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Oil Pollution in the North Sea

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Oil Pollution in the North Sea

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Aims and Scope

Since 1980, *The Handbook of Environmental Chemistry* has provided sound and solid knowledge about environmental topics from a chemical perspective. Presenting a wide spectrum of viewpoints and approaches, the series now covers topics such as local and global changes of natural environment and climate; anthropogenic impact on the environment; water, air and soil pollution; remediation and waste characterization; environmental contaminants; biogeochemistry; geoecology; chemical reactions and processes; chemical and biological transformations as well as physical transport of chemicals in the environment; or environmental modeling. A particular focus of the series lies on methodological advances in environmental analytical chemistry.

Series Preface

With remarkable vision, Prof. Otto Hutzinger initiated *The Handbook of Environmental Chemistry* in 1980 and became the founding Editor-in-Chief. At that time, environmental chemistry was an emerging field, aiming at a complete description of the Earth's environment, encompassing the physical, chemical, biological, and geological transformations of chemical substances occurring on a local as well as a global scale. Environmental chemistry was intended to provide an account of the impact of man's activities on the natural environment by describing observed changes.

While a considerable amount of knowledge has been accumulated over the last three decades, as reflected in the more than 70 volumes of *The Handbook of Environmental Chemistry,* there are still many scientific and policy challenges ahead due to the complexity and interdisciplinary nature of the field. The series will therefore continue to provide compilations of current knowledge. Contributions are written by leading experts with practical experience in their fields. *The Handbook of Environmental Chemistry* grows with the increases in our scientific understanding, and provides a valuable source not only for scientists but also for environmental managers and decision-makers. Today, the series covers a broad range of environmental topics from a chemical perspective, including methodological advances in environmental analytical chemistry.

In recent years, there has been a growing tendency to include subject matter of societal relevance in the broad view of environmental chemistry. Topics include life cycle analysis, environmental management, sustainable development, and socio-economic, legal and even political problems, among others. While these topics are of great importance for the development and acceptance of *The Handbook of Environmental Chemistry,* the publisher and Editors-in-Chief have decided to keep the handbook essentially a source of information on "hard sciences" with a particular emphasis on chemistry, but also covering biology, geology, hydrology and engineering as applied to environmental sciences.

The volumes of the series are written at an advanced level, addressing the needs of both researchers and graduate students, as well as of people outside the field of "pure" chemistry, including those in industry, business, government, research establishments, and public interest groups. It would be very satisfying to see these volumes used as a basis for graduate courses in environmental chemistry. With its high standards of scientific quality and clarity, *The Handbook of Environmental Chemistry* provides a solid basis from which scientists can share their knowledge on the different aspects of environmental problems, presenting a wide spectrum of viewpoints and approaches.

The Handbook of Environmental Chemistry is available both in print and online via www.springerlink.com/content/110354/. Articles are published online as soon as they have been approved for publication. Authors, Volume Editors and Editors-in-Chief are rewarded by the broad acceptance of *The Handbook of Environmental Chemistry* by the scientific community, from whom suggestions for new topics to the Editors-in-Chief are always very welcome.

Damià Barceló
Andrey G. Kostianoy
Editors-in-Chief

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Introduction

Angela Carpenter

Abstract This book presents a review of knowledge on oil pollution in the North Sea. Making use of a range of data from satellite imagery, remote-sensing, aerial surveillance, in situ monitoring, oil spill sampling and beached bird surveys, it presents a picture of trends in oil pollution in the region over many years. It examines national practices in a number of North Sea states, the impact the North Sea being given Special Status for oil under the MARPOL Convention and the activities of the Bonn Agreement, OSPAR Commission and EMSA CleanSeaNet in monitoring the region. It also examines the development of a common method for oil spill identification by the Bonn-Oil Spill Identification Network and the use of sensors to identify spills in the German North Sea. The use of beached bird surveys in North Sea and in Dutch waters also provides a tool for monitoring chronic oil pollution in coastal waters. The publication brings together the work of scientists, legal and policy experts, academic researchers and specialists in various fields relating to marine environmental protection, oil pollution and the North Sea.

Keywords Aerial surveillance, Beached bird surveys, Bonn Agreement, CleanSeaNet, European Maritime Safety Agency, European Union, MARPOL Convention, North Sea, Oil installations, Oil pollution, Oil spill monitoring, OSPAR Convention, Satellite monitoring, Shipping

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The North Sea lies between Norway, Denmark, Germany, the Netherlands, Belgium, France and the United Kingdom (see Fig. 1) [1]. It measures approximately 960 km from north to south and 580 km east to west at its widest point and has a surface area of approximately 750,000 km^2 [2]. The North Sea is home to the largest commercial ports in Europe – Rotterdam, Antwerp and Hamburg – together with many other ports providing access to Europe for both global and internal maritime traffic [3]. In 2007, around 2.6 million passengers travelled on ferry routes connecting the UK with Belgium, the Netherlands, Germany, Denmark and Norway [3]. The shipping lanes of the North Sea are some of the busiest in the world. In 1996, for example, around 270,000 ships entered the 50 main ports in the North Sea and English Channel area. In that year, on a daily basis, around 600 ships crossed the Strait of Dover (of which 200 were passenger ferries) and 400 ships travelled through the strait either entering or exiting the North Sea [2]. Ships travelling to and from the Baltic Sea must also sail through the North Sea.

Fig. 1 Map of the North Sea. *Source*: adapted from Wikimedia map – North Sea relief location map [1]

The North Sea has also been the site of Europe's offshore oil and gas production industry since the 1960s, with oil installations generally in the area lying between the northeast UK and southwest Norway and gas installations in the southern North Sea, between the UK and the Netherlands [4]. In 2012 there were 161 oil production installations operating in the North Sea region and 326 gas production installations [5]. Some substances discharged from oil installations have been found in the sediments of the Skagerrak and the Norwegian Trench, and, during severe weather, those substances may become resuspended as a result of wave action, potentially reintroducing pollutants to the marine environment [6].

In addition to shipping and oil and gas extraction, a number of other activities take place in the region. These include mariculture (e.g. the farming of salmon, shellfish and mussels), the fishing sector and developments in marine renewable energy generation (e.g. offshore wind turbines and wave energy) [6]. Land-based industries such as the chemical industry, petroleum refineries, ship-building and power stations are located on the region coasts and estuaries, while underwater data and energy cables, as well as oil and gas pipelines, are submerged in the North Sea sediments [6].

Tourism and recreational activities also bring visitors to coastal areas around the region, generating economic benefits and providing employment in those areas. Nearly 80 million tourists visited coastal areas around the North Sea in 2007 [5] which results in increased pressure on natural habitats and ecosystems and can contribute to pollution and litter entering the marine environment. Those habitats include sea cliffs, sand dunes, shingle banks, salt marshes, intertidal mudflats and subtidal sediments and rocky areas [6]. Many of these habitats, and the wildlife and plants that live in and around them, can be severely damaged by marine pollution from oil or other substances.

The marine environment of the North Sea region has a wide range of measures in place to protect it from oil and other pollution from sources such as shipping, oil and gas installations and land-based sources/riverine outputs. A framework for the environmental protection of the North Sea has developed extensively over many decades. This includes a series of International Conferences on the Protection of the North Sea, the first of which was held in Bremen in 1984 [7]. It also includes the OSPAR Convention [8] (superseding the earlier Oslo and Paris Conventions [9, 10]), the Bonn Agreement [11] and measures taken by the International Maritime Organization (IMO) such as the MARPOL Convention [12] under which the North Sea is a Special Area for the purposes of oil pollution. The European Union (EU, formerly European Community) has also developed measures to try to reduce or prevent oil pollution from entering the marine environment from shipping [13, 14]. The EU Directive on port reception facilities [15] has, for example, led to increased provision of port reception facilities in North Sea ports and an increase in the volumes of oil discharged into those facilities, resulting in more oily waste and residues being discharged in ports and less oil entering the marine environment [16, 17]. The EU also established the European Maritime Safety Agency (EMSA) [18] which has a specific role to monitor and protect Europe's seas through operational activities such as its CleanSeaNet (CSN) Service [19]. In addition, measures taken under the auspices of the Helsinki Convention [20] may also impact on the protection of the North Sea with, for example, cooperation in aerial surveillance with the Bonn Agreement.

Oil pollution entering the marine environment from shipping, oil and gas installations, and other sources has been an issue of concern for many decades. Oil pollution from ships was brought sharply into public focus in the late 1960s following the grounding, in March 1967, of the *Torrey Canyon* on Pollard Rock on the Seven Sisters Reef between the Scilly Isles and Lands End in the United Kingdom (UK). Around 119,000 tonnes of Kuwait crude oil was spilled into the sea and was spread widely on the prevailing winds and tides. Oil contaminated the beaches of south Cornwall and Devon in the UK and the beaches of Normandy in France. When chemical dispersants failed to break up the slick which measured 35 miles by 20 miles, the decision was taken to try and disperse it using bombs. Images of the grounded vessel, and of the oil fires which resulted from the bombing, appeared in the newsprint and broadcast media around the globe [21].

The *Torrey Canyon* was the biggest recorded oil spill up to that time. It resulted in questions being asked about how to prevent oil pollution from ships and how to provide compensation in the event of accidents at sea. It led to the adoption of two international measures, the International Convention on Civil Liability for Oil Pollution Damage in 1969 [22] and the MARPOL Convention in 1973 [12].

Oil entering the marine environment can come from many sources including natural seeps from the sea bed and erosion of sediments, atmospheric deposition from incomplete combustion of fuel, run-off from rivers and land-based sources, refineries and oil terminals, and from shipping where oil inputs can be as a result of accidents, operational discharges and illegal discharges. Its effects can be chronic and long lasting, or short-lived, depending on the source and type of oil.

Oil is a generic term that normally covers a very wide range of natural hydrocarbon-based substances and refined petrochemical products. Crude oil is generally made up of a complex mixture of three main chemical groups, alkanes (paraffins), naphthenes and aromatics which, when refined, produce petrochemical products including fuel oils, kerosene and gasoline, together with chemicals such as benzene and ethane. Depending on where it comes from, crude oil may also contain asphaltics (substances with a tar-like consistency at low temperature which cannot be distilled); organic compounds containing oxygen, nitrogen and sulphur; and trace metals including nickel, copper and heavy metals. Light, sweet crude oil has a lower density and lower sulphur content than heavy, sour crude oil. It is generally easier to refine using factional distillation and contains more valuable fractions such as petroleum gases, light gasoline, kerosene and diesel fuel; it also has lower levels of residues at the end of the refining process.

Table 1 illustrates the characteristics of crude oil from different locations globally, with North Sea crude having a fairly low density and a yield of valuable fractions of over 50% [23]. By contrast, South American crude has a high density and a yield of only 15%.

There are also differences in sulphur content from different locations. For example, North Sea, Brent crude, which has a fairly low density, also has a low

Table 1 Typical characteristics of crude oil from different locations

	North Africa	North Sea	Middle East	North America	South America
Density at 15°C (kg/l)	0.801	0.842	0.869	0.890	1.000
Vaporisation temperature	Percentage yield by weight of various cuts				
Petroleum gases	3.2	2.0	1.3	0.4	0.0
Light gasoline (petrol) (0–70°C)	8.8	5.8	4.7	2.4	0.1
Naphtha (70–140°C)	16.0	11.0	7.9	6.5	1.1
Kerosene (140–250°C)	26.3	18.6	16.4	15.6	4.4
Diesel fuel (250–350°C)	18.2	19.1	15.3	19.6	9.6
Residue (350°C +)	27.5	43.5	54.4	55.5	84.8

Source: Royal commission (1981, page 9) [23]

sulphur content of around 0.5%, while Mexico, Maya Crude, is a heavy crude with a high sulphur level of nearly 3.5% [24]. The lightest, sweetest crudes are Malaysia, Tapis, and Algeria, Sahara, blend, both of which have a low density and virtually no sulphur content [24].

Factors such as the source and composition of oil, whether it is unrefined or refined, and also weather conditions such as wind speed, levels of sunlight, wave motion and temperature can influence the length of time that an oil spill will linger in the marine environment and whether it will have short-term or long-term, chronic impacts. In an oil spill, the lighter fractions will generally evaporate quickly, leaving behind the heavier fractions. The colder the weather, the longer it will take for oil (particularly the heavier fractions) to disperse, and so a spill may have longer-lasting and more visible impacts such as the formation of a water in oil emulsion (mousse) or heavy, thick, tar-like substances (known as “tar balls”) washing up onto the shoreline. Figure 2 illustrates the fate of oil spilled on the sea surface [25, 26].

In addition to crude oil and refined petroleum products (petrochemicals), there are other types of nonpetroleum oils such as fish oil, vegetable and animal oils which, when transported in bulk, may enter the sea as a result of accidental spills and result in damage to the marine environment.

Estimated volumes of oil entering the North Sea from all sources vary widely. For example, 1993 figures for oil entering the North Sea on an annual basis range from 7,000 to 15,000 tonnes/year (t/year) input from atmospheric sources; between 16,000 and 46,000 t/year input from rivers and land run-off and between 15,000 and 60,000 t/year from accidental or illegal discharges from shipping [4]. Total inputs to the North Sea were estimated, in 1993, as being anywhere between 86,000 and 210,000 t/year input to the marine environment [4].

