates in birds found dead on the coastline	Can be carried out as part of existing surveys.	Standard protocol for recording entanglement would need to be developed and implemented.
OSPAR Fulmar Plastic Ecological Quality Objective (EcoQO)	Mass of plastic in stomachs of beached seabirds (Fulmars)	Operational and tested in North sea. Applicable everywhere in most of OSPAR area	Focuses on surface litter in offshore habitats; not yet operational in all EU regions: Need further developing.
Ingestion by other marine organisms	Abundance of plastic by mass	Potentially similar to Fulmar EcoQO approach	Need to be developed and tested
Microplastic on shorelines	extraction of fragments from sediment samples and subsequent identification using FT_IR spectroscopy	Positive identification of specific polymers	Analysis is time consuming and is unlikely to detect all of the microparticles . This is especially true for very small fragments (< 100 µm)
Microplastic at Sea surface	extraction of fragments from Continuous Plankton Recorder samples and subsequent identification using FT_IR spectroscopy	Positive identification of specific polymers	Analysis is time consuming and is unlikely to detect all of the microparticles. CPR operates only approximately 10m below the sea surface
Socio-economic	Assessment of direct costs through survey based methods	Provides indication of economic burden on marine and coastal sectors	Does not capture full impact of degradation of ecosystem goods and services due to marine litter

3. Temporal/spatial scales for the descriptor

Any assessment of the descriptors should consider short term variations caused by meteorological and/or hydrodynamic events and seasonal fluctuations which will influence our ability to detect underlying trends. Variability in human activities such as seasonal tourism can also cause short term changes in the input of litter to the marine system. These considerations should be taken into account when planning monitoring schemes.

The assessment of temporal trends for litter loads and amounts is a main goal of monitoring. Data must then fulfill the requirements of data quality and representativeness for this purpose. Details of trend assessments in environmental monitoring have been described in the ICES Working Group on Statistical Aspects of Environmental Monitoring 2001/2 [http://www.ices.dk/workinggroups/ViewWorkingGroup.aspx?ID=106].

Due to the persistence of some litter materials, monitoring of litter must consider the decadal scale of both accumulation and recovery processes. Timescales of observation should therefore be adapted, requiring multiannual frequencies for surveys.

The aggregation of assessments for the evaluation at sub-regional or even regional scale is different for the various parameters to be considered.

Beached litter surveys and socio-economic studies can be readily applied to the European spatial scale. Sea floor monitoring is more relevant at smaller scales, due to the low density of observations for practical and economical constrains. In the same way some monitoring techniques have little application on the local spatial scale. This is true for the OSPAR Fulmar Plastic EcoQO since fulmars are highly mobile and long-lived birds, and therefore their stomach contents represents input over a great spatial and temporal scale. Considerations of the adequate spatial and temporal scale of potential monitoring programmes are therefore essential.

Coastline

Spatial and temporal short and long-term variation in factors that influence litter stranded on the coastline leads to a high variation in the amount of litter recorded there.

The survey sites must be selected carefully in order that the results of the surveys reflect the different, litter-related characteristics and features of the region they are to cover. It is important that the surveys at least cover the different seasons (e.g. summer, autumn, winter and spring or tourist season/non-tourist season), as seasonal differences in the human use of coastal waters and the coast exist, which influence the amount and composition of the litter deposited on the coastline. Assessments at local, regional, basin and European level are possible. In order to have information on the geographic origins of waste and thus to have a basis for the implementation of actions aimed at reducing litter pollution, it is necessary to make very regular surveys and analyze the results in relation to local weather conditions and geography.

Floating litter

Spatial and temporal short and long-term variations in influencing factors (e.g. North Atlantic Oscillation, hydrodynamics) lead to temporal and spatial variation in the amounts of litter recorded on the sea surface. If possible surveys should be carried out throughout the year and cover extensive offshore areas (aerial surveys). In practice weather conditions will limit the number of surveys, which can be carried out during the winter months (direct observations). Aerial surveys method can be applied to very large areas (i.e. the German Exclusive Economic Zone). Up till now, however, the aerial surveys are a byproduct of surveys of marine mammals. In some cases, e.g. Germany, they cover all territorial waters. This will not be the case in all EU countries. The use of regular flights within European countries for oil spill detection should therefore also be considered for litter evaluation.

Sea floor

As at the surface, both in the open ocean and on the coasts, it is clear that the abundance and distribution of debris show considerable spatial variability. The geographical distribution of plastic debris is strongly influenced by hydrodynamics, geomorphology and human factors. Under the weight of fouling by a wide variety of bacteria, algae, animals and accumulated sediment, plastics can sink to the bottom. Current will then enable transportation of litter to areas where they can accumulate. Then the deep sea floor will be a possible location for strong accumulation. Moreover, there is notable temporal, particularly seasonal, variation with a tendency for accumulation and concentration along coastal and particular geographical areas. Interpretation of temporal trends is therefore complicated by annual variations in debris transport, such as seasonal changes in flow rate of rivers. Other seasonal factors include variation in the position of water fronts, the intensity of currents, swell, winds and upwelling and the conformation of deep sea floor, which influence both the distribution and densities. Nevertheless, if we extrapolate from existing data, it would appear that the Mediterranean Sea is the most affected part of the European coasts. Then the evaluation of litter in very deep sea areas will have to consider specific and well defined areas and focus where important accumulation will happen. Due to the persistence of some litter materials, the monitoring of litter on the sea floor must consider accumulation processes for past decades. Also recovery will be very long, at decade scale. Timescales of observation should therefore be adapted, requiring multiannual frequencies for sea floor surveys.

Entanglement rates of animals found dead on the coastline

With the exception of the Northern Gannet *Morus bassanus,* entanglement rates are quite low (less than 1% of beached birds in the southern North Sea region). The numbers of entangled animals recorded on the coastline is also limited. Local assessment will thus not be possible in most cases. Depending on the abundance of seabirds and litter pollution levels, regional (i.e. southern North Sea), basin (i.e. North Sea) or European scale assessments should be possible. Annual or 5-year average values for entanglement rates should be achievable.

OSPAR Fulmar Plastic EcoQO and other biomonitoring of ingestion

Temporal and spatial "resolution" of the Fulmar EcoQO has already been illustrated in section 2.4 with associated graph. Further in detail, the North Sea Fulmar study has provided good documentation that industrial plastic pollution (e.g. plastic pellets) in the marine environment has strongly decreased: current levels of industrial granules in stomachs are about half those that were observed in the 1980's (van Franeker *et al*., 2005), a phenomenon not only visible in Fulmars in the North Sea, but worldwide in several seabird species (Ryan, 2008). The benefit however was 'lost' by an increase in user plastics. Spatial patterns of different subcategories of plastics have provided evidence that most of North Sea litter is of local origin, and strongly related to shipping activities.

Fulmars occur over most of the North Atlantic, but not the southern EU parts or inside Mediterranean and Baltic. For some regions pilot studies using other seabirds are already underway, but in some areas it may be wiser or necessary to use different types of animals, for which pilot studies should be developed.