Globally, the estimated average inputs of oil from ships and other sea-based activities for the period 1988–1997 was 1,245, 200 t/year [27]. This included 457,000 t/year from ships, 20,000 t/year from offshore exploration and production activities, 115,000 t/year from coastal facilities, 53,000 t/year from small craft and

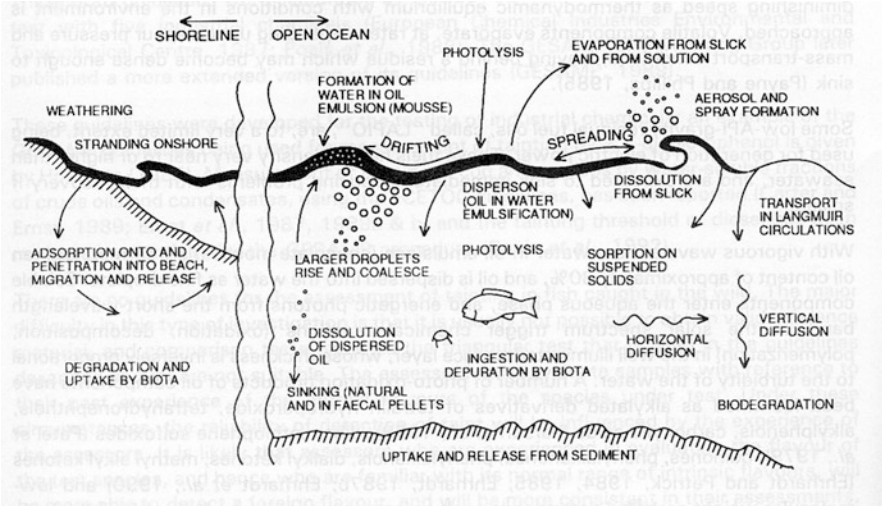

Fig. 2 Schematic diagram of oil spill processes at sea and shorelines. *Source*: GESAMP (1993), page 42 [25]. (This diagram was originally produced by MacKay (1985) in Englehardt ed. (1985) [26]

200 t/year from unidentified sources. The largest estimated source was, however, natural seeps, at around 600,000 t/year [27]. Globally, operational discharges from ships were estimated to make up 45% of the 457,000 t/year from ships, with accidents making up a further 36%. Of those operational discharges, around 186,000 t/year (68%) were estimated as coming from fuel oil sludge during routine operations. Tanker and barge accidents, meanwhile, accounted for approximately 158,000 t/year, even though very large spills from tanker accidents occur only infrequently [27].

Many of the largest oil spills occurring globally since the late 1960s took place in the waters of the North East Atlantic (see Table 2 [28]). These include the *Amoco Cadiz* spill off the Brittany coast of France in 1978 (number 4 out of the top 20); the *Urquiola* off La Coruña, Spain, in 1976 (number 10) and the *Jakob Maersk* off the coast of Portugal in 1975 (number 13). Other spills in the North East Atlantic include the *Aegean Sea*, *Khark 5*, *Brear* and *Sea Empress* spills, together with two spills not in the top 20 – the *Erika* spill off Brittany, France, in 1999 (which released around 19,800 tonnes of oil) and the sinking of the tanker *Prestige* off Cap Finistere, northwest Spain in 2002 (which released around 62,650 tonnes of oil). In the North Sea, there have been two very large spills, the *Torrey Canyon* spill off the Isles of Scilly in 1967 (number 7 out of the top 20) and the tanker *Texaco Denmark* which released 107,100 tonnes into the sea off Belgium in 1971 [25].

The *Texaco Denmark* spill is not included in the top 20 spills set out in Table 2, although it would be number 9 if it had been included.

Since 1970 almost all accidental oil spills (81% of nearly 10,000 spills) have been less than 7 tonnes in size [28]. In 1970s, there were, on average, 24.5 spills per

Table 2 Top 20 major oil spills since 1967

Rank	Ship name	Year	Location	Spill size (tonnes)
1	Atlantic Empress	1979	Off Tobago, West Indies	287,000
2	ABT Summer	1991	700 Nautical miles off Angola	260,000
3	Castillo De Bellver	1983	Off Saldanha Bay, South Africa	252,000
4	Amoco Cadiz	1978	Off Brittany, France	223,000
5	Haven	1991	Genoa, Italy	144,000
6	Odyssey	1988	700 Nautical miles off Nova Scotia, Canada	132,000
7	Torrey Canyon	1967	Scilly Isles, UK	119,000
8	Sea Star	1972	Gulf of Oman	115,000
9	Irenes Serenade	1980	Navarino Bay, Greece	100,000
10	Urquiola	1976	La Coruna, Spain	100,000
11	Hawaiian Patriot	1977	300 Nautical miles off Honolulu	95,000
12	Independenta	1979	Bosphorus, Turkey	94,000
13	Jacob Maersk	1975	Oporto, Portugal	88,000
14	Braer	1993	Shetland Islands, UK	85,000
15	Aegean Sea	1992	La Coruna, Spain	74,000
16	Sea Empress	1996	Milford Haven, UK	72,000
17	Khark 5	1989	120 Nautical miles off the Atlantic coast of Morocco	70,000
18	Nova	1985	Off Kharg Island, Gulf of Iran	70,000
19	Katina P	1992	Off Maputo, Mozambique	67,000
20	Prestige	2002	Off Galicia, Spain	63,000

Note: Quantities rounded to the nearest 1,000 tonnes. Spills highlighted in grey occurred in the North East Atlantic and North Sea regions
Source: ITOPF (2015) [28]

year. By 2000s this had fallen to an average of 3.4 per year, while between 2010 and 2014, there were less than 2 spills a year (1.8 spills) on average [28]. Globally, in 2014, the total recorded amount of oil lost to the environment as a result of tanker accidents was approximately 4,000 tonnes [28]. That is in contrast to a figure of 636,000 tonnes in 1979 (the largest amount in any year between 1970 and 2014) and a low of 1,000 tonnes in 2012 [28]. Figure 3 illustrates the quantities of oil spill annually for the period 2000–2014 [28].

Inputs from oil and gas installations in the region have varied widely over time. In the early 1990s to 1990, cuttings (solid material removed from drilled rock together with any solids and liquids, such as oil-based muds, derived from any adherent drilling fluids) were the main source of oil at around 90% of total discharges from production platforms, with the remaining oil being discharged in produced water [29]. Since 1996, no oil-based mud cuttings have been discharged, and since 2004, there have been virtually no discharges of cuttings containing

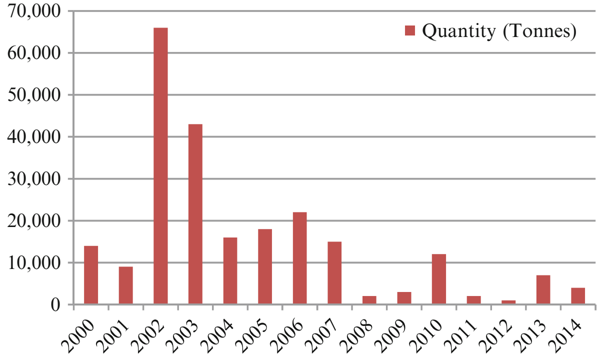

Fig. 3 Quantities of oil spill globally from tanker incidents between 2000 and 2014. *Note*: additional data on quantities of oil spill from tanker incidents is available from the international tanker owner pollution federation limited for the period 1970 onwards. *Source*: ITOPF (2015) [28]

organic-phase drilling fluids (OPFs) [30]. The vast majority of cuttings containing OPFs are now transported to shore for treatment and disposal, with smaller amounts being injected into disposal wells [31]. This is a direct result of stricter standards being imposed on oil and gas installations by OSPAR [31] together with agreed levels of sampling and analysis methods [32].

Produced water (PW, a by-product of oil and gas production operations) and displacement water (DW, seawater used to ballast storage tanks of offshore installations) have, since the early 2002, been the main source of oil input to the sea from installations, together with some accidental discharges which accounted for less than 5% of total discharges from installations for the years 1999–2012, excluding 2007 [30]. Around 400 million m^3 of PW were discharged to the sea in 2001, falling to around 34.4 million m^3 in 2012. For the same years, DW inputs to the sea were 67.75 million m^3 and 34.4 million m^3 respectively [30]. Again, stricter standards set out by OSPAR have resulted in that reduction, through setting maximum permissible levels of oil discharged in PW [33].

While there have been some accidental spills from oil and gas installations, they account for less than 5% of oil discharges to the North Sea [30].

Aerial surveillance of the North Sea has been conducted under the Bonn Agreement aerial surveillance programme since the mid-1980s, and there is clear evidence of a reduction in oil spills since that time, in all areas of the North Sea [34]. Data from Bonn Agreement annual surveillance reports [35], together with increasing availability of satellite imagery from EMSA CSN and national programmes, shows a downward trend in the number of observed slicks from more than 1,100 in 1990 (nearly 1,200 in 1997) to around 140 in 2013. Since 2003, confirmation of the type of slick – mineral or other types of oil or sheen on the water – has increased the accuracy of the data provided in Bonn Agreement annual reports. Satellite imagery has been available since 2004. Improvements in night-time surveillance, attribution of many spills to individual ships or to oil installations and continued cooperation between North Sea states all contribute to the effective monitoring of the marine environment for oil pollution.

This book follows on from an earlier volume on *Oil Pollution in the Baltic Sea* [36]. It contains 14 chapters including the Introduction and Conclusions written by the volume editor. This Introduction, which provides an overview of the North Sea and some of the problems of oil pollution facing it, is followed by a chapter on actions taken by the Bonn Agreement to eliminate illegal and accidental oil pollution from ships in the North Sea, for example, through its BE-AWARE project, an area-wide risk assessment of marine pollution under a common methodology [37]. The next chapter examines the development of the European Maritime Safety Agency and its CleanSeaNet operational task in the North Sea. The role of the International Maritime Organization and its role in the prevention of illegal oil pollution from ships is the next chapter, which examines the North Sea as a Special Status Area. The following four chapters consider the state of oil pollution in the North Sea waters of Denmark, Belgium, the Netherlands and the United Kingdom. The use of beached bird surveys as a tool to monitor oil pollution in the North Sea forms the next chapter, which is followed by two further chapters on monitoring methods. The first of those chapters examines the German operational monitoring system in the North Sea, looking at the use of sensors, monitoring methods and example data. The other monitoring chapter considers oil pollution from oil installations in the North Sea and makes use of data from the Bonn Agreement Secretariat and the OSPAR Commission. Bonn Agreement activities for oil spill sampling are then considered, with the development of a common method for oil spill identification under Bonn-Oil Spill Identification Network (OSI-Net). The review of the state of the North Sea, carried out initially by the North Sea Task Force and then the OSPAR Commission, examines the impact of oil spills on the marine environment of the North Sea from all sources, providing a multi-decadal overview of the state of the marine environment. The book ends with some conclusions.

The book is aimed at a wide audience of national, regional and international agencies and government bodies, together with policy makers and practitioners in the fields of shipping, ports and terminals, oil extraction and marine management. It is also aimed at graduate and undergraduate students in marine environmental sciences, as well as policy studies and legislative studies. It will provide a valuable resource of knowledge, information and references on oil pollution in the North Sea.

Work started on this volume in October 2013 when a number of authors were approached to contribute to this volume on oil pollution in the North Sea. The response to those invitations was overwhelmingly positive. Following final agreement with Springer Verlag, in February 2014, to go ahead with this volume, it took about 18 months to bring together all the chapters. During that time, there have been no major oil spills in the North Sea from either shipping or from oil installations. This is a very positive situation and illustrates the success of measures put in place to minimise oil pollution in the region over several decades.

Since starting work on this book, only one major oil spill has occurred at sea; the sinking of a small tanker loaded with approximately 3,000 tonnes of bitumen in the South China Sea [28]. In 2013 and 2014 combined, there were only 4 oil spills over 700 tonnes from tankers and 9 further spills of less than 700 tonnes [28]. A very large spill did take place in the Houston (Texas, UK) ship channel in March 2014, when a barge loaded with heavy oil released around 170,000 gallons from a cargo of 900,000 gallons following a collision with another ship [38]. That spill was contained by the use of booms along the coastline to prevent the oil from entering the marine environment.

This book follows on from the “Oil Pollution in the Baltic Sea” volume in the Springer Verlag Handbook of Environmental Chemistry book series [36]. I was very glad to be given the opportunity to edit and contribute to this new volume in the series, and there are plans to continue the book series with further volumes on the Mediterranean, Black and Caspian Seas, for example.

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Bonn Agreement Actions to Eliminate Illegal and Accidental Oil Pollution from Ships in the North Sea

Ole Kristian Bjerkemo and Johannes Huisman

Abstract Preventing maritime disasters is very important. Accidental or illegal pollution from ships is a threat to the maritime environment. The Greater North Sea and its wider approaches are one of the busiest and intensively used maritime areas in the world. With the ever-increasing competition for space comes an increased risk of accidents that could result in marine pollution; the Bonn Agreement contracting parties decided to establish the BE-AWARE project to undertake the first area-wide risk assessment of marine pollution using a common methodology that allows the risk to be mapped and compared under different scenarios. Under the International Convention on Marine Pollution from Ships (MARPOL 73/78), the whole of the North Sea area is a 'special area' for oil discharges; any oily discharge that is visible as a sheen on the water is illegal. The number of oil slicks detected shows that there is still work to do to bring to justice the offenders responsible for those slicks. The North Sea Network of Investigators and Prosecutors and the Bonn Agreement work together on enforcement. The contracting parties have also undertaken to conduct surveillance of the area as an aid to detecting and combating pollution and to preventing violation of anti-pollution regulations, known as MARPOL. Satellite surveillance also plays an (still growing) important role in the detection of possible pollution at sea. The contracting parties have developed an Aerial Operations Handbook (AOH).

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Contents

1 Introduction

On the website of the Bonn Agreement, it is stated that international cooperation works in preventing maritime disasters and cleaning up after maritime disasters is very important. This is the lesson that comes from nearly 40 years of scientific, technical and operational work of the Bonn Agreement. Through this cooperation, the BONN parties have developed great expertise in handling these many threats to the marine environment.

The perils of the sea are only too real and ever present. Ever since mankind started using the sea for trade, ships have sunk and been wrecked. Since the time of ancient Greece, traders have insured their cargoes against the perils of the sea. For the last two centuries, shore-based lifeboats have sought to save human life from the perils of the sea, supported now by radar, aeroplanes, helicopters and the most modern satellite technology.

However, it was only when ships began carrying massive quantities of potentially damaging material that it became clear that the perils of the sea could threaten the well-being of sea itself and all who depend on its waters, coasts and produce. Maritime pollution – from shipwrecks, shipping collisions and illegal discharges – became a substantial threat.

In 1967, the tanker *Torrey Canyon* (Fig. 1) was wrecked on the Seven Stones off the Isles of Scilly (south-west of England). It was carrying 117,000 tonnes of crude oil. As this cargo turned into a black tide sweeping east up the English Channel, the

Fig. 1 The Torrey Canyon

need for international cooperation to deal with such problems became clear. Coastal states could not wait until the threat was in their waters: they needed to respond collectively as soon as possible (http://www.bonnagreement.org/eng/html/briefing_document/briefing%20document.htm).

Within 2 years, Belgium, Denmark, France, Germany, the Netherlands, Norway, Sweden and the United Kingdom had set up the 1969 Agreement for Cooperation in Dealing with Pollution of the North Sea by Oil (Bonn Agreement) to meet this need for cooperation. When the agreement was revised in 1983, it was extended to cover pollution from other harmful substances, and the European Community became a contracting party. In 1987, the agreement was extended to cover cooperation in surveillance. In 2010 Ireland joined the Bonn Agreement, and from that time the Bonn Agreement covered the North Sea area, Irish waters and related Norwegian and UK waters [1].

2 What Does the Bonn Agreement Cover?

The actions within the Bonn Agreement to eliminate illegal and accidental oil pollution from ships in the North Sea are based on the contracting parties' implementation of the agreement by:

- Keeping their zones of responsibility under surveillance for threats of marine pollution, including coordinating aerial and satellite surveillance
- Alerting each other to such threats
- Adopting common operational approaches, with the objective to rely on each other to achieve the necessary standards of prevention and clean-up
- Supporting each other (when asked to do so) in response operations
- Sharing research and development
- Carrying out joint exercises
- Carrying out analysis to define risk and propose risk-reducing measures

3 Changes in Traffic Levels and Pollution: The BE-AWARE Project

The Greater North Sea and its wider approaches are one of the busiest and intensively used maritime areas in the world. With the ever-increasing competition for space comes an increased risk of accidents that could result in marine pollution [2].

In this area, there was no overall risk assessment for marine pollution. The risk was mapped with a variety of national risk assessments which are undertaken using differing methodologies, thus reducing comparability between those assessments. Because of this lack of comparability, the Bonn Agreement contracting parties decided to establish the BE-AWARE project to undertake the first area-wide risk assessment of marine pollution using a common methodology that allows the risk to be mapped and compared under different scenarios.

The overall objective of BE-AWARE was to gain a better understanding of the regional and subregional risk of accidents and of the potential for marine pollution events in the Greater North Sea and its approaches. This objective was achieved by focusing on the risk of accidents and the potential for spills of oil and hazardous and noxious substances (HNS) from shipping. Risks derived from collisions with offshore installations (both wind farms and oil and gas installations) and from spills from installations themselves were also included. As a discrete task, a regionally specific methodology for environmental and socioeconomic vulnerability analysis was also developed.

The project was a 2-year initiative (2012–2014), co-financed by the European Union, with participation and support from the Bonn Agreement Secretariat, Belgium, Denmark and the Netherlands, with co-financing from Norway. In 2014 the Bonn Agreement contracting parties decided to extend the project with a phase II, aiming to describe the impact of oil releases considering sensitivity in the area. The phase II is also co-financed by the European Union.

3.1 *Results from Phase I of the BE-AWARE Project*

The methodology used was similar to that developed in the BRISK (Subregional risk of spill of oil and hazardous substances in the Baltic Sea) project [3] that had been undertaken in the HELCOM (HELsinki COMmittee) maritime area [4], using a multi-model approach, calculating the risk and magnitude of spills. Analysis was undertaken for both 2011, the baseline year for the project, and 2020, taking into consideration the expected changes in traffic routing and intensities and maritime uses. The methodology included defining the key parameters to be taken into consideration, such as:

- Hazard identification
- Ship traffic

- Classification of oil
- Oil transport model
- Traffic prognosis
- Frequency and quantity of oil spills
- Oil spills related to offshore installations
- Qualitative analysis of HNS risks

The models used a considerable amount of data, including accident statistics, automatic identification system (AIS) data, cargo data, risk-reducing measures, locations of fixed objects, etc. In order to collect a standard set of data for the whole Bonn Agreement area, a Data Collection Note was developed, outlining the data types and formats required from the relevant contracting parties. The data was collected in a central Regional Resource Database by the Bonn Agreement Secretariat, to be used as a future resource for the Bonn Agreement.

The ship traffic model, developed by BE-AWARE, was based on the AIS data. From the intensity of the ship traffic, a route net was developed that described the primary sailing routes and the number of vessels on those routes. This was then used to develop a traffic model that was a database of identified route passages, including direction (see Fig. 2) and vessel characteristics. In that figure, the map of traffic density is based on the counted number of AIS records per cell. Due to the higher sampling rate around Denmark, the coloured scale in that area has been adjusted to match the rest of the BE-AWARE area. The database provided traffic data for the calculation of accident and spill frequencies, which were dependent upon the traffic, its volume and composition.

Using individual vessel information from the World Shipping Encyclopaedia (http://www.ihsfairplay.com/Maritime_data/sample_pages/wsedemocomp.html?product=WSE&i=2), the model was able to estimate the consequences of an accident, based on the vessel characteristics. This was then combined with the cargo model, which described the probability of a certain ship type and ship size sailing on a specific route being loaded with a certain type of cargo. This used information that included ships routes, lists of substances and port data.

The risk of the spill from collisions with offshore gas and oil installations and offshore wind farms was also included. The assessment therefore modelled several types of spills: spills from ships colliding with platforms or renewable energy installations, spills from platforms resulting from collisions with ships and spills from oil platforms from other damage. For oil platforms, risk calculations were related to daily operations and to risks such as blowouts (noting the infrequent occurrence of these) with distinctions made between normal and high-pressure, high-temperature wells.

The ultimate results for risks of spills for 2011 and 2020 scenarios were then obtained by undertaking a further integrated analysis to take into account existing and intended risk reduction measures (RRMs) such as pilotage, surveillance, vessel traffic services (VTS), obligatory routing (TSS), emergency towing, etc. As the long-term aim was to identify the best measures to reduce these risks at a subregional level, the results were then presented for five subregions (Fig. 3): the

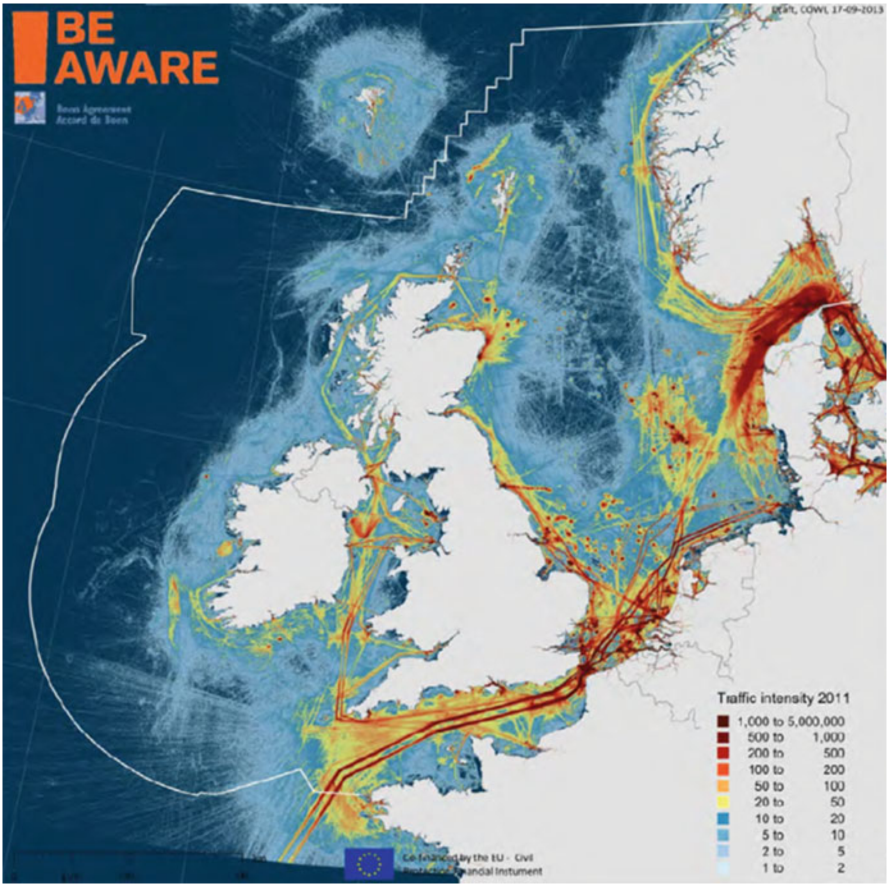

Fig. 2 Map of traffic intensity based on counted number of AIS records per cell. *Source*: BE-AWARE technical sub-report 1: ship traffic (http://beaware.bonnagreement.org/final-report)

Atlantic, the Northern North Sea, the Eastern North Sea, the Southern North Sea and the Channel.

3.1.1 Sensitivity Analysis and Vulnerability Mapping

In addition to the above modelling work, BE-AWARE prepared the ground for later projects developing a simple, qualitative and commonly acceptable environmental and socioeconomic sensitivity analysis methodology. This was done via expert workshops and resulted in a BE-AWARE Environmental and Socioeconomic Sensitivity Mapping approach. The common sensitivity mapping approach contained three distinct steps.

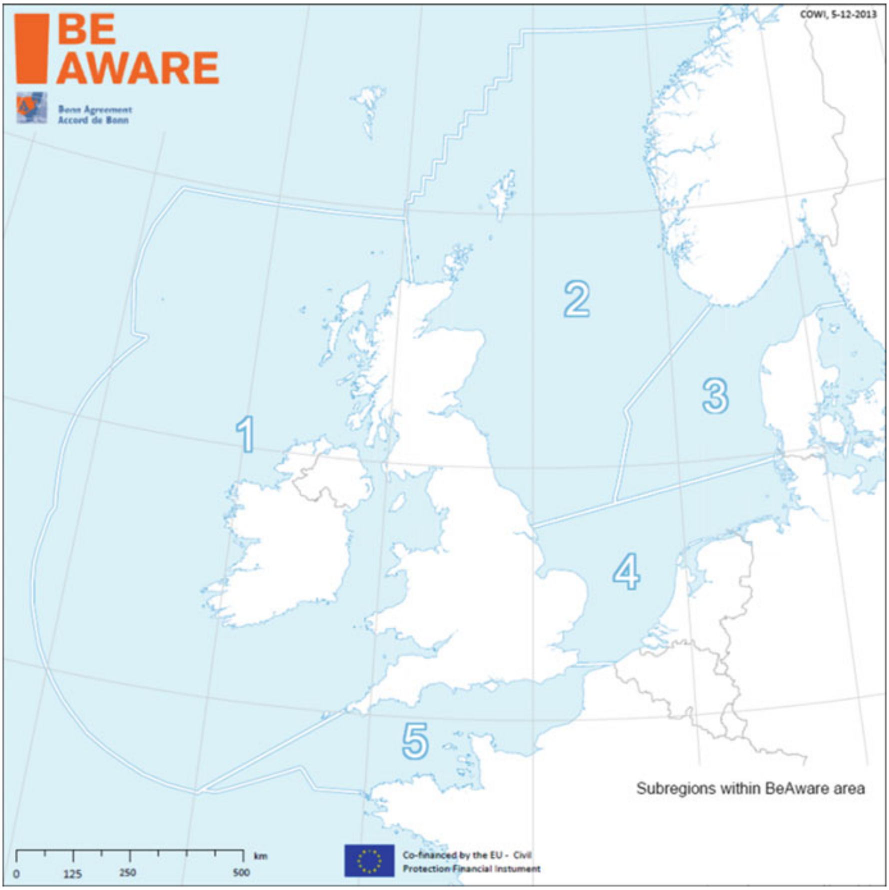

Fig. 3 Subdivision of the area. *Reference*: BONN BE-AWARE project 1. Final reporting (http://beaware.bonnagreement.org/final-report)

3.1.2 Quantitative Analysis of Oil Spill Risk

The main output of the project was the result of the quantitative analysis of oil spill risk, which showed significant regional differences. Within each of the BE-AWARE subregions, the frequency of different accident types was calculated for both the existing situation, 2011 (Fig. 4), and the future 2020 scenario. The frequency for individual spill sizes was also calculated.