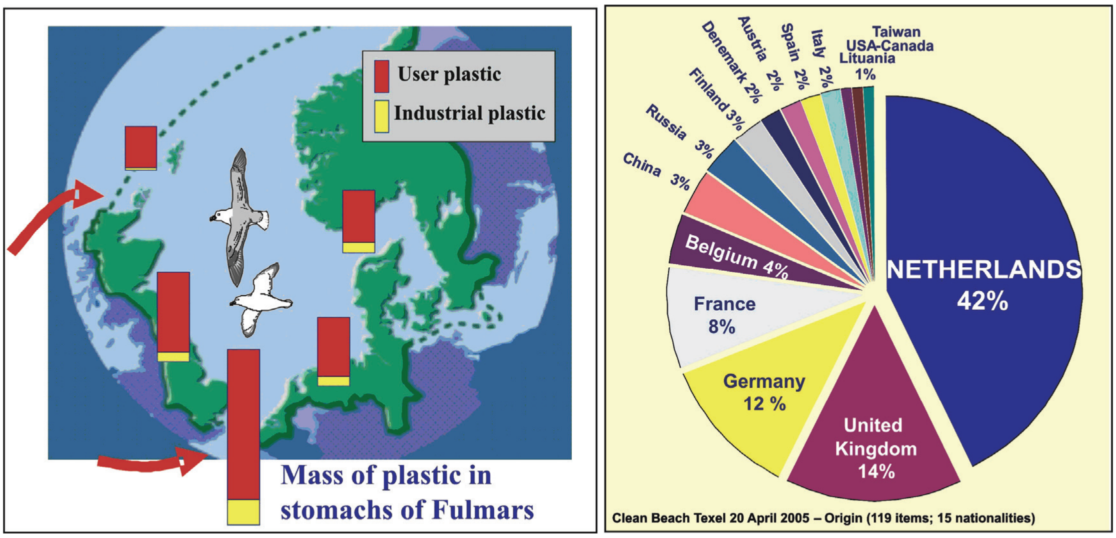

Illustration: Origin of marine litter in the North Sea

The regional pattern of mass of plastic in stomachs of Fulmars in the North Sea provides evidence that the bulk of the debris in the area originates from local sources rather than distant ones. Theoretically the Warm Gulfstream could import much litter into this area. However, the Scottish Islands and the Channel receive largely the same water, but the strong difference in plastic mass in the stomach contents of Fulmars in the two areas (see also Chpt.2.4) shows that large amounts of debris are added to water entering the North Sea through the Channel area. A similar conclusion is evident from a major beach clean-up on the Dutch island Texel where items were checked for evidence of producer information and bar-codes. Around 80% of traceable items had their origin in countries bordering the North Sea (van Franeker 2005).

Microparticles

Our knowledge of the distribution and abundance of microparticles (mainly plastics) is far from complete and requires further evaluation. Fragments as small as 1.6µm have been reported in sediments and in the water column and material smaller than 5mm is present at sites worldwide, However, we have limited knowledge of the sources and sinks of this material. One study in the UK showed that the abundance of microplastic in the shallow subtidal was greater than in nearby intertidal habitats and it seems likely that items of plastic that are buoyant when they enter the sea can subsequently be transported to the seabed.

In the Northeast Atlantic monitoring using the Continuous Plankton Recorder has shown that the abundance of small fragments of plastic has increased significantly since the 1960s (Thompson *et al.*, 2004).

Socio-economic

The socio-economic impact of litter is relevant at all spatial scales from the local to European as its effect can be measured from a scale as small as an individual harbour to its impact on the entire ecosystem. In the temporal scale the impacts are likely to be on a much longer timescale as litter in its various stages of degradation could have an economic impact many decades after it enters the marine environment.

4. General framework and recommendations for describing environmental status

The group recommends the overriding objective to be a measurable and significant decrease in comparison with the initial baseline in the total amount of marine litter by 2020 using the following criteria and methodologies for the evaluation of the state of good environmental status.

- Amount, distribution and composition of litter washed ashore and/or deposited on coastlines.
- Amount, distribution and composition of litter at sea and on the sea floor.
- Amount, distribution and composition of litter impacting marine animals.
- Amount, distribution and composition of microparticles .

Monitoring results combined with research on social, economic and ecological harm will lead to improved knowledge of critical thresholds.

4.1. *Amount and composition of litter washed ashore and/or deposited on coastlines*

The attribute will indirectly measure inputs, impacts on aesthetic values, the presence of toxic compounds and socio-economical damage.

Comprehensive litter assessments need to be planned to ensure that they fit within the context of regional management frameworks. Recommendations for monitoring litter on the coastline are based on the UNEP Guidelines. It is strongly recommended to further harmonize monitoring protocols and methods in the European region.

Counts of the amount and types of litter recorded on a given stretch of coastline are the standard component of beached litter surveys. The accumulation rate of litter on the coastline can be measured when surveys are repeated at regular intervals. Frequency of surveys can vary from a count after each high tide to only one or a few counts each year. Four counts each year in spring, summer, autumn and winter as proposed by UNEP, allows for the assessment of seasonal differences in litter accumulation. Criteria for the selection of survey sites are included in Cheshire *et al*. (2009).

A unified system of classifying litter items is necessary at least on a regional seas level. Low resolution systems (1-6 categories of debris) supply a low error rate and more consistency, however, high resolution systems (> 20 categories of debris) provide the possibility to identify changes in the composition of the litter being assessed and consequently to follow changes in sources of litter or usage of items.

Quality assurance and guidelines are part of the protocol and will improve the reliability of the results. The beach surveys can supply information on the quantity of litter (number, weight, volume and size), the quality of litter (Composition, nature and Principle items) and trends (changes in the quantity or quality and new items entering the environment). The analysis and reporting of the data can be carried out at different levels including item types (e.g. plastic bottles, metal drinks cans, microplastics), groups (e.g. sanitary, packaging), material (plastic, paper, metal etc.), sources (e.g. fisheries) and uses (professional, consumer)

Finally , the data can be amalgamated to produce values for local, regional and basin and European level .

The group recommends that the overriding objective would be a measurable and significant decrease (e.g. 10%/year) in comparison with the initial baseline in the total amount of marine litter by 2020.

4.2. *Amount and composition of litter at sea and on the sea floor*

The attribute will measure litter dynamics and potential interactions with marine life. Accumulation areas will be located

4.2.1. Ship surveys of surface and water column litter

It is strongly recommended to further harmonize monitoring protocols and methods in the European region. For abundance of floating or water column debris at local scale, counts by net trawls are recommended. Net-based surveys are less subjective than direct observations. To date, most studies have sampled floating debris, but some litter items are equally dense or denser than seawater, making it important to sample the water column. A unified system of classifying litter items is necessary at least on a regional seas level. Each litter item should be identified and allocated to a given litter category. Categories will include size, type and source.

4.2.2. Sampling and reporting of marine litter found on sea floor

Standard methods are used for surveys of litter on sea floor performed during International bottom trawl surveys (IBTS) in the North Sea and MEDITS program in the Mediterranean.

Trawling will sample 0.2 (beam trawling) – 1-2 hectare areas using standardized nets (mesh etc.) at fixed locations. Remote cameras may also provide an objective sampling strategy for benthic litter, notably when trawling is difficult to perform. Visual sampling using divers or submersibles can be used to assess quantities per 0.1- 1 km. Frequency of surveys can vary from a count every year (shallow waters) to one count every 5 years or decade (deep sea floor). A medium resolution classification system recording a minimum of 6 debris categories is required (UNEP 2009). Finally, the data can be amalgamated to produce values for local, regional and basin and European level.

4.3. *Amount and composition of litter impacting marine animals*

The attribute measures time-trends and spatial variation in inputs of litter and its impact on marine life.