In the results, significant regional differences were seen. Accidents caused by collisions were predicted to be most pronounced in areas with high intensity traffic, in combination with narrow straits or areas with crossing traffic or complex traffic patterns. These significant regional differences also showed in the risk of spills, which is presented in Fig. 4 for 2011. In the northern part of the North Sea, there

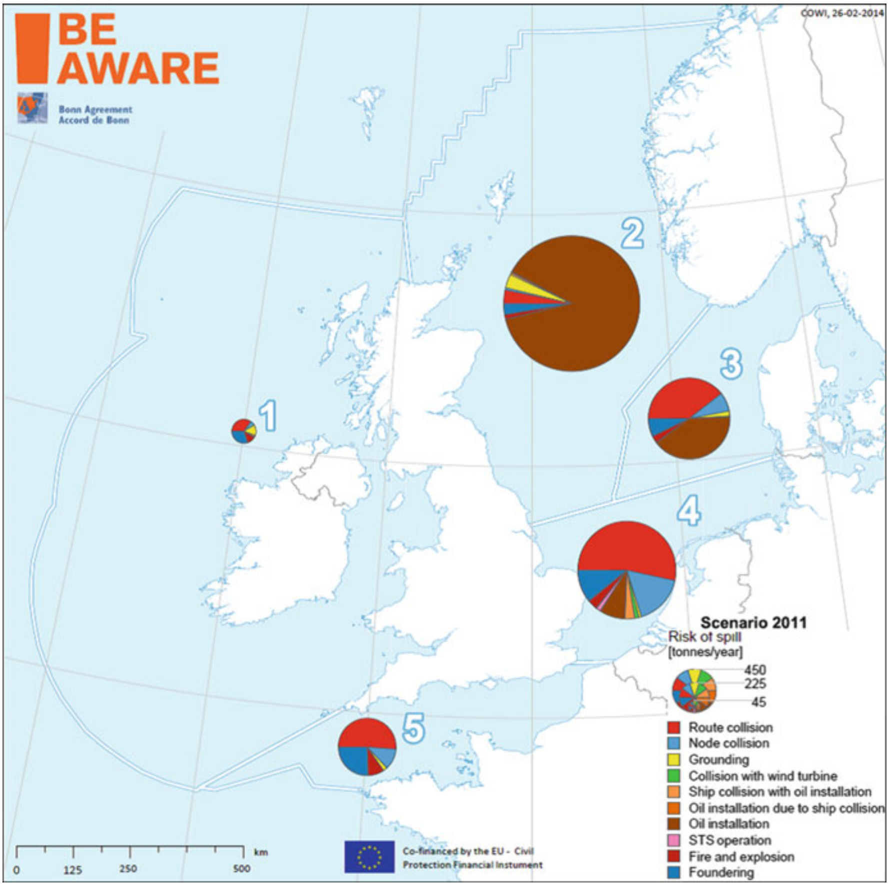

Fig. 4 Relative risk of all spills for the different BE-AWARE subregions in tonnes per year for the 2011 scenario. *Source*: BE-AWARE summary report (http://beaware.bonnagreement.org/final-report)

was limited traffic over a very large area, hence reducing the probability of ship-ship collisions. However, due to the presence of a substantial number of oil platforms, the risks of spills from the platforms were the largest contributors in this area. In high-traffic areas such as along the coast of the Netherlands, Belgium and Germany, the ship-ship collision risks became much more pronounced and constitute the largest contribution to the overall picture.

There were also significant differences overall and on a regional level between the 2011 and the 2020 scenarios. These were related to the changes in the levels of traffic, the development in ship size, the development in risk-reducing measures and the increase in new uses of maritime space. In particular an increased risk was predicted from collisions with wind turbines due to the development of new offshore wind farms to meet renewable targets. These changes were most notable in the Channel and Southern and Eastern North Sea.

Whilst large spills can come from offshore installations, overall, the largest contributor of spills was the outflow of liquid cargo as a result of collisions involving large tankers. Minor and medium-sized spills were typically from accidents where the vessels had only sustained minor damage. Groundings mainly contributed to the risk of minor and medium-sized spills.

3.1.3 Qualitative Analysis of HNS Spill Risk

Another key pollution risk in the Greater North Sea is spills of hazardous and noxious substances (HNS). The project produced a qualitative analysis of this risk. This was because less information was available on the more diverse and complex HNS shipping activity, combined with very different outcomes from spills of different substances into the sea. The analysis focused on categorising the different hazards posed by the substances in terms of how they react when released in an accident, their risk to public health and their risk to the environment. It was nevertheless recognised that there were shortcomings with the modelling, particularly that more local trade patterns of HNS were not captured by the analysis.

The results showed the spread of risk for HNS between those substances carried in bulk and those packed in containers as packed goods. This highlighted that higher levels than expected of HNS are transported as packed goods:

- From the ten collisions that occur every year in the Bonn Agreement area, one collision would involve a vessel that carried substances classified as IMDG 1-9. Approximately 2,200 tonnes of HNS would be involved in the collision.
- Approximately 0.3 collisions (once in 3 years) would include a chemical tanker of class I or II. Per year, approximately 3,000 tonnes of HNS would be involved in a collision.
- Approximately 0.1 collisions (once in 10 years) would include a vessel that carried substances from the Top 20 ARCOPOL (The Atlantic Regions' Coastal Pollution Response) list (http://www.arcopol.eu/p_proyecto.aspx). Per year, approximately 90 tonnes of ARCOPOL HNS would be involved.

For HNS transported as packed goods, the following was concluded:

- It was estimated that there would be 0.8 collisions per year that involved a vessel with HNS on board.
- The total amount of HNS involved in a collision would be 843 tonnes per year, which would include four different HNS shipments.

3.2 Conclusions

In order to undertake the BE-AWARE risk analysis, a significant amount of data was required as input to the models. This data collection was a major challenge for

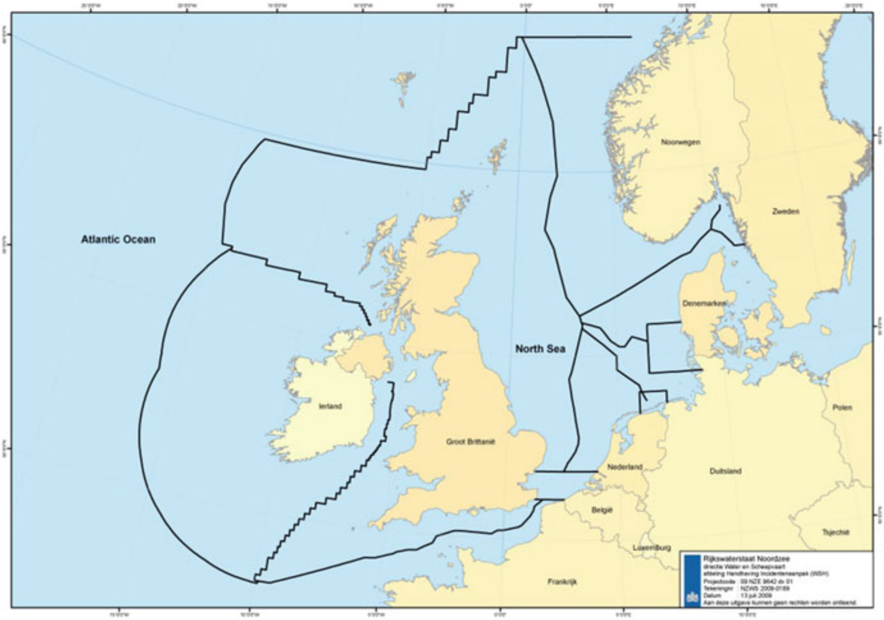

Fig. 5 The wider North Sea and its approaches. *Reference*: www.bonnagreement.org

the project. In future projects better data, for instance, from satellite AIS could give better results and more detailed cargo information from more ports would also be desirable. In this project nevertheless, the data received was relatively sufficient to be able to undertake the analysis with sufficiently reliable results.

The BE-AWARE project successfully modified established models to apply them to the Greater North Sea and its wider approaches (Fig. 5). The inclusion of risk from the offshore oil and gas industry and the expected increase in numbers of offshore wind farms provided useful insight into key risks from spills in the different subregions and the change in risk towards 2020.

The project identified that, overall, the main risk for oil pollution was due to collisions involving ships. Generally the largest contributor to oil spills was the outflow of cargo as a result of collisions involving large tankers, even if the risk frequency for this type of event was very low. Minor and medium-sized spills were typically from accidents where the vessels had only sustained minor damage or had been grounded. The frequency of collision accidents was mainly spread along the areas of the North Sea with the highest amount of traffic: the Channel and the Southern and Eastern North Sea.

For the qualitative risk of HNS, the analysis focused on categorising the different hazards posed by the substances in terms of how they react when released in an accident, their risk to public health and their risk to the environment. The analysis again indicated that the main risks existed in the regions with the highest shipping density.

4 Marine Pollution Offences

4.1 Development of the North Sea Manual on Maritime Oil Pollution Offences

The best of legislation will have no impact on the real world unless it is implemented and enforced. Because of this there is still much room for improvement in the implementation and enforcement of MARPOL (http://www.imo.org/OurWork/Environment/PollutionPrevention/SpecialAreasUnderMARPOL/Pages/Default.aspx).

At the third International Conference on the Protection of the North Sea in The Hague in 1990 [5], the Ministers and EC Commissioner decided that common actions should be taken at national and international levels in order to improve the effectiveness of prosecution for violations of the international rules and standards established by MARPOL and the associated collection of evidence.

As a first step, the Ministers invited the contracting parties to the Bonn Agreement to produce a manual explaining the systems of airborne surveillance and other methods used for identifying offenders and for obtaining evidence. The manual 'Oil Pollution At Sea – Securing Evidence on Discharges from Ships' was published in 1993 by the Bonn Agreement and was disseminated worldwide through the International Maritime Organization. The manual was addressed to authorities in charge of detecting violations, police officers, prosecutors, defence lawyers and courts in order to explain how evidence can be gathered and to indicate the reliability of the methods used. It was intended to facilitate the common understanding of the methods used for those who are not familiar with the technicalities.

The manual has been further developed and today is the *North Sea Manual on Maritime Oil Pollution Offences* which is regularly updated [6]. The intention behind the manual is to assist in this process in the North Sea area the waters covered by the Bonn Agreement (Fig. 5).

(Information at: www.bonnagreement.org)

4.2 Purpose of the Manual

The manual is addressed, in the first place, to the national enforcement agencies concerned with implementing international rules and standards against oil pollution from ships and the national legislation applying them. This refers to the so-called operational discharges also known as MARPOL violations. Daily operations on board vessels may lead to discharges of water containing waste oil particles and in that respect differ from the accidental spills. To achieve their purpose, this legislation must be effectively enforced. It is therefore essential that ships which contravene the legislation by illegally discharging materials are detected, prosecuted and convicted. Shipping is an international business and the North Sea area covers some of the busiest shipping routes in the world. A pollution incident may affect more than one country. For example, a vessel may discharge an illegal quantity of oil in the exclusive economic zone (or equivalent area of jurisdiction) of one state whilst en route between ports in two other countries. Cooperation between neighbouring states is therefore essential, and effective cooperation requires a common understanding of what is involved.

The manual therefore aims to set out a common understanding of the impacts of oil pollution, how evidence of maritime pollution offences can be gathered and the reliability of the methods used.

The manual is also addressed to those involved in the processes of bringing offenders to justice prosecutors, defence lawyers and magistrates and judges. For them, it is intended to provide an internationally agreed statement of the significance of maritime oil pollution offences and of good practice in assembling, presenting and evaluating evidence on such offences. Since violations of the regulations on maritime pollution offences can cause serious environmental damage and lead to heavy costs for combating the oil spills and clearing up the damage, it is essential that appropriate action is taken against the violators and the manual is intended to support such action.

4.3 Chapters in the Manual

The manual [6] is an extensive document which covers a large area related to Maritime Oil Pollution Offences. Chapters of the Manual include:

Chapter 2: Oil Pollution and Its Significance

This chapter provides general information on oil spills, their behaviour and effects, including an explanation of the weathering process. It also outlines the operational strategy for dealing with oil pollution at sea and on the coasts.

Chapter 3: International Law

The chapter sets out the framework within which regional and national arrangements must work. This chapter is subdivided into two main parts. The first part deals with the equipment and discharge regulations in MARPOL. The second part gives an overview of the legal instruments for cooperation in the field of prosecuting illegal maritime pollution.

Draft Chapter 5: Gathering and Presenting Evidence

The chapter describes the variety of issues that should be brought as possible evidence of a violation of MARPOL. This would concern sensor data and imagery but also oral communication transcripts. All the different information is to be presented in the legal formal way to be admissible as evidence to court.

Chapter 6: Visual Observation

This chapter deals with direct visual observation as one of the most effective ways of recognising and assessing an oil spill exceeding the legal limits of MARPOL. The approximate volume of the oil contaminating a sea area can be estimated by assessing the coverage and observing the appearance and colour of the oil.

Chapter 7: Remote Sensing

This chapter deals with airborne remote sensing systems, which are an efficient means of detecting discharges of oil at sea and supplying information for use as evidence. The data collected from all sensors is stored and can be examined either in flight or after landing. Also, stills or frozen images and conventional high-resolution photographic prints annotated with date, time, position and other mission data can be stored or transferred to the ground via an image link.

Chapter 8: Modelling the Behaviour of Spilt Oil

It is possible, using a computer, to run a mathematical model of the behaviour of spilt oil, the direction and speed at which it moves and the way in which it spreads and changes its properties. It is also possible to use these techniques to follow a spillage back to the geographical area whence it originated.

Chapter 9: Sampling and Analysis

When there is doubt as to whether the observation on the sea surface corresponds to oil, sampling of polluted water is one way to remove the doubt. When traces of the oil discharged remain on board the suspected ship, comparisons of samples of oil taken on board the ship and in the spill or contaminated area may assist in the identification. There are several techniques for such comparisons. Combined gas chromatography and mass spectrometry techniques (GC/MS) are one system currently in use. It can provide a very detailed pattern which is characteristic of the oil analysed, a 'fingerprint'. This is discussed further in the chapter by Dahlmann and Kienhuis [7] in this volume.

Chapter 10: Vessel Identification

Automatic identification systems (AIS) for vessels enable both shore-based and airborne observers and other vessels to identify vessels automatically. This has particular uses in linking observed oil slicks to the relevant vessels.

5 Surveillance

5.1 Zones of Responsibility (Control Zones)

For the purpose of the agreement, the North Sea area is divided into zones of responsibility (or control zones), of which the borders are the same as the exclusive economic zones (EEZs). These zones, together with continental shelf boundaries, are indicated on the map on Article 6 of the agreement stating that if the sea in the zone of responsibility of one of the coastal states is polluted or threatened by pollution, by oil or other harmful substances, and there is serious danger to the interests of one or more contracting parties, that coastal state shall make the necessary assessments of the state of the casualty or of the type, quantity and behaviour of the pollution [8].

Article 6A further provides that surveillance shall be carried out, as appropriate, by the contracting parties in their zones of responsibility or joint responsibility and that contracting parties may make agreements or arrangements for cooperation in the organisation of such surveillance. A number of such arrangements and agreements are in force.

The responsible country shall then immediately inform all the other contracting parties through their competent authorities of its assessment and of any action taken.

In the revision of the Bonn Agreement for the accession of Ireland, contracting parties agreed to make the zones of responsibility coincide with the boundaries of the EEZ or equivalent.

5.2 *Purpose of Surveillance Flights*

The purpose of surveillance flights (Fig. 6) is to routinely monitor the defined sea area and in doing so to detect, investigate, gather evidence and monitor spillage of oil and other harmful substances, whether the spillage is a result of an accident or caused deliberately in contravention of international conventions. The threat posed to the environment and coastlines of the North Sea will dictate the degree of

Fig. 6 A surveillance aircraft

investigation and monitoring carried out. Routine patrolling for the detection of violations also supports the preparation for accidental spills with large volumes of oil.

Bonn Agreement participants have been instrumental in exploring collaborative aerial surveillance and reporting procedures to enhance operational efficiency. There is a free exchange of information on the development of remote sensing and other surveillance systems. The aim of cooperation between Bonn Agreement participants is to ensure balanced surveillance coverage of the North Sea. The purposes of aerial surveillance are also to deter potential polluters from spilling, to detect and track possible spills and, in some cases, to catch polluters red-handed by combined use of aircraft and satellite.

Satellite images are used for surveillance aircraft mission planning and statistics. Through the European Cooperation programme, chaired by EMSA, the CleanSeaNet (http://emsa.europa.eu/operations/cleanseanet.html), all satellite imagery (footprints) can be made available to the member states. Again in Bonn Agreement neighbouring countries explore ways to make efficient use of assets for the validation of satellite detections of possible slicks.

5.3 Flight Types

Various flight types have been developed under the auspices of the Bonn Agreement. These have been defined by the Working Group on Operational, Technical and Scientific Questions Concerning Counter Pollution Activities (OTSOPA working group) as follows:

- *National flights*. Flights conducted by an individual country to cover its zone (EEZ).
- *Regional flights*. Flights conducted under bilateral or multilateral agreements between participating countries for the coordination of surveillance and/or assistance in areas of mutual interest.
- *Tour de Horizon flights*. Flights conducted primarily to monitor the oil and gas industries in the North Sea. However, all pollution will be investigated and reported, whether from installations or ships.
- *CEPCO flights*. A Coordinated Extended Pollution Control Operation (CEPCO) can be defined as a continuous sequence of aerial surveillance flights if possible supported by seaborne law enforcement assistance to ensure a permanent presence over a minimum of 24 h in an area with a high likelihood of illegal or operational discharges of oil and/or other harmful noxious substances. CEPCO comes in various concepts. See Part 2, Chapter 3.
- *Aerial surveillance exercise flights*. Flights conducted against known targets to check remote sensing systems and procedures.

5.3.1 National Flights

All contracting parties plan national programmes to conduct aerial surveillance over their individual zones of responsibility or (part) of their exclusive economic zone. These schedules need not be coordinated with neighbouring states.

Reports on spillages detected are normally made to national administrative authorities only. An annual overview on performed flight hours and detected and observed pollution is reported to the Bonn Agreement, OTSOPA working group.

For statistical purposes, navigation points (way points) and/or flight tracks normally remain in force for a number of years.

In case of a detection of pollution in the zone of the neighbouring contracting party, close to the border between the two member states, the observing crew will report the pollution to the authorities of the other state.

5.3.2 Regional Flights

Bilateral and multilateral agreements between contracting parties have been established for mutual assistance in response operations and in aerial surveillance. Examples are the agreements between Denmark, Germany and the Netherlands (DenGerNeth plan) and Norway/United Kingdom (NORBRITPLAN). At the time of writing, these plans were not available online but will be made available through a planned update to the Bonn Agreement website. Such agreements may make more effective use of available resources. Close cooperation in aerial surveillance will require the careful coordination of flight programming and planning. National navigation points are normally utilised during regional flights. However, a few mutual navigation points have been established. For example, there are some joint German/Netherlands navigation points.

5.3.3 Tour de Horizon Flights

Contracting parties have adopted a plan for all coastal states to conduct both periodic and random surveillance flights for the detection of spillages in the offshore oil and gas industry areas in the North Sea. Irrespective of the main aim, all other suspected polluters are also to be identified and reported.

The programme for Tour de Horizon flights is prepared by the lead country for discussion and agreement by the OTSOPA meeting.

5.3.4 Coordinated Extended Pollution Control Operation (CEPCO)

The contracting parties have agreed a programme of Coordinated Extended Pollution Control Operation (CEPCO). Two regional CEPCOs, one in the north and one in the south, are programmed every year. Those contracting parties in the region will normally take part; however, a general invitation to participate is sent to all contracting parties.

The aim of the operation is to enhance the enforcement of discharge provisions at sea, to optimise prosecution of illegal offenders and to increase the deterrent effect of aerial surveillance activities.

In the OTSOPA meeting, parties may decide to organise a Super CEPCO surveillance period that will last up to 10 days and will cover a specific, extensive, sea area. Additional CEPCOs may be organised by neighbouring countries, on a voluntary basis, covering a limited sea area which is continuously overflown for 24 h or more. During these CEPCOs, participating aircraft will use their normal national operating airports. Detailed guidelines have been agreed for CEPCO missions.

5.3.5 Aerial Surveillance Exercise

Contracting parties agreed to increase cooperation by participating in counter-pollution exercises, and each agreed to collaborate to the best of their abilities. One such exercise is the Aerial Surveillance Exercise. The exercise consists of field trials and a 'workshop' to compare results and exchange operational and technical experience and information to further the development and improvement of remote sensing techniques and procedures.

The organising country is required to set up suitable trials to test remote sensing systems and aircrews and to provide all participants with the opportunity to compare results and experience. Participants collaborate to the best of their ability and provide all collected comparison data to the organising country, which presents a full report to the following OTSOPA working group meeting.

The organising country drafts a report to all participants, and a final report, including the results of the evaluation meeting, is submitted to OTSOPA.

Bonn contracting parties have established a Research, Trial and Training Group with the task to coordinate national exercises and trials for Bonn Agreement contracting parties to participate. The objective of the group is to use every opportunity for concerted action, especially when real mineral oil is released into the marine environment.

5.3.6 National Navigation Points

Participants, with the exception of the United Kingdom, have established navigation points in their zones for the purpose of national flights. Aircraft of other nations may use the same navigation points. This has the benefit of relating observed pollution to specific points for reporting purposes.

Any changes in navigational points are to be notified to the lead country for aerial surveillance so that the Aerial Operations Handbook may be updated.

5.4 *Reporting from Surveillance Flights*

A surveillance aircraft overflying the North Sea area in its national zone of responsibility may detect and observe a possible violation of MARPOL regulations in the area of the adjacent country. The crew of the detecting aircraft will report an illegal discharge to the national focal point of the coastal state in whose zone of responsibility the violation was observed. The responsibility for initiating prosecution of the suspected polluter lies with another country having jurisdiction over that part of the continental shelf. In the case of an oil slick affecting the two countries, cooperation on response operation may be required, and the aircraft could be asked to stay in the area for further observations and guidance.

There is a standard reporting system within the Bonn Agreement for the reporting of detected pollution. All surveillance flights will be concluded with a standard report, which is forwarded to the responsible national authorities, other contracting parties as appropriate and to the lead country on a monthly basis for collation purposes.

5.4.1 Reporting to Responsible Authorities

During an operational surveillance flight, the system operators/observers will try to contact the appropriate focal point immediately by radio to report a detected pollution.

Completed Standard Pollution Reporting Log is to be forwarded to the national authority under whose responsibility a surveillance flight was performed. The responsible authority will compile the summary data in accordance with the standard reporting format for submission of the data, annually, to the Bonn Agreement Secretariat.

All relevant log sheets, data tapes, imagery, video tapes, photography and radio circuit recordings are made available to national administrative authorities as evidence in prosecution cases and can be made available to another contracting party if the prosecution is to take place within its jurisdiction.

5.5 *Surveillance Evidence: The Present*

Aircrew must continue to be guided by the unilaterally developed guidelines set by their own countries for the collection and handling of aerial surveillance evidence. There are, however, some basic principles, which seem to transcend the requirements of individual countries. These are as follows:

- It is paramount that full and proper evidence is collected against a suspected polluter who is detected or observed to be discharging oil or other harmful substance or ship-borne generated waste in contravention of international conventions (MARPOL).

- The observers have to act to the best of their abilities to provide the responsible authorities with reports and evidence using Standard Pollution Reporting Log
- Pollution Report on Polluters and Combatable Spills
- Side Looking Airborne Radar (SLAR)/Infrared (IR)/Ultraviolet (UV)/Forward Looking InfraRed (FLIR) imagery both in tape and hard copy form
- Photography
- Video tape
- Tape recording or transcript of any radio contact
- Signed official reports or statements
- Oil samples, in compliance with national legislation
- Any other type of data that could serve as a part of the evidence

- The official report should contain the essential information recorded on the Pollution Report Form on polluters, and it should cross refer to the imagery and photography hard copy annexed to the official report.
- Where systems with such facilities are fitted, imagery and photographic hard copy should bear data blocks giving date, time and position.
- Photographs should show clearly the name and registration of the suspected polluters as well as the pollution itself. It is important to show that the sea surface ahead of a suspected polluter is clear of pollution. Both oblique angle and downward looking photographs appear to be acceptable as evidence in court.
- There are countries, also Bonn Agreement members, with a judicial system requiring a sample, proving the detected/observed discharge consisted of mineral oil. Oil sample buoys have been developed that can be dropped from aircraft, provided permission is prearranged with civil aviation authorities. A vessel or a helicopter should be directed to the area to pick up the buoy, and then the instrument should be taken to the laboratory for sample analysis. The outcomes can be made available to the authorities initiating proceedings. However, in practice it is not easy to have the full logistics in place, and dropping the buoy successfully during darkness is a challenge. Some countries have experienced that the sampling is counterproductive.

6 Conclusions

Authorities of the coastal states around the North Sea area have since many years recognised the necessity to cooperate in avoiding pollution and if it occurs – in whatever way – take adequate response measures in a comprehensive procedure. Following international legislation, implemented in national law in order to secure effective prosecution, the industry working in the area is monitored. Shipping, offshore oil and gas, fishery, renewable energy parks and recreation may all be suspected of pollution violating international legislation.

The operational working group under the Bonn Agreement has developed different plans to also cooperate in the execution of the monitoring and response activities.