The OSPAR Fulmar Plastic EcoQo has a fully established and published methodology (van Franeker and Meijboom, 2002; van Franeker, 2004; Van Franeker *et al.*, 2008; OSPAR, 2008) and has historic monitoring data from the Netherlands going back to the early 1980's and North Sea wide starting 2002. It is recommended to apply this method also in other regions where Fulmars occur, which is basically all over the North Atlantic north of Brittany in France.

Currently, an average of 55% of Fulmars in the North Sea exceeds the critical OSPAR EcoQO level of 0.1 gram of plastic in the stomach, with regional variations ranging from around 45% to well over 60% of birds exceeding the critical level. As indicated (Chapter 2.4) the OSPAR EcoQO has defined a target level of less than 10% of such birds, but without a strongly established date. In an example of 10% annual reduction (cf the example in coastal amount of litter) and an effective start of such a reduction rate by the year 2014, a GES example target would translate to a threshold of around 30% of Fulmars having more than 0.1g plastic in the stomach by the year 2020. Continued improvements in later years at the same rate would realize the 10% OSPAR target around year 2030, and virtual elimination of birds with more than 0.1 g plastic by year 2050.

In regions where no Fulmars occur, methods will need some adaptation if applied to other bird species. Exploratory work using shearwaters from the warmer parts of the Atlantic and Mediterranean is already underway, but expansion of those studies is strongly recommended. Additional projects using other species groups such as turtles, fish and/or marine mammals should be initiated, in particular in those sea areas where bird monitoring may not offer sufficient perspective.

For seabirds, entanglement rates similar to use of the oil-rate of Guillemots in the OSPAR EcoQO approach to oil pollution could be used in addition to marine litter monitoring. This will require an additional protocol for data collection in the current system of Beached Bird Surveys (BBS) in a range of countries conducted in relation to oil pollution. Some data on entanglement rates have been collected already in Germany and the Netherlands, but without protocol for a systematic approach. This method has limitations for quantitative marine litter monitoring, because the amount of collectable samples are rather low. However this method can provide a valuable indicator of harm in the marine environment.

4.4. *Amount, distribution and composition of microparticles*

The attribute will establish baseline quantities, properties and potential impacts of microparticles. Microplastic is likely to be the most significant part of this.

Our knowledge of the accumulation, sources, sinks and environmental impacts of microplastics is currently limited. Further work is needed to establish temporal and spatial patterns and potential physical and chemical impacts. Microplastic particles have been monitored in the water column using the continuous plankton recorder (CPR). Additional analyses on existing data should be carried out. Monitoring of both sediments and seawater needs to be done according to standard procedures in order to ensure consistency (Thompson, 2004). Identification of microplastic particles requires skilled analytical techniques such as FT-IR spectroscopy approaches and clean conditions.

To date several sites have been sampled in the EU including locations in the UK, France, Sweden and Spain. It is recommended that additional sites are examined with inclusion of the intertidal and subtidal zones. This will also provide a baseline for future temporal comparisons. The relative importance of various sources of microparticles in the proximity of industrial locations where plastic powders are produced or used should also be undertaken, together with sampling of sewage outfalls and locations where plastics are used as shot blasting .

5. Monitoring

There is a need to harmonise data collection across Europe and an expert group needs to be established to undertake this

What are the data needs for the descriptor?

- Coastline: The amount and composition, in categories of litter indicative of sources, washed ashore or deposited on the coastline as number of items, volume or weight on a given stretch of coast.

- Water Column, Surface and Sea Bed: The amount and composition, in categories of litter indicative of sources at sea and on the seafloor recorded in appropriate units e.g. items/m2 for sea bed, items/m3 for water column.

- Bio monitoring: The amounts and categories of litter ingested by representative species of wildlife expressed in units of mass

- Microparticles: Amount, distribution and composition of microparticles recorded in density units. This will establish baseline quantities, properties and potential impacts of microparticles. Microplastic is likely to be the most significant part of this

What data needs are covered by national monitoring programmes, What is poorly or not covered ?

- Coastline: Monitoring needs to be undertaken on a regional basis within a coordinated programme. (see 2.1)

- OSPAR has a voluntary monitoring programme
- HELCOM has adopted monitoring guidelines
- MEDPOL is considering applying UNEP guidelines
- Black Sea is considering applying UNEP guidelines

There is a need to further increase coverage of survey sites, further development of data analysis and quality insurance in the OSPAR programme and for the implementation of coordinated monitoring programmes in all other regions

- Water Column, Surface and Sea Bed: There are currently no coordinated national or regional monitoring programmes for surface water, water column or seabed within Europe. Surface water monitoring is not done on a regular basis by observers or net based surveys. However seabed monitoring has been undertaken as part of the International bottom trawl surveys (IBTS) in the North Sea and MEDITS program in the Mediterranean.

- Bio monitoring: the North Sea and most of the OSPAR area are covered by the Fulmar Plastic Particle EcoQO (see chapter 2.4). For southern parts of the OSPAR region and the MEDPOL region, pilot studies using other seabird species are being conducted. For other regions suitable species need to be identified and tested.

- Microparticles: There are currently no monitoring programmes for microparticles within Europe, however, data from continuous plankton recorders could be used to quantitatively analyse trends in larger microplastics but this would require further development. Developing monitoring programmes for the full size range of microparticles and different compartments of the environment requires dedicated research to develop monitoring standards and baselines.

Are there existing methodological standards that cover these data needs?

- Coastline: OSPAR, HELCOM and UNEP have adopted guidelines on monitoring coastline litter

- Water Column, Surface and Sea Bed: UNEP has developed protocols

- Bio monitoring : In OSPAR there are methodological standards for the Fulmar EcoQO, which may act as an example for standards using other monitoring species.

- Microparticles: Research analytical protocols exist for microplarticles however sampling protocols need to be harmonized.

Identify where it is possible to make improvements through targeted and focused additional monitoring?

- Water Column, Surface and Sea Bed: Implement and improve the existing IBTS and MEDITS marine litter protocols and extend them to other regions

- Bio monitoring: For areas where there are not suitable species pilot projects need to be undertaken to identify suitable species

- Microparticles: Implement and improve the national monitoring programs involved in the sampling of plankton (Continous plancton recorder), water and sediment.

Quality assurance

Quality assurance is taken up in guidelines as mentioned above and those from associated regional institutions. Recommendations for monitoring litter on the coastline are based on the UNEP Guidelines.

6. Recommended background research in relation to GES assessments

An initial evaluation will be performed by all member states on the current state of research in their region/subregion to give a scientific and technical basis for monitoring, define knowledge gaps and priority areas for research. Harmonisation will require coordination by relevant representatives from each member state; this will lead to common and comparable monitoring approaches, recommendations and guidelines to assess GES on a regional/European scale. The results of this evaluation will help to clarify any fundamental research gaps required to link quantities of litter and associated harm in the context of GES.

6.1. Factors influencing the localisation of litter at sea

An important aspect of litter research to be established is the evaluation of links between hydrodynamic factors such as velocity, turbidity, turbulence, density of water masses, residual circulation and other forcing variables. These factors will determine the behaviour of the different types of litter in the marine environment (varying according to nature, size and composition). This will give us a better understanding of transport dynamics and accumulation zones. Close links also exist between the presence of litter in marine medium and the anthropic and geographical coastal conditions. Further development and improvement of modelling tools must be considered for the evaluation and identification of both sources and fate of litter in the marine environment.

Nowadays long-term simulations are widely used for comprehensive model based descriptions of the meteo-marine and hydro-sedimentary systems e.g. the data base CoastDat (www.coastdat.de) provides reconstructed fields of water levels and currents for about 50 years on an hourly basis with high spatial resolution.

It is proposed that these already existing data sets and models be used for supporting interpretation of marine litter monitoring data. Comprehensive models should define source regions of interest. In a similar way backtrack simulations should be initialised at those locations, where monitoring data are collected. Drift calculations will differ between different types of material being exposed to wind, wave and current forcing in different ways.

Amongst others the following information would become available:

- Patterns of regional connectivity in the sense that certain receptor regions are particularly exposed to litter.
- Average drift times between source and receptor regions.
- Estimated residence times
- Weather and current driven variations of advection rates (on all time scales),

Drift simulations should comprise all periods covered by the monitoring program.

Geomorphological factors (e.g. slope, canyons, rocks, beaches...) are key elements determining litter distribution and must be studied in more detail because they will affect the fate and accumulation rate of litter on the seafloor. Furthermore sedimentation will determine the rate of smothering and must be considered when evaluating litter sinks.

Anthropogenic inputs may have changed and sources are maybe shifting between tourism fishing, shipping and marine industry. More research towards a clear evidence base is necessary to ensure efficient policy decisions.

6.2. The degradation process

The persistence through time is key characteristic of marine litter. We need a better understanding about rates of degradation of litter in the environment and this should include examination of so called biodegradable materials with enhanced degradation properties as there is concern they may break down into non degradable fragments. At present the lower limit of detection for plastic particles is around 1µm. It seems likely that even smaller particles of litter (nanoparticles) may exist, however we need to develop appropriate methodology to quantify these. We also need a better understanding of the potential sink/types and habitat where this material is most likely to accumulate.

Microplastic particles are a recently described phenomena (Thompson *et al*., 2004) and our knowledge of the accumulation and environmental consequence of this material are relatively limited. Research has shown that microplastic particles of a range of common polymers are present on shorelines worldwide (Barnes *et al*., 2009) and that the abundance of this material has increased significantly in the water column in recent decades. It seems likely that this material is accumulating as a consequence of the fragmentation of larger items of debris together with direct inputs of small particles. It therefore seems likely that the quantity of microplastic in the environment will continue to increase even if inputs of larger items of debris begin to decline. Existing data indicate that microplastics are not necessarily transported in the same way as larger items. Coupled with this we need a better understanding of point and diffuse sources for direct inputs of microplastic particles that are used in production of plastic items and as abrasives and shot blasting media. Perhaps most importantly we need fundamental research to establish the environmental consequences of this relatively recently described type of debris. There is evidence from the natural environment and the laboratory that fragments of plastic can accumulate and transport potentially toxic chemicals and laboratory experiments predict that in some habitats relatively small quantities of plastic (parts per million) could significantly increase the transport of these chemicals to marine organisms. However, we have limited knowledge about the full environmental relevance of microplastic particles. We advocate monitoring in parallel with further fundamental research to establish potential physical and chemical impacts on wildlife, marine living resources and the food chain.

6.3. The ecological impact on marine organisms

Studies are urgently needed quantifying the impact of marine litter on marine organisms at a population and community level. Ingestion of, and entanglement in marine litter may be important mortality factors for many marine species. However, there is a lack of knowledge of effects at population level. There are a few studies demonstrating that entanglement in marine litter is a serious mortality factor for some marine species, e.g. for the Hawaiian monk seal *Monachus shauinslandi*, (Henderson, 1990, 2001; Boland and Donohue, 2003), the northern fur seal, *Callorhinus ursinus*, (Fowler, 1987), and the endangered Florida manatee (*Trichechus manatus latirostris*) (Beck and Barros, 1991; Marine Mammal Commission, 2006). There are also a few studies trying to quantify the population level effect of ghost fishing, e.g. Breen (1987). However, such studies are rare and there are no estimates of litter-related mortality for the vast majority of affected species. There is an important knowledge gap on how litter ingested by marine organisms affects their physiological condition and chemical burdens, and how these reduce survival and reproductive performance, and ultimately affect their populations. Linking population parameters directly to litter abundance in monitoring studies will be extremely complicated, because these parameters are influenced by a very wide range of interacting natural and anthropogenic circumstances, of which many are not properly measured and not sufficiently understood. Thus, expressing harm from litter on animal populations (including ultimately man) must be a combination of experimental approaches with data collected from animal populations in the wild. Thus it is recommended to initiate research that may result in defining new protocols to improve our knowledge and ability to monitor harmful effects of litter on a population (impact on population vital rates) or community level (altering biocommunity structure). Validation of target species for monitoring ingestion and entanglement along the European coasts is required.

6.4. The socio economic impact

In order to assess the socio economic impact of marine litter it is essential that common methodologies are developed to collect both social and economic data. Currently if the required data is recorded it is in a range of formats and in most cases is not collected centrally by member states making it difficult to access. This must be addressed to develop comparable datasets for evaluation at the EU level. The evaluation of direct costs and loss of income to industry and local authorities should be evaluated on a yearly basis by a single agency with overall responsibility for marine litter, as part of a national marine litter strategy in each member state.

There has only been a limited amount of research into the social and economic effects of marine litter and there are many aspects that require further research, especially in relation to the definition of harm. What level of litter in the marine environment is acceptable to the public? What is the economic cost to industry, local authorities and governments through direct costs and loss of income and what impact are they willing to accept? What is the impact on human health? What is the cost of litter to ecosystems goods and services? However, before these questions can be answered, common methodologies and reporting mechanisms need to be developed to gather data in a consistent and comparable manner and other areas of litter research need to be advanced.

In relation to the economic costs of marine litter more specific research needs to be undertaken in order to assess:

- Tourism and the potential loss of income to due to beach litter
- Fishing and the potential loss of fish stocks due to abandoned and lost fishing gear
- Direct costs to industry, local authorities and governments
- The cost of litter to ecosystems goods and services

In relation to the social cost of marine litter more specific research needs to be undertaken:

- Assess socially acceptable levels of marine litter to the public and industry
- Develop effective litter management plans and legislation
- Improve tools such as GIS, socio economic models, drift modeling etc. enabling evaluations of the social impact and contributing to management efforts.
- Establish the impact of marine litter on human health

6.5. Novel methods and automated monitoring devices

Repeatability, optimisation, robustness and reliability of methods will require further research to develop rapid interpretation of litter data.

6.5.1. Large scale surveys of litter

Litter floating on the sea surface is recorded during aerial surveys of Harbour Porpoise in German territorial waters (Herr, 2009). Using geolocalisation and navigation data densities of litter or the number of items per km of transect can be calculated (Buckland *et al*., 2001). The present methods applied are a good tool for mapping litter distribution as a way of identifying litter sources, but need to be further developed before they can be used for monitoring purposes. Especially ground truthing needs to be incorporated in the programme and problems related to recording numbers of litter items in areas with high concentrations of litter or litter conglomerations need to be solved. Standard methods of litter identification and assessment could be developed from methods used to survey marine mammals and birds. These methods are based on the Distance Sampling line transect or strip transect technique.

The introduction of high resolution georeferenced images (5 cm resolution) for wildlife monitoring purposes may offer a high quality platform for surface litter monitoring at sea. Such images are at present obtained in selected areas of the UK waters and will get more widely used in the future.

This could even be improved and extended in the future by high resolution satellite images and other approaches using automated image analysis.

Other possibilities include development of ship based camera monitoring coupled with automated image analysis to help recognise items of litter. Stationary platforms for such purposes could also be suggested. From these platforms automated cameras with automated image transfer to land are in place (see http://www.fino-offshore.de/).