It is considered a major step forward that Bonn now has a common basis in the analysis of risks, through the BE-AWARE project.

At the same time it should be acknowledged that shipping industry in the past decades, also based on measures taken in the framework of the International Maritime Organization, has achieved to reduce pollution from vessels sailing the oceans. Technical improvements on board vessels (engine room management) and training of crew in environmental awareness contributed to less pollution.

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European Maritime Safety Agency *CleanSeaNet* Activities in the North Sea

Angela Carpenter

Abstract The transport of goods and people both within and from outside of the European Union (EU) depends heavily on its seas and oceans and the ports located on Europe's coasts. The European Maritime Safety Agency (EMSA) plays a significant role in monitoring and protecting those maritime regions of Europe from pollution and also in areas such as maritime safety and maritime security. Since its establishment in 2002, the role of EMSA has developed so that it offers a broad range of implementation and operational services to the European Commission and to EU Member States. The operational tasks of EMSA include providing a pollution prevention service, for example, and Earth Observation Services using satellite imagery. In particular, its *CleanSeaNet* (CSN) Service offers a European satellite-based oil spill and vessel detection service to help identify pollution entering the marine environment from ships in EU waters. This chapter provides an overview of the activities of EMSA in general and then considers in more detail the CSN Service. It examines data on satellite imagery for the period 2007–2011 for the North Sea region of Europe and identifies how those images have contributed to monitoring the region to identify oil inputs to the sea.

Keywords CleanSeaNet, European Maritime Safety Agency, North Sea, Oil pollution, Satellite monitoring

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Contents

1 Introduction

The seas, oceans and coastal regions of Europe provide a vital link in the transport of goods and people both within the European Union (EU) and globally (see Fig. 1). The EU's Member States have over 12,000 commercial ports and over 100,000 km of coastline between them [2]. Very large numbers of ships operate in EU waters and in 2008, for example, 22,752 merchant ships called into European ports and there were over 694,500 movements in ports by ships sailing in EU waters [2].

The European Maritime Safety Agency (EMSA) is the body which facilitates cooperation between EU Member States and the European Commission in a number of areas to monitor and protect Europe's marine environment and help maintain the safety and security of maritime traffic in the region.

This chapter presents an overview of the history of EMSA and its role in helping to protect Europe's maritime regions. It then briefly outlines some of EMSA's operational activities relating to maritime safety through its Vessel Reporting Service, Integrated Maritime Service and Pollution Response Service. Next it considers in more depth at the EMSA Earth Observation Service, particularly as it relates to marine environmental protection from oil pollution. The chapter then examines EMSA data on oil spills in the North Sea, based on satellite imagery from its *CleanSeaNet* (CSN) Service for the years 2007 to 2011. Finally, some conclusions are presented on the benefits that EMSA *CleanSeaNet* provides to monitoring oil pollution in the region.

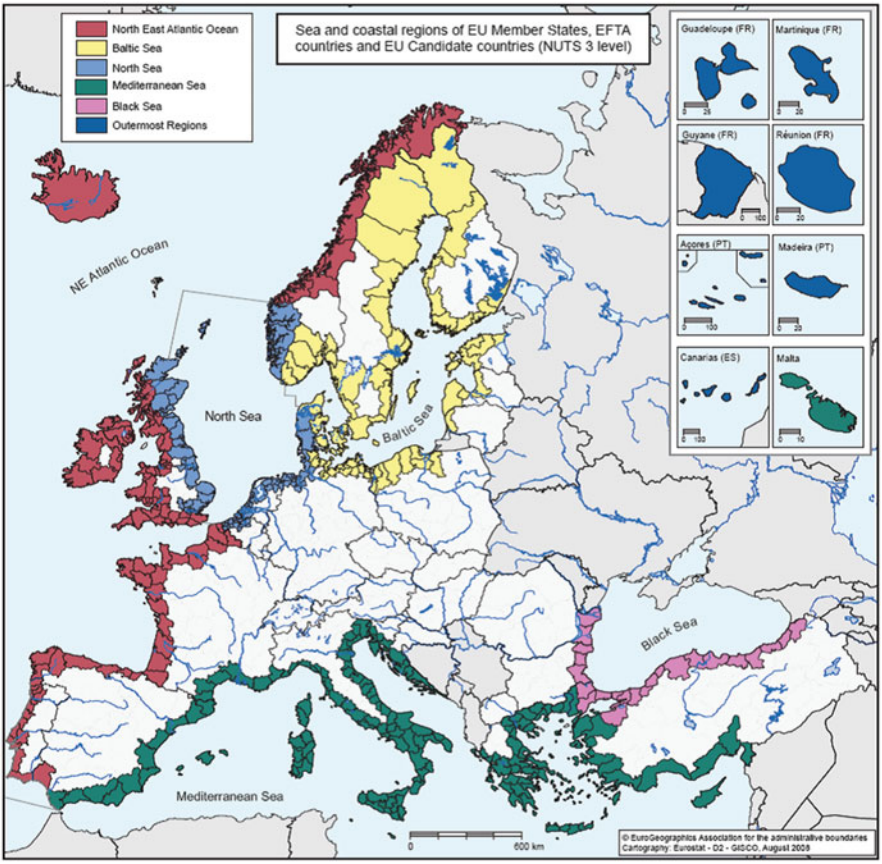

Fig. 1 Europe's Sea and Coastal Regions. *Source*: Eurostat (2009), Fig. 1 [1]

2 History of the European Maritime Safety Agency

The European Maritime Safety Agency (EMSA) is based in Lisbon. It was established following the sinking of the oil tanker *Erika* off the coast of France in December 1999. Following on from that sinking, the European Commission put forward two sets of measures relating to Europe's maritime safety policy. Within three months of the sinking, in March 2000, the Commission adopted its so-called *Erika I* measures through a Communication on the Safety of the Seaborne Oil Trade (COM (2000) 142 final) [3]. That communication included proposals for measures on international standards for ship safety and pollution prevention and a proposal for a Regulation (No. 417/2002) on accelerated phasing-in of double-hulled oil tankers. That Regulation entered into force in February 2002 [4].

In December 2000, the Commission set out a second set of measures on maritime safety, in a Commission Communication known as *Erika II* measures

[5]. That communication (COM (2000) 802 final) set out a Proposal for a Directive on Community monitoring, control and information systems for maritime traffic; a Proposal for a Regulation establishing a compensation fund for oil pollution damage; and, in relation to this chapter, a Proposal for a Regulation establishing a European Maritime Safety Agency. The objective of the proposed Regulation was to establish a specialised agency, able to provide Member States and the Commission with the necessary technical and scientific support to properly apply community legislation relating to maritime safety and also able to monitor implementation of that legislation and assess its effectiveness [5].

EMSA was subsequently established in 2002 under Regional (EC) No. 1406/2002 of the European Parliament and of the European Council [6]. Article 1 of that regulation sets out the main purpose of EMSA as being to ensure uniform and effective maritime safety and prevention of pollution from ships operating in EU waters. In order to do so, Article 2 identified that EMSA was to provide objective, reliable and comparable information and data so that Member States could take steps to improve both maritime safety and prevent marine pollution.

2.1 EMSA Structure

EMSA is managed by an Executive Director whose duties and powers are defined in Article 15 of its establishing Regulation [6]. Those duties include preparation of the EMSA work programme which, after consultation with the European Commission, is submitted to the Administrative Board. Once that work programme is agreed, the Executive Director is responsible for ensuring that all its requirements are properly carried out and will report annually to the Administrative Board on the work of EMSA.

The Administrative Board of EMSA is led by a Chairperson, selected from among the membership of the Board. That membership is made up of one representative from each of the 28 EU Member States, 4 representatives from the European Commission, 4 non-voting members who are independent professionals in different sectors of the maritime industry with experience of maritime safety and pollution prevention and 2 non-voting members from Iceland and Norway. The Administrative Board works under a set of Rules of Procedure [7] and supervises the work undertaken by the Agency and the Executive Director. In particular, the Administrative Board adopts the Agency's Work Programme, budget and establishment plans.

The Executive Director is supported by three Heads of Department, a policy advisor, together with communications, accounting and auditing functions. EMSA has 9 units, under 3 departments: Department A, Corporate Services; Department B, Safety and Standards, which covers visits and inspections, ship safety, marine environment and port state control; and Department C, Operations. Department C is responsible for the 4 EMSA Operational Tasks discussed in this chapter, i.e. its integrated maritime, vessel reporting, earth observation and Pollution Response Services.

2.2 The Developing Role of EMSA

In recognition that about 20% of global discharges of wastes and residues to the sea come from shipping, the EU, during the late 1990s, developed a Directive on Port Reception Facilities for ship-generated waste and cargo residues (published in 2000 as Directive 2000/59/EC, PRF Directive) [8]. That Directive, which entered into force in December 2002, required ports in the EU to put in place adequate reception facilities in order to reduce the discharges of ship-generated waste into the sea, especially illegal discharges from ships using EU ports [9]. A large number of EU ports located in the North Sea region already had port reception facilities in place [10], in order to meet the requirements under various Annexes of the MARPOL Convention [11].

One of the earliest responsibilities of EMSA was to assist the European Commission and Member States by establishing appropriate information and monitoring systems to identify ships that did not deliver their waste according to the PRF Directive, monitoring operational implementation of the Directive, assessing systems applied in Member States and proposing common criteria for a harmonised EU approach [12]. This role is still ongoing as one of the EMSA Implementation Tasks relating to the marine environment.

Among its Implementation Tasks, EMSA has a role in accident investigation relating to marine casualties and incidents. That includes casualties involving ships such as capsizing, collisions, groundings and strandings and fire or explosions, for example. It also covers occupational accidents relating to injuries or loss of life of crewmembers, for example.

Other Implementation Tasks of EMSA include monitoring the functioning of port state control operations in EU ports (PSC, see Sect. 3.2) under which ships sailing in EU waters and entering its ports are inspected against a range of international standards. EMSA also runs training sessions and workshops and produced training material in areas including maritime surveillance, marine accident investigation and oil pollution response exercises.

EMSA also has a range of Operational Tasks and these are discussed in Sects. 3 and 4 of this chapter.

3 EMSA Operational Tasks

EMSA has a range of Operational Tasks[1] under the headings of Vessel Reporting Services, Earth Observation Services, Integrated Maritime Services and Pollution Response Services. This section provides an overview of three of these operational tasks, the Vessel Reporting, Integrated Maritime and Pollution Response Services.

[1] For further information on all of the Operational Tasks of EMSA, see http://emsa.europa.eu/operations.html

The activities conducted by EMSA under its Earth Observation Services are discussed in greater detail in Sect. 4.

3.1 Vessel Reporting Service

One of the operational tasks of EMSA is vessel reporting, and as part of that task, ship movements are monitored under SafeSeaNet (SSN), a network for maritime data exchange across Europe (all EU Member States, Norway and Iceland). SSN uses automatic identification systems (AIS, a maritime broadcast system, based on the transmission of very-high-frequency radio signals) to track ship movements. It also provides information on ship type, course, speed and destination, together with information on hazardous cargoes being carried by a ship. This contributes to the enhanced safety and efficiency of maritime traffic, helps reduce accidents or potentially dangerous incidents and can assist with search and rescue activities in Europe's seas and coastal waters. The position of around 17,000 vessels can be located in near real time using AIS which transmits a signal from a ship to the various maritime authorities of the EU (see Fig. 2).

As part of its Vessel Reporting Service, EMSA also facilitates the long-range tracking of vessels, outside the range of coastal AIS systems, through its Long-

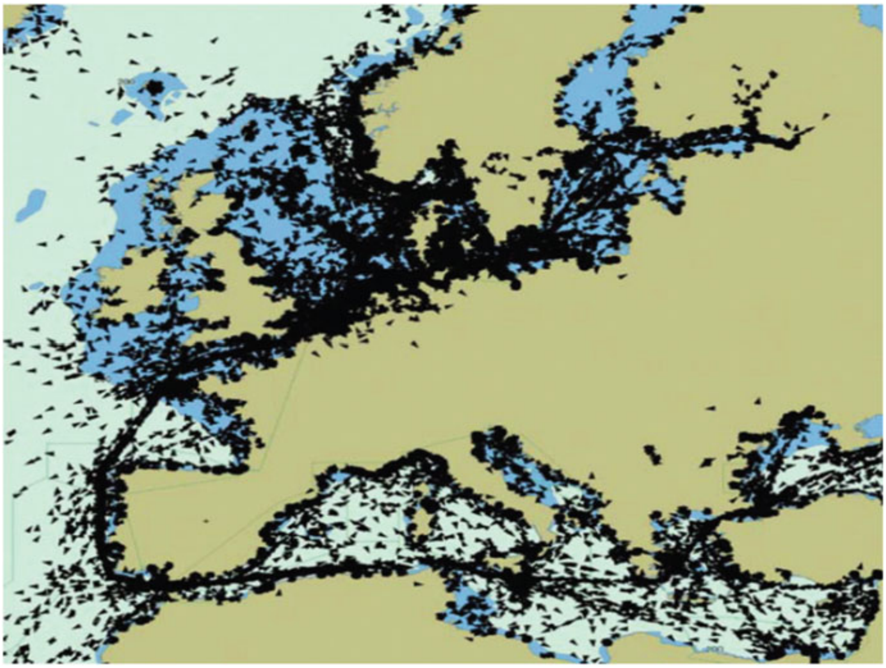

Fig. 2 SSN Vessel Tracking Screenshot. *Source*: EMSA (2011) [13]

Range Identification and Tracking System (LRIT). This is a mandatory international system which can track ships around the world.