Automated watersamplers and measuring devices could be designed to quantify microplastics.

6.5.2. Dose response studies

In order to quantify harmful physical and chemical effects, studies on dose response need to be undertaken in relation with types and quantities of marine litter. These studies will enlarge our understanding and enable a more science based definition of threshold levels.

More research should also be undertaken to harmonize the tools for analysis geostatistics of social sciences with those of oceanographical sciences

7. References

Abu-Hilal, A., Al-Najjar, T. (2009). Marine litter in coral reef areas along the Jordan Gulf of Aqaba, Red Sea. Journal of Environmental Management 90: 1043-1049.

Arthur, C., Baker, J., Bamford, H. (eds) (2009). Proceedings of the International Research Workshop on the Occurrence, Effects and Fate of Microplastic Marine Debris. Sep 9-11, 2008.. NOAA Technical Memorandum NOS-OR&R-30. NOAA, Silver Spring 530pp.

Auman, H.J., Ludwig, J.P., Giesy, J.P. and Colborn, T. (1997). Plastic ingestion by Laysan Albatross chicks on Sand Island, Midway Atoll, in 1994 and 1995. In: Robertson, G. and Gales, R. (Eds.), *Albatross biology and conservation*. Chipping Norton: Surrey Beatty and Sons; pp. 239–244.

Azzarello, M.Y. ,Van Vleet, E.S (1987). Marine birds and plastic pollution. *Marine Ecology Progress Series*, *37*, 295–303.

Ballance, A., Ryan, P. G., Turpie, J. K. (2000). How much is a clean beach worth? The impact of litter on beach users in the Cape Peninsula, South Africa. *South African Journal of Science,* Vol.96, No.5.

Barnes, D. K. A. (2002). Invasions by marine life on plastic debris. Nature 416, 808–809. (doi:10.1038/416808a)

Barnes, D.K.A., Milner, P. (2005). Drifting plastic and its consequences for sessile organism dispersal in the Atlantic Ocean. *Marine Biology*, *146*, 815–825.

Barnes , D.K.A., Galgani, F., Thompson, R. C. & Barlaz, M. (2009). Accumulation and fragmentation of plastic debris in global environments. *Philosophical Transactions of the Royal Society B*, 1985-1998.

Beck, C.A., Barros, N.E. (1991). The impact of debris on the Florida Manatee. Marine Pollution Bulletin, 22, 508–510.

Boland, R.C., Donohue, M.J. (2003). Marine debris accumulation in the nearshore marine habitat of the endangered Hawaiian monk seal, *Monachus schauinslandi* 1999–2001. *Marine Pollution Bulletin*, *46*, 1385–1394.

Borja, A., Galparsoro. I., Solaun, Muxika, I., Tello, E. A., Uriarte, A., Valencia, V. (2006). The European Water Framework Directive and the DPSIR, a methodological approach to assess the risk of failing to achieve good ecological status, Estuarine, Coastal and Shelf Science 66 , 84-96

Breen, P.A. (1987). Mortality of Dungeness crabs caused by lost traps in the Fraser River Estuary, British Columbia. North American Journal of Fisheries Management, 7, 429–466.

Browne, M. A., Galloway, T., Thompson, R. (2007). Microplastic—an emerging contaminant of potential concern. Integr. Environ. Assess. Manag. 3, 559–566.

Browne, M. A., Dissanayake, A., Galloway, T. S., Lowe, D. M., Thompson, R. C. (2008) Ingested microscopic plastic translocates to the circulatory system of the mussel, Mytilus edulis (L.). Environ. Sci. Technol. 42, 5026–5031. (doi:10.1021/es800249a)

BSC, 2007. Marine litter in the Black Sea Region: A review of the problem. Black Sea Commission Publications 2007-1, Istanbul, Turkey, 160 pp.

Buckland, S. T., Anderson, D. R., Burnham, K. P., Laake, J. L., Borchers, D. L., Thomas, L. (2001). Introduction to distance sampling: Estimating abundance of biological populations. Oxford University Press, New York.448 pp.

Burnham, K. P., Anderson, D. R. 1984. The need for distance data in transect counts. Journal of Wildlife Management, 48: 1248-1254.

Camphuysen, Kees C.J. (2005). Oiled-guillemot-EcoQO— implementation document. North Sea pilot project on ecological quality objectives, Issue 4. Seabirds, EcoQO element (f). NIOZ Report. Texel: Royal Netherlands Institute for Sea Research. 16 pp.

Camphuysen, Kees ,C.J. (2008).Verstrikkingen van zeevogels in zwerfvuil en vistuig, 1970-2007 (entanglements of seabirds in marine litter and fishing gear, 1970-2007.) Sula 21/2, pp 88-91.

Carpenter,E., J.,Anderson, S.J., Harvey, G.R., Miklas, H. P., Bradford, B. P. (1972). Polystyrene spherules in coastalwaters. Science 178, 749–750. (doi:10.1126/science.178.4062.749)

Cheshire, A.C., Adler, E., Barbière, J., Cohen, Y., Evans, S., Jarayabhand, S., Jeftic, L., Jung, R.T., Kinsey, S., Kusui, E.T., Lavine, I., Manyara, P., Oosterbaan, L., Pereira, M.A., Sheavly, S., Tkalin, A., Varadarajan, S., Wenneker, B., Westphalen, G. (2009). *UNEP/IOC Guidelines on Survey and Monitoring of Marine Litter.* UNEP Regional Seas Reports and Studies, No. 186; IOC Technical Series No. 83: xii + 120 pp.

Chiappone, M., White, A., Swanson, D.W. and Miller, S.L. (2002). Occurrence and biological impacts of fishing gear and other marine debris in the Florida Keys. *Marine Pollution Bulletin*, *44*, 597–604.

Coe, J.M. and Rogers, D.B. (1997) Marine debris: sources, impacts, and solutions. New York, NY: Springer.

Colton,J. B., Knapp, F. D. & Burns, B. R. (1974). Plastic particles in surface waters of the Northwestern Atlantic. *Science* 185, 491 - 497.

Derraik, J.G.B. (2002). The pollution of the marine environment by plastic debris: a review. *Marine Pollution Bulletin*, *44*, 842–852.

De Wit, C. A. (2002) An overview of brominated flame retardants in the environment. *Chemosphere* 46, 583-624.

Donohue, M.J., Boland, R.C., Sramek, C.M. and Antonelis, G. (2001). Derelict fishing gear in the Northwestern Hawaiian Islands: diving surveys and debris removal in 1999 confirm threat to coral reef ecosystems. *Marine Pollution Bulletin*, *42*, 1301–1312.

Eagon, P. K., Chandar, N., Epley, M. J., Elm, M. S., Brady, E. P., Rao, K. N. (1994). Di(2-ethylhexyl)phthalate-induced changes in liver estrogen metabolism and hyperplasia. *International Journal of Cancer* 58, 736 – 743

Endo, S., Takizawa, R., Okuda, K., Takada, H., Chiba, K., Kanehiro, H., Ogi, H., Yamashita, R. , Date, T. (2005) Concentration of polychlorinated biphenyls (PCBs) in beached resin pellets: Variability among individual particles and regional differences. *Marine Pollution Bulletin* 50, 1103-1114.

Fanshawe, T, Everard, M. (2002). The Impacts of Marine Litter, Marine Pollution Monitoring Management Group, Report of the Marine Litter Task Team (MaLiTT) May 2002.

Feldkamp, S., Costa, D., DeKrey, G.K. (1989). Energetics and behavioral effects of net entanglement on juvenile northern fur seals *Callorhinus ursinus*. *Fisheries Bulletin*, *87*, 84–94.

Fleet, D. M., van Franeker, J. A, Dagevos, J , M. Hougee.(2010). Wadden Sea QSR Report - Marine Litter. In prep.

Fowler, C.W. (1987) Marine debris and northern fur seals: a case study. Marine Pollution Bulletin, 18, 326–335.

Galgani, F., Andral, B. (1998). Methods for evaluating debris on the deep sea floor. OCEANS'98/IEEE/OEC Conference, Nice 28/09-01/10/98 3, 1512–1521.

Galgani, F. , Lecornu, F. (2004). Debris on the sea floor at 'Hausgarten': in the expedition ARKTIS XIX/3 of the research vessel POLARSTERN in 2003. Berichte Polar Meeresforsch. 488, 260–262.

Galgani, F., Souplet, A., Cadiou, Y. (1996). Accumulation of debris on the deep sea floor of the French Mediterranean coast. Mar. Ecol. Progr. Ser. 142, 225–234. (doi:10.3354/meps142225)

Galgani F., Leaute J. P., Moguedet P., Souplet A., Verin Y., Carpentier A., Goraguer H., Latrouite D., Andral B., Cadiou Y., Mahe J. C., Poulard J. C., Nerisson P. (2000). Litter on the Sea Floor Along European Coasts. Marine Pollution Bulletin 40(6):516-527. (doi:10.1016/S0025-326X(99)00234-9)

Goldberg, E. (1994). Diamonds and plastics are forever? Editorial. Mar. Pollut. Bull. 28, 466. (doi:10.1016/0025- 326X(94)90511-8)

Goldberg, E. (1995). Emerging problems in the coastal zone for the twenty-first century. Mar. Pollut. Bull. 31, 152– 158. (doi:10.1016/0025-326X(95)00102-S)

Gregory, M. R. (1978). Accumulation and distribution of virgin plastic granules on New Zealand beaches. *New Zealand Journal of Marine and Freshwater Research* 12, 339-414.

Gregory, M.R. (1999). Plastics and South Pacific island shores: environmental implications. Ocean and Coastal Management, 42, 603–615.

Gregory, M. R. (2009). Environmental implications of plastic debris in marine settings – entanglement, ingestion, smothering, hangers-on, hitch-hiking, and alien invasions. *Philosophical Transactions of the Royal Society B* 364, 2013-2026 (doi:10.1098/rstb.2008.0265)

Hall, K. (2000). Impacts of Marine Debris and Oil. Economic & Social Costs to Coastal Communities. Publication of Kommunenes Internasjonale Miljøorganisasjon (KIMO).

Helsinki Commission (2007): Assessment of the Marine Litter problem in the Baltic region and priorities for response, Baltic Marine Environment Protection Commission, 21pp

Henderson, J.R. (2001). A pre- and post- MARPOL Annex V summary of Hawaiian monk seal entanglement and marine debris accumulation in the Northwestern Hawaiian Islands. Marine Pollution Bulletin, 42, 590–597.

Henderson, J.R. (1990). Recent entanglements of Hawaiian monk seals in marine debris. In: Shomura, R.S., Godfrey, M.L. (Eds.), Proceedings of the Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, Hawaii. NOAA-TM-NMFS-SWFSC-154. Washington, DC: Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service; pp. 540–553.

Herr, H. 2009. Vorkommen von Schweinswalen (Phocoena phocoena) in Nord- und Ostsee im Konflikt mit Schifffahrt und Fischerei?. Dissertation zur Erlangung des Doktorgrades des Departments Biologie der Fakultät für Mathematik, Informatik und Naturwissenschaften der Universität Hamburg. 118pp.

Hess, N., Ribic, C., Vining, Y. (1999). Benthic marine debris, with an emphasis on fishery-related items, surrounding Kodiak Island, Alaska, 1994–1996. Mar. Pollut. Bull. 38, 885–890. (doi:10.1016/S0025-326X(99)00087-9)Katsanevakis S, 2008. Marine debris, a growing problem: Sources, distribution, composition, and impacts. In: Hofer TN (ed) Marine Pollution: New Research. Nova Science Publishers, New York. pp. 53–100.

IEH. (1995) *Enviromental oestrogens consequences to Human health*. Leicester: MRC.

IEH. (1999) *IEH Asssesement on the ecological significance of endocrine disruption: effects on reproductive function and consequences for natural populations (Assessement A4)*. Leicester: MRC.

Ivar do Sul, J.A., Costa, M.F. (2007). Marine debris review for Latin America and the Wider Caribbean Region: From the 1970s until now, and where do we go from here? Marine Pollution Bulletin, 54, 1087–1104.

Katsanevakis S. (2008). Marine debris, a growing problem: Sources, distribution, composition, and impacts. In: Hofer TN (ed) *Marine Pollution: New Research*. Nova Science Publishers, New York. pp. 53–100.

Katsanevakis S. (2009). Estimating abundance of endangered marine benthic species using Distance Sampling through SCUBA diving: the *Pinna nobilis* (Mollusca: Bivalvia) example. In: Columbus AM, Kuznetsov L (eds) Endangered Species: New Research. Nova Science Publishers, New York. pp. 81–115.

Katsanevakis, S. , Katsarou, A. (2004). Influences on the distribution of marine debris on the seafloor of shallow coastal areas in Greece (Eastern Mediterranean). *Water, Air and Soil Pollution*, *159,* 325–337.

Katsanevakis, S., Verriopoulos, G., Nikolaidou, A. ,Thessalou-Legaki, M. (2007). Effect of marine pollution with litter on the benthic megafauna of coastal soft bottoms. *Marine Pollution Bulletin*, *54*, 771–778.

Koch, H. M. & Calafat, A. M. (2009). Human body burdens of chemicals used in plastic manufacture. *Philosophical Transactions of the Royal Society B* 364, 2063-2078.

Koutsodendris, A., Papatheodorou, A., Kougiourouki, O., Georgiadis, M. (2008). Benthic marine litter in four Gulfs in Greece, Eastern Mediterranean; abundance, composition and source identification. Est. Coast. Shelf Sci. 77, 501–512. (doi:10.1016/j.ecss.2007.10.011)

Laist, D.W. (1987). Overview of the biological effects of lost and discarded plastic debris in the marine environment. *Marine Pollution Bulletin*, *18*, 319–326.

Laist, D. W. (1997). Impacts of marine debris: entanglement of marine life in marine debris including a comprehensive list of species with entanglement and ingestion records. In Marine debris:

sources, impacts and solutions (eds J. M. Coe & B. D. Rogers), pp. 99–141. Berlin, Germany: Springer.

MAP (2003). Strategic Action Programme: Guidelines for Management of Coastal Litter for the Mediterranean Region (document UNEP(DEC)/MED WG 231/7), 17p.

Machado, A.A., (2006). Estudo da contaminação por resı´duos sólidos na Ilha do Arvoredo: Principal ilha da Reserva Biológica Marinha do Arvoredo (RBMA), SC. Monograph, Fundação Universidade Federal do Rio Grande, p. 50.

Marine Mammal Commission (2006). Annual Report to Congress 2005. Bethesda, MD.

Masó, M., Garcés, J., Pagès, F., Camp, J. (2003). Drifting plastic debris as a potential vector for dispersing Harmful Algal Blooms (HAB) species. Sci. Mar. 67, 107–111.