3.2 Integrated Maritime Services

The European Commission's Integrated Maritime Policy (IMP) set out the need for greater cooperation in policy development and decision making relating to how Europe relates to the seas around it [14]. As a result, it identified a number of areas where action should be taken to develop a coherent policy framework. Those areas included a European Maritime Transport Space, a European network for maritime surveillance and the reduction of CO_2 emissions and pollution by shipping, for example.

EMSA offers a number of services to support the IMP through vessel traffic reporting under SSN and LRIT and satellite monitoring under *CleanSeaNet* (CSN, see Sect. 4) and via port state control through its Hybrid European Targeting and Inspection System (Thetis), an information system supporting measures for ships to be inspected in ports.[2]

Specific operational activities conducted under the Integrated Maritime Service function of EMSA include traffic monitoring, search and rescue, pollution monitoring, maritime border control, anti-piracy, fisheries monitoring and antidrug trafficking [15].

3.3 Pollution Response Service

In relation to marine pollution preparedness and response, EMSA provides operational assistance and information to Member States through a number of different activities. EMSA has, for example, a network of over 20 stand-by oil spill response vessels and equipment located at various points on the European coastline (see Fig. 3), available to deal with oil recovery within 24 h of an accident [16]. Covering the northern North Sea are two vessels (product tankers) based in Sunderland (UK), each with oil detection systems and carrying sweeping arms, booms and skimmers for oil collection, together with oil storage capacity of over 5,000 m^3 on board. There are also two smaller vessels (hopper dredgers) based in Ostend (Belgium) covering the southern North Sea with similar equipment on board and storage capacity of just over 1,800 and 2,700 m^3, respectively.

[2] Ships are inspected under the aegis Paris Memorandum of Port State Control to ensure they meet relevant international standards for safety, crew training and pollution prevention measures, for example. Further information on the Paris MOU is available at https://www.parismou.org/

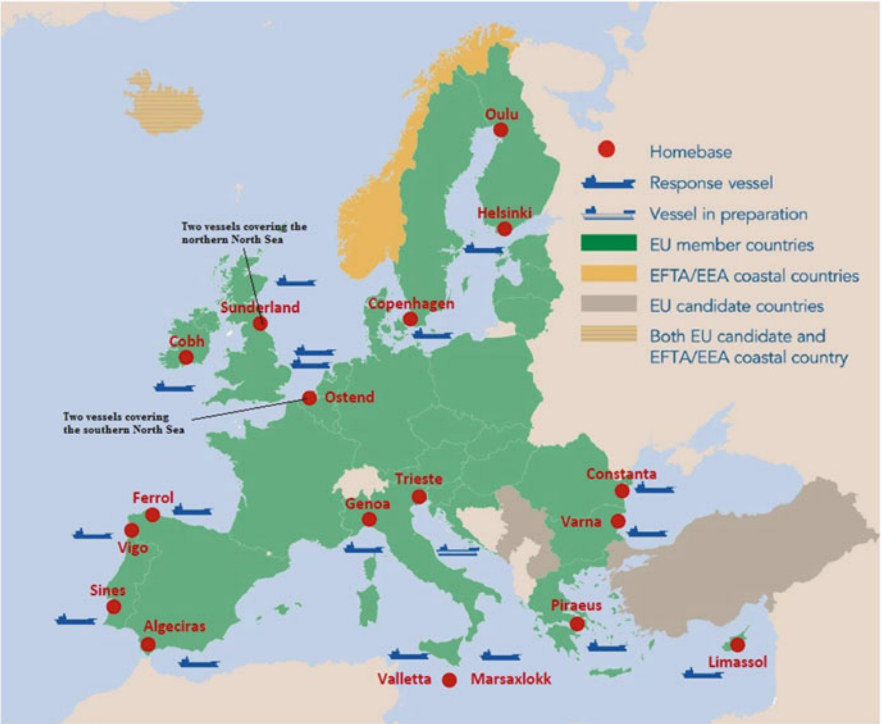

Fig. 3 Locations of EMSA Oil Spill Response Vessels and Equipment in 2014. *Source*: EMSA (2014), p. 7 [16]. *Note*: Map has been adapted to highlight the location of ships covering the North Sea

The EMSA Pollution Response Service uses CSN information to assist in responding to ship-source pollution (both oil pollution and hazardous and noxious substances). It has, since March 2013, also had a mandate to respond to marine pollution from oil and gas installations [17]. Information relating to chemical spills at sea is provided through the MAR-ICE (Marine Intervention in Chemical Emergencies) Information Service.

In relation to technical cooperation on pollution preparedness and response, EMSA also works with international bodies such as the International Maritime Organization (IMO) where it is part of the European Commission delegation to the IMO Marine Environment Protection Committee on Oil Pollution Preparedness, Response and Cooperation – Hazardous and Noxious Substances (MEPC OPRC/HNS) [18]. It also works with regional bodies including the Bonn Agreement (North Sea), Helsinki Commission (HELCOM, Baltic Sea), the Barcelona Convention (Mediterranean Sea) and the Bucharest Convention (Black Sea Commission) [18].

4 EMSA Earth Observation Services

4.1 Integrated Maritime Service Activities

The Earth Observation Service operational task of EMSA is divided into two components. One of these is Earth Observation for Integrated Maritime Services which includes aspects of vessel detection and target activity detection using high-resolution radar and optical satellite images. This uses a range of information sources to identify vessels that might be involved in illegal activities, and so it supports EU maritime border control activities under FRONTEX, a system under which the European Borders Agency monitors the EU's external borders, including its sea borders and seaports, and supports Member States in responding to the illegal trafficking of migrants, for example [19]. It also supports anti-piracy activities undertaken by EU Naval Forces (EU NAVFOR) in areas around the Horn of Africa, off the coast of Somalia and in the Indian Ocean, for example [20].

4.2 CleanSeaNet Service

CSN is the second element of the Earth Observation Service [21]. It is a European satellite-based oil spill and vessel detection service and fulfils the requirements of an EU Directive on ship-source pollution dated September 2005 (Directive 2005/35/EC) [22]. Article 10 of that Directive set out specific requirements for EMSA to work with Member States to develop technical solutions and provide technical assistance in areas including development of information systems for the effective implementation of the Directive, establishment of common practices and guidelines in areas such as monitoring and early identification of ships discharging polluting substances in violation of this Directive and reliable methods of tracing polluting substances in the sea to a particular ship [22]. This can assist relevant agencies in the identification, and potentially prosecution, of polluters.

A number of satellites and their on-board sensors provide wide-area surveillance across all EU maritime zones and can also be targeted to monitor specific locations or activities. CSN supplements existing surveillance systems nationally and regionally. In the North Sea, for example, this means CSN satellite data supports the activities of the Bonn Agreement Secretariat which undertakes aerial surveillance in the region and also makes use of satellite imagery to identify potential oil spills. Images are available from a number of national satellite programmes operated by Norway, Sweden and a tripartite programme between the UK, Germany and the Netherlands, for example. For further information on how CSN supports the Bonn Agreement and national agencies in monitoring oil pollution in the North Sea region, see Chapter X of this volume [23].

Across the EU, around 2,000 satellite images are analysed each year, and when a possible oil spill is detected, an alert is sent to the relevant country in whose waters it is located. Between 16 April 2007 and 31 January 2011, the CSN First Generation service was based on 3 polar orbiting SAR (synthetic aperture radar) satellites – the

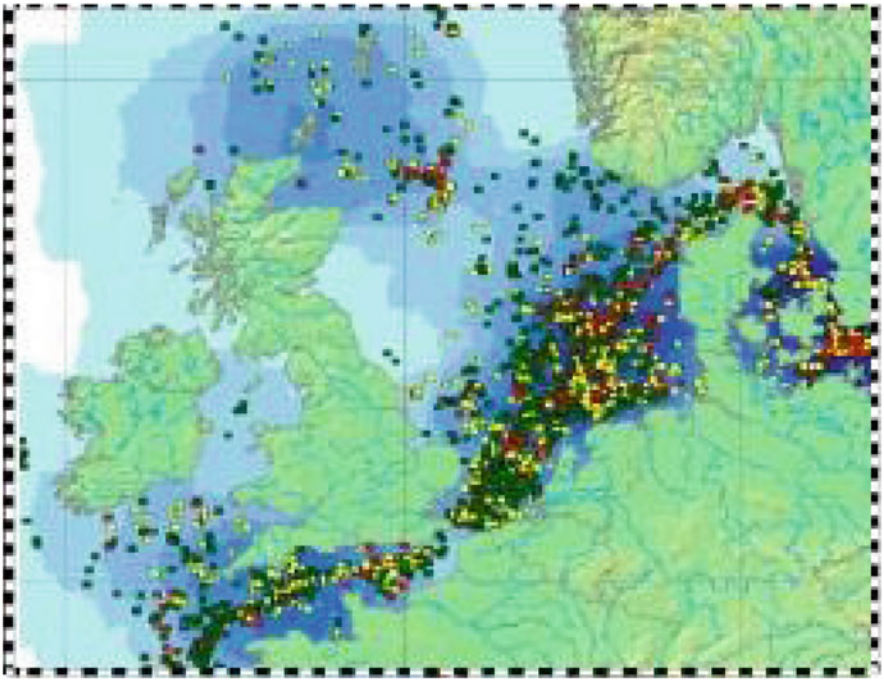

Fig. 4 Sea Area Coverage of EMSA CleanSeaNet for countries bordering the North Sea. This figure has been adapted to show the area bordered by North Sea states. For Norway, satellite images extend to the north of the country, into the Barents Sea, for example. For Germany and Denmark, coverage includes their sea areas in the Baltic Sea. *Source*: Adapted from EMSA (2011), p. 8 [25]

European Space Agency's ENVISAT and the Canadian Space Agency's RADARSAT's 1 and 2 [24]. During that period, across the whole of Europe, over 1,000 million km^2 of sea area was monitored and 8,866 possible spills were detected and reported by CSN. 2,828 possible spills were checked on site, 50% of which were checked within 3 h using aerial surveillance. 80% of spills (over 590 out of 745 spills) were confirmed as being mineral oil; the remaining 20% being confirmed as other substances [24].

The ENVISAT satellite was used until 8 April 2012; RADARSAT1 until 29 March 2013. After those dates there was no more ASAR (advanced synthetic aperture radar) or SAR data from those satellites. RADARSAT-2 satellite images continue to be used for northern European waters, in conjunction with Member States' own national satellite programmes. EMSA has also, since 2012, obtained some SAR images from the Italian Space Agency's COSMO-SkyMed (CSK) satellites. The use of CSK for routine pollution detection is limited as priority is given to providing images for defence purposes. CSK does, however, provide images for specific surveillance operations and supports response operations in case of accidental spills [24].

Figure 4 illustrates the CSN satellite coverage for the countries bordering the North Sea. There were 1–2 satellite images per month covering pale blue areas; more than 20 per month in the darkest blue areas. Green squares represent satellite detections, yellow are detections which were checked and red are confirmed detections.

5 5 EMSA CSN First Generation Data by North Sea State, 2007-2011

This section examines EMSA CSN First Generation data for North Sea states which covers the period 16 April 2007 to 31 January 2011. Table 1 identifies the number of satellite images acquired via CSN annually [25]

In the case of Denmark, Germany and Sweden, the number of acquisitions included images covering their Baltic Sea regions, while for Norway they also covered the north of the country, including the Barents Sea. For Norway, this means that the CSN data covered the areas of oil and gas production located in both the North Sea and Barents Sea (discussed in chapter of this volume [23]).

In Table 1, it should be noted that images ordered by neighbouring countries may have partially covered the area of another country and so counted towards the total of that other country, even though it did not request an image. For example, an image ordered by the UK may have partially covered the area of interest of the Netherlands and would therefore be included in the Netherlands total.

Table 2 shows the number of satellite detections by North Sea state for the period 16 April 2007 to 31 January 2011 and the average number of spills per image (figure in brackets).

For Denmark, satellite detections were distributed across its entire maritime area of interest, in both the North Sea and the Baltic Sea. Detections were checked and confirmed as spills across the entire maritime area [25, p. 20].

For Germany, a much large number of satellite detections were located in its North Sea area, far fewer in its Baltic Sea area, although satellite coverage (average number of images per month) was higher in its Baltic Sea area. Confirmed spills were located in both German maritime areas [25, p. 28].