Mato, Y., Isobe, T., Takada, H., Kanehiro, H., Ohtake, C., Kaminuma, T. (2001). Plastic resin pellets as a transport medium for toxic chemicals in the marine environment. Environ. Sci. Technol. 35, 318–324. (doi:10.1021/es0010498)

McCauley, S.J., Bjorndal, K.A. (1999). Conservation implications of dietary dilution from debris ingestion: sublethal effects in post-hatchling loggerhead sea turtles. *Conservation Biology*, *13*, 925–929.

Moore, C.J., Moore, S.L., Leecaster, M.K., Weisberg, S.B. (2001). A comparison of plastic and plankton in the North Pacific Central Gyre. *Marine Pollution Bulletin*, *42*, 1297–1300.

Moore, C.J., Moore, S.L., Weisberg, S.B., Lattin, G.L., Zellers, A.F. (2002). A comparison of neustonic plastic and zooplankton abundance in southern California's coastal waters. *Marine Pollution Bulletin*, *44*, 1035–1038.

Ng, K. L., Obbard, J. P. (2006). Prevalence of microplastics in Singapore's coastal marine environment. Marine Pollution Bulletin 52, 761-767.

Oehlmann, J., Schulte-Oehlmann, U., Kloas, W., Jagnytsch, O., Lutz, I., Kusk, K. O., Wollenberger, L., Santos, E. M., Paull, G. C., Van Look, K. J. W., Tyler, C. R. (2009). A critical analysis of the biological impacts of plasticizers on wildlife. Philosophical Transactions of the Royal Society B 364, 2047-2062.

OSPAR (2007a). OSPAR Pilot Project 2000-2006 on Monitoring Marine Beach Litter. Final Report. OSPAR report 306.

OSPAR(2007b). Background report on Fishing for litter activities in the OSPAR Region. OSPAR Report 325

OSPAR (2008). Background Document for the EcoQO on plastic particles in stomachs of seabirds. OSPAR Commission, Biodiversity Series. ISBN 978-1-905859-94-8 Publication Number: 355/2008. OSPAR, London, 13pp.
http://www.ospar.org/documents/dbase/publications/p00355_EcoQO%20Plastics%20in%20seabird%20stomachs.pdf

OSPAR (2009). Marine litter in the North-East Atlantic Region: Assessment and priorities for response. London, United Kingdom, 127 pp.

Provencher, J.F.; Gaston, A.J.; Mallory, M.L (2009). Evidence for increased ingestion of plastics by northern fulmars (|Fulmarus glacialis|) in the Canadian Arctic. Marine Pollution Bulletin 58: 1092-1095.

Rios, L. M., Moore, C., Jones, P. R. (2007). Persistent organic pollutants carried by Synthetic polymers in the ocean environment. *Marine Pollution Bulletin* 54, 1230-1237.

Ryan, P.G. (1988). Effects of ingested plastic on seabird feeding: evidence from chickens. *Marine Pollution Bulletin*, *19*, 125–128.

Ryan, P.G. (2008). Seabirds indicate changes in the composition of plastic litter in the Atlantic and south-western Indian Oceans. Marine Pollution Bulletin 56: 1406-1409.

Ryan, P.G., Connell, A.D., Gardner, B.D. (1988). Plastic ingestion and PCBs in seabirds: is there a relationship? *Marine Pollution Bulletin*, *19*, 174–176.

Ryan, P.G., Cooper, J. (1989). Observer precision and bird conspicuousness during counts of birds at sea.. S. Afr. J. Mar. Sci. 8: 271-276.

Ryan, P.G., Moore, C.J., Van Franeker, J.A. , Moloney, C.L. (2009). Monitoring the abundance of plastic debris in the marine environment. Phil. Trans. R. Soc. B. 364. (doi: 10.1098/rstb.2008.0207)

Save the North Sea (2004). Reduce Marine Litter. Save the North Sea Project Results.

Sievert, P.R., Sileo, L. (1993). The effects of ingested plastic on growth and survival of albatross chicks. In: Vermeer, K., Briggs, K.T., Morgan, K.H. and Siegel-Causey, D. (Eds.), *The status, ecology, and conservation of marine birds of the North Pacific*. Otawa: Canadian Wildlife Service Special Publication; pp. 212–217.Sprengler A, Costa MF, 2008. Methods applied in studies of benthic marine debris. Marine Pollution Bulletin 56: 226-230.

Spengler A, Costa MF, 2008. Methods applied in studies of benthic marine debris. Marine Pollution Bulletin 56 (2): 226-230.

Stefatos, M., Charalampakis, M., Papatheodorou, G. , Ferentinos, G. (1999). Marine debris on the sea-floor of the Mediterranean Sea: examples from two enclosed gulfs in Western Greece. Mar. Pollut. Bull. 36, 389–393.

Swan, S. (2005). Decrease in anogenital distance among male infants with prenatal phtalate exposure (vol 113, pg 1056, 2005). *Environmental Health Perspectives* 113, A583-A583.

Takehama, S. (1990). Estimation of damage on fishing vessels caused by marine debris based on statistics of the damage insurance for fishing vessels. In: Shomura, R.S., Godfrey, M.L. (Eds.), Proceedings of the Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, Hawaii. NOAA-TM-NMFS-SWFSC-154. Washington, DC: Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service; pp. 792–809.

Talsness, C. E., Andrade, A. J. M., Kuriyama, S. N., Taylor, J. A. , vom Saal, F. S. (2009). Components of plastic: experimental studies in animals and relevance for human health. Phil. Trans. R. Soc. B. 364. (doi:10.1098/rstb.2008.0281)

Teuten, E. L., Rowland, S. J., Galloway, T. S., Thompson, R. C. (2007). Potential for plastics to transport hydrophobic contaminants. *Environmental Science and Technology* 41, 7759-7764.

Teuten, E. L., Saquing, J. M., Knappe, D. R. U., Barlaz, M. A., Jonsson, S., Björn, A., Rowland, S. J., Thompson, R. C., Galloway, T. S., Yamashita, R., Ochi, D., Watanuki, Y., Moore, C., Viet, P., Tana, T. S., Prudente, M., Boonyatumanond, R., Zakaria, M. P., Akkhavong, K., Ogata, Y., Hirai, H., Iwasa, S., Mizukawa, K., Hagino , Y., Imamura, A., Saha, M., Takada, S. (2009) Transport and release of chemicals from plastics to the environment and to wildlife. *Philosophical Transactions of the Royal Society B* 364, 2027-2045.

Thompson, R. C., Olsen, Y., Mitchell, R. P., Davis, A., Rowland, S. J., John, A. W. G., McGonigle, D. & Russell, A. E. (2004). Lost at sea: where is all the plastic? Science 304, 838. (doi:10.1126/science.1094559)

Thompson, R. C., Moore, C., vom Saal, F. S., Swan, S. H. (2009). Plastics, the environment and human health: current consensus and future trends. Phil. Trans. R. Soc. B 364.(doi:10.1098/rstb.2009.0053)

Tudor DT, Williams AT. Investigation of litter problems in the severn estuary/Bristol channel area, R&D Technical Summary, E1-082/TS. Bristol: Environment Agency; 2001.

Turner, R. K, D. Hadley, T. Luisetti, V. Lam (2009) Cheung Socio economic assessment within a marine strategy framework , 2009, OSPAR Draft.

UNEP,(2009).Marine Litter: A Global Challenge. Nairobi: UNEP. 232 pp

van Franeker, J. A., Bell, P. J. (1988) Plastic ingestion by petrels breeding in Antarctica. Mar. Pollut. Bull. 19, 672–674.

Van Franeker, J.A., Meijboom, A. (2002). Litter NSV - Marine litter monitoring by Northern Fulmars: a pilot study.. ALTERRA-Rapport 401. (Alterra, Wageningen, 72pp)

Van Franeker, J.A. (2004). Save the North Sea - Fulmar Study Manual 1: Collection and dissection procedures.. Alterra Rapport 672. Alterra, Wageningen. 38pp.

Van Franeker, J.A., Heubeck, M., Fairclough, K., Turner, D.M., Grantham, M., Stienen, E.W.M., Guse, N., Pedersen, J., Olsen, K.O., Andersson, P.J., Olsen, B. (2005). 'Save the North Sea' Fulmar Study 2002-2004: a regional pilot project for the Fulmar-Litter-EcoQO in the OSPAR area.. Alterra-rapport 1162. Alterra, Wageningen. 70pp.

Van Franeker, J.A., Meijboom, A., De Jong, M., Verdaat, H. (2009). Fulmar Litter EcoQO Monitoring in the Netherlands 1979-2007 in relation to EU Directive 2000/59/EC on Port Reception Facilities.. Wageningen IMARES Report nr C032/09. Wageningen IMARES, Texel. 39pp

Van Franeker, J.A., the SNS Fulmar Study Group (2008). Fulmar Litter EcoQO monitoring in the North Sea - results to 2006. IMARES Report nr C033/08. Wageningen IMARES, Texel. 53pp..

Welshons, W. V., Nagel, S. C. ,vom Saal, F. S. V. (2006). Large effects from small exposures. III. Endocrine mechanisms mediating effects of bisphenol a at levels of human exposure. *Endocrinology* 147, S56-S69.

Wallace, B. (1990). How much do commercial and recreational fishermen know about marine debris and entanglement? Part 1. In: Shomura, R.S., Godfrey, M.L. (Eds.), Proceedings of the Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, Hawaii. NOAA-TM-NMFS-SWFSC-154. Washington, DC: Dept of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service; pp. 1140–1148.

Winston, J.E. (1982). Drift plastic – an expanding niche for a marine invertebrate? *Marine Pollution Bulletin*, *13*, 348–357.

Zubris, K. A. V., Richards, B. K. (2005). Synthetic fibers as an indicator of land application of sludge. *Environmental Pollution* 138, 201-211.

8. Members of the Task Group 10 on Marine litter

Ezio Amato, ISPRA, Italy(e.amato@icram.org)
Alexei Birkun, Brema Laboratory,Ukraine (AlexeiBirkun@home.cris.net)
David Fleet MLUR, Germany (david.fleet@lkn.landsh.de)
Jan van Franeker, IMARES , The Netherlands (Jan.vanFraneker@wur.nl)
Francois Galgani (Chair), IFREMER, France (Francois.galgani@ifremer.fr)
Colin Janssen, University of Ghent, Belgium (Colin.Janssen@UGent.be)
Stelios Katsanevakis, HCMR, Greece (stelios@katsanevakis.com)
Thomas Maes, CEFAS, UK (thomas.maes@cefas.co.uk)
John Mouat, KIMO, Shetland, UK (john.mouat@kimo.shetland.org)
Lex Oosterbaan, Ministry of Transport, The Netherlands (lex.oosterbaan@rws.nl)
Isabelle Poitou, MerTerre, Marseille (isabelle.poitou@mer-terre.org)

And

Carly Brooks (Observer), OSPAR, (carly.brooks@defra.gsi.gov.uk)
Georg Hanke (European Commission), JRC (Georg.hanke@jrc.ec.europa.eu)
George Kamizoulis (Observer), MEDPOL (gkamiz@unepmap.gr)
Ib Krag Petersen (Observer), HELCOM (ikp@dmu.dk
Richard Thompson (Invited expert), University of Plymouth, England
(R.C.Thompson@plymouth.ac.uk)
Violetta Velikova (Observer), Black Sea Commission (violeta.velikova@blacksea-commission.org)

European Commission

EUR 24340 EN – Joint Research Centre

Title: Marine Strategy Framework Directive – Task Group 10 Report Marine litter.

Authors: F. Galgani, D. Fleet, J. Van Franeker, S. Katsanevakis, T.Maes, J. Mouat, L. Oosterbaan, I. Poitou, G. Hanke, R. Thompson, E. Amato, A. Birkun & C. Janssen

Luxembourg: Office for Official Publications of the European Communities
2010 – 48 pp. – 21 x 29.7 cm
EUR – Scientific and Technical Research series – ISSN 1018-5593
ISBN 978-92-79-15653-3
DOI 10.2788/86941

Abstract

The Marine Strategy Framework Directive (2008/56/EC) (MSFD) requires that the European Commission (by 15 July 2010) should lay down criteria and methodological standards to allow consistency in approach in evaluating the extent to which Good Environmental Status (GES) is being achieved. ICES and JRC were contracted to provide scientific support for the Commission in meeting this obligation.
A total of 10 reports have been prepared relating to the descriptors of GES listed in Annex I of the Directive. Eight reports have been prepared by groups of independent experts coordinated by JRC and ICES in response to this contract. In addition, reports for two descriptors (Contaminants in fish and other seafood and Marine litter) were written by expert groups coordinated by DG SANCO and IFREMER respectively.
A Task Group was established for each of the qualitative Descriptors. Each Task Group consisted of selected experts providing experience related to the four marine regions (the Baltic Sea, the North-east Atlantic, the Mediterranean Sea and the Black Sea) and an appropriate scope of relevant scientific expertise. Observers from the Regional Seas Conventions were also invited to each Task Group to help ensure the inclusion of relevant work by those Conventions. This is the report of Task Group 10 Marine litter.

How to obtain EU publications

Our priced publications are available from EU Bookshop (http://bookshop.europa.eu), where you can place an order with the sales agent of your choice.

The Publications Office has a worldwide network of sales agents. You can obtain their contact details by sending a fax to (352) 29 29-42758.

The mission of the JRC is to provide customer-driven scientific and technical support for the conception, development, implementation and monitoring of EU policies. As a service of the European Commission, the JRC functions as a reference centre of science and technology for the Union. Close to the policy-making process, it serves the common interest of the Member States, while being independent of special interests, whether private or national.

LB-NA-24340-EN-N

JRC
EUROPEAN COMMISSION

Finalized research in the prospect of answering to social expectations (climate change effects, marine biodiversity, pollutions prevention, seafood quality…). The results are scientific knowledge and technological innovations, but also ocean observation and exploration systems. The partnership is public, private or both.
Oceans seas and coastal waters' monitoring, in support with public policy for the environment and its resources. In the form of notices or studies reports, the results provide the information about the environment state or the evaluation of a resource and permit the expertise on sea-related questions.
Development, management and open access of large research infrastructures – fleet, calculation means, data centres, experimental facilities – which are made available to the whole National and European scientific community, as well as to private partners.

Ifremer

International Council for the Exploration of the Sea
Conseil International pour l'Exploration de la Mer

The Mission of ICES is to advance the scientific capacity to give advice on human activities affecting, and affected by, marine ecosystems.

ICES International Council for the Exploration of the Sea
CIEM Conseil International pour l'Exploration de la Mer

ISBN 978-92-79-15653-3

9 789279 156533

Publications Office
Publications.eu.int