Table 1 Annual number of image acquisitions for North Sea States, 16 April 2007–31 January 2011

	Year					
Country	2007	2008	2009	2010	2011	Totals by country: 16.04.07–31.01.11
Belgium	86	136	105	107	6	440
Denmark	320	621	581	594	65	2,181
Germany	273	497	485	544	56	1,855
Netherlands	197	334	264	281	35	1,111
Norway	85	383	373	333	44	1,218
Sweden	365	628	631	591	42	2,257
UK	343	590	508	582	55	2,078

Table 2 Annual number of satellite detections for North Sea States and average number per image, 16 April 2007–31 January 2011

Country	Year					Totals by country: 16.04.07–31.01.11
	2007	2008	2009	2010	2011	
Belgium	5 (0.06)	12 (0.09)	5 (0.05)	6 (0.06)	0	28
Denmark	62 (0.19)	131 (0.21)	92 (0.16)	86 (0.14)	1	372
Germany	59 (0.22)	117 (0.24)	61 (0.13)	50 (0.09)	2	289
Netherlands	80 (0.41)	189 (0.57)	121 (0.46)	109 (0.39)	2	501
Norway	13 (0.15)	82 (0.21)	39 (0.10)	23 (0.07)	1	158
Sweden	99 (0.27)	178 (0.28)	121 (0.19)	48 (0.08)	9	455
UK	142 (0.41)	241 (0.41)	185 (0.36)	136 (0.23)	14	718

Note: As the figures for 2011 are for 1 month only, no average number of detections per image is provided

For Norway, the majority of satellite detections were located to the south and to the north of the country. There were, however, areas along its western coastline where there was no satellite coverage. Very few detections were checked or confirmed as spills in Norwegian waters [25, p. 44].

For Sweden, there were many more satellite detections in its Baltic Sea area, of its south and east coasts, with far fewer in the North Sea of its western coast. For detections which were checked, all were in the Baltic Sea area where there level of satellite coverage (average number of images per month) was also higher [25, p. 56].

For the remaining North Sea states, detections covered only the North Sea. For the Belgian maritime area, there were few detections per satellite image annually (minimum 5; maximum 12) and only a single confirmed spill in 2010. The highest average number of detections per satellite image for the period between 2007 and 2010 were in the Dutch and UK areas of the North Sea.

Figure 5 illustrates the number of possible spills detected in the waters of Denmark, Germany, the Netherlands, Sweden and the UK in 2009. In that year, no spills were detected in the waters of Belgium or Norway. The highest number of satellite detections checked and verified by aerial surveillance within 3 h of detection that were confirmed as spills was in Danish waters at 80%. For the other North Sea states, the numbers confirmed as spills were in Germany, 36%; the Netherlands, 16%; Sweden, 30%; and the UK, 25%.

In 2010, there were 20 aircraft verifications within 3 h in Danish waters, and 7 of those verifications were confirmed as spills. For Germany, the figures were 19 verifications, of which 5 were confirmed spills; for the Netherlands, 20 verifications and 3 confirmed spills; and for Sweden, 2 verifications and 2 confirmed spills.

No specific data for the North Sea is available for the period from February 2011 onwards. However, in 2011, there were 2,141 detections across all EU waters (5.08 detections per 1,000 km^2). In 2012, there were 2069 detections (4.53 per 1,000 km^2), and in 2013, there were 2176 detections (3.89 per 1,000 km^2). This is a fall from 3,311 detections in EU waters in 2008 at a rate of 10.77 detections per

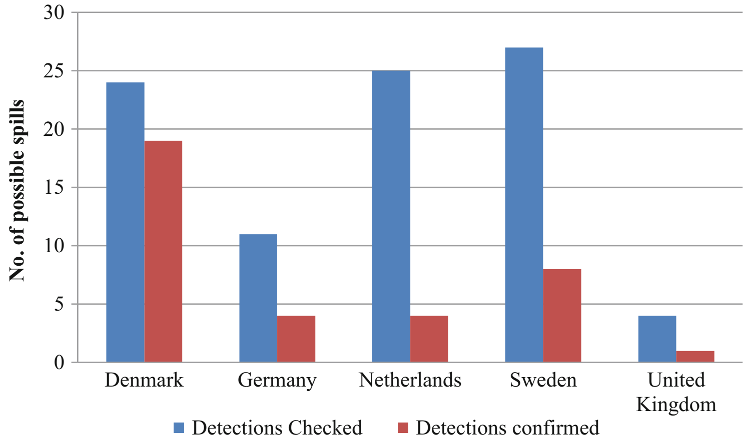

Fig. 5 Number of possible spills checked and confirmed by aircraft verification within 3 h, 2009

1,000 km^2, and it is clear that there has been a reduction in the number of possible spills detected from those figures [24, p. 44].

6 Conclusions

This chapter has presented an overview of the development of the European Maritime Safety Agency and its role in supporting the European Commission and EU Member States in areas such as maritime safety and security and more specifically marine environmental protection.

The EMSA CleanSeaNet Service, in conjunction with other services such as SafeSeaNet, plays a major role in helping detect pollution entering Europe's marine areas and in identifying the source of that pollution, for example. It also plays a role in providing an emergency response within 24 h to support efforts to clean up accidental oil spills at sea.

Satellite imagery is an important tool in identifying oil (and other) pollutants on the sea surface, and CSN images from EMSA support international and regional activities relating to pollution prevention. Those satellite images, in conjunction with images generated by national satellite programmes, monitor over 1 million km^2 of sea area across Europe.

Detailed information on the number of satellite images provided to North Sea states and the annual number of satellite detections is only available for the North Sea for a short period (April 2007–January 2011). However, in combination with more general data for the whole EU for the years 2008 to 2013, it is apparent that there has been a reduction in the number of spills, including confirmed oil spills, observed using satellite imagery, both in the North Sea and across the whole

EU. CSN therefore has an important role to play in the continued monitoring of Europe's seas to prevent illegal pollution from taking place.

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The Role of the International Maritime Organization in the Prevention of Illegal Oil Pollution from Ships: North Sea Special Status Area

Neil Bellefontaine and Tafsir Johansson

Abstract Principles and standards corresponding to the prevention and control of vessel-source marine pollution are one of the most amply regulated areas of public international law. Vessel-source pollution, or in more restricted terms illegal oil pollution from ships, is not a new phenomenon. Although there seems to exist far-reaching regulations governing compensation for natural resource injury consequential to an oil spill, the European Union (EU) has apparently advanced a rather controversial position on this subject. International Maritime Organization (IMO) acknowledges the rights of victims of illegal oil pollution and has marked out specific maritime zones of the world that are in need of special attention. The North Sea, as such, falls within the territory of respective states of the EU. Major maritime incidents including illegal discharges of oil by Flag States in the pristine waters of the North Sea have led EU to believe that injury to natural resources per se and their economic valuation as laid down by IMO is more contentious then the current reality. Hence, the Special Status Areas (SSA) of the North Sea are under the disarray influence of legal contradiction. The assessment of injury to natural resources embraces complex questions surrounding both the assessment of injury to natural resources and then the award of appropriate compensatory damages. To what length can IMO assess this damage and prescribe a successful indemnification through the tools of civil liability and compensation regime for a region that has always adopted unilateral measures has left a question mark on the role of IMO. This endeavors to discuss the role of IMO in terms of the North Sea SSA and seeks to examine both the civil liability and criminal liability regimes for injury to natural resources consequential to an illegal oil discharge under both international law and the EU regional law. In essence, the article investigates the adequacy of the

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international system in compensating for natural resource injury and compares this to the corresponding, more compensatory, EU Directive approach.

Keywords Civil liability, Criminal liability, Directive 2005/35/EC, International Maritime Organization, MARPOL 73/78, North Sea, Special Status Area

Contents

1 Introduction

The last century has witnessed the apparition of the oceans as an exhaustless reservoir of resources, ultimately traversed on and polluted by the increased commercialization of the world fleet. The international liability and compensation regimes corresponding to vessel-source pollution emanated from the notion of unwillingness and incapability of Flag States to institute elaborate domestic regimes for remedying of transboundary pollution damage, as well as in order to bridge gaps among various municipal legal systems. This also comprises generic legal rules on liability and redress, which are commonly developed on a national level. However, the problem of the inadequacy of such domestic regimes is particularly evident in the sphere of marine pollution given that almost 50% of the world maritime fleet is registered with the "flags of convenience" (FOC) countries [1]. Ships are usually registered under flags of convenience to reduce operating costs or avoid the regulations of the owner's country which many international actors have termed as "relaxed" environmental regulation and a more lenient system of fines and sanctions.

As a response to this "relaxed" system, international instruments of liability and compensation were instituted either in the form of a separate treaty or a supplementary element to an existing Multilateral Maritime Environmental Agreement (MMEA). The first of such international legal regimes that to date remains the only operative and successful ones are the 1969 International Convention on Civil Liability for Oil Pollution Damage [1969 CLC] and the 1971 International

Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage [1971 Fund Convention]. In this context, the Legal Committee of IMO has adopted amendments to raise by 50% the limits of compensation payable to victims of pollution by oil from oil tankers. While the Civil Liability Convention regulates the shipowner's liability, the fund is made up of contributions from oil importers. The principle is that if an accident at sea results in pollution damage which exceeds the compensation available under the Civil Liability Convention, the fund will be available to pay an additional amount. In this way, the combined regime established by the two treaties ensures that the burden of compensation is spread more evenly between shipowner and cargo interests. Although the Fund Convention was established under conventions adopted under the auspices of IMO, they are independent legal entities. The Civil Liability Convention was implemented with a deterrent objective that manifests civil liability and that compensation is available to persons who suffer oil pollution damage resulting from maritime casualties involving oil-carrying ships. The convention places the liability for such damage on the owner of the ship from which the polluting oil escaped or "was discharged," i.e., intentional or illegal oil pollution. Hence, illegal oil pollution from ships is a central focus of the civil liability regime of CLC.

Then again, from a more downright approach, IMO has developed an instrument that embodies technical and legal framework for operational oil pollution that is noteworthy for its idiosyncrasy. This, to a broader extent, covers illegal oil pollution and the North Sea and pertains to incorporate a prescriptive essence to "safeguarding North Sea environment" dimension. Adopted by IMO in 1973, the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 (MARPOL 73/78), consisted of a new and important feature of the 1973 convention which was the concept of "special areas" considered to be susceptible to pollution by oil. To that extent oil discharges within them have been completely prohibited, with minor and well-defined exceptions [2]. The IMO via MARPOL 73/78 has demonstrated its concern for the North Sea vulnerable areas and continues to assume its role as a "vanguard of the pristine." But problems arise when all of these efforts of IMO are undermined by regional laws stipulating "zero tollerance policy" for the same areas in respect to the North Sea. What has been termed as "strict" and "appropriate" by the EU Commission has resulted in a status quo complex legal scenario for the North Sea Special Status Areas where the international and regional laws are in a constant state of conflict. This also renders the EU Member States who are parties to relevant IMO Conventions in a state of perplexity.

Although accidental pollution by oil, when carried as cargo, is believed to be the most common pollutant originating from ships, there has been a dramatic decrease in oil pollution from tanker incidents since the 1970s which has been highlighted by the International Tanker Owner Pollution Federation Limited (ITOPF) [3]. Moreover, contrary to general perception, the greatest threat of ecological harm from vessels originates from operational discharges and in particular the illegal discharge of oil through routine operations. This is supported by evidence gathered from the report by the Organisation for Economic and Co-operation Development (OECD) that has indicated that "...illegal discharge of oil into the sea through routine operations is equal to over eight times the Exxon Valdez oil spill or over 48 times the 1997 Nakhodka spill off the coast of Japan – every year" [4]. Considering the veracity of this report, it can be lucidly concluded that the special areas of the North Sea are indeed at risk owing to the illegal oil discharges by commercial vessels of all type. Then again, oil pollution from vessels must also be distinguished from marine pollution caused by seabed activities and land-based sources. While "an ounce of prevention" is still worth "a pound of cure," this paper through comparative analysis between regional oil pollution legislation and the civil liability regime approved by the International Maritime Organization (IMO) highlights that the dominance of the latter is still preceded by an effective yet balanced dissuasive liability regime for the special areas of the North Sea. In an effort to understand the role of IMO in the prevention of illegal oil pollution from ships in the special areas of the North Sea, the scope of this paper relatively narrows down to the meaningful discussion of the application of both civil and criminal liabilities. Whether or not the function of IMO in its work relating to the North Sea is justified and neutral is a question of legal speculation.

2 Status Quo of the North Sea

The North Sea contains some of the busiest shipping routes in the world. It is deduced that approximately 600,000 ship movements take place into, and out of, the 50 main ports around the North Sea [5] (see Fig. 1). On an average, more than 400 ships a day pass through the Strait of Dover and, at the same time, 600 ships cross those straits, including 200 ferries [5]. The North Sea coupled with its natural resources embodies a pristine territory which constitutes a significant, yet irreplaceable environment. Hence, the concept of "increasing ship traffic," by now, has become a cliché when describing the North Sea. In terms of future "maritime" occurances, the North Sea today can metaphorically be described as *status quo ante bellum*, i.e., the state existing before war.

2.1 Abstraction of Special Status Area

The 1972 "Stockholm Declaration on the Human Environment" is accredited as the first treaty to deal with environmental protection [6]. Although the convention covered land-based sources, it has also paved the way for future conventions that would deal with extended environmental issues. The positive criticism posed towards the conference is that it pushed for legal initiatives for the development of legally binding rules [7]. It is noteworthy that principle 7 of the declaration embraces the holistic nature of all states to take steps to prevent marine pollution [8]. Nevertheless, there was no specific mention of operational or intentional oil

Fig. 1 Status quo of the North Sea

pollution in the declaration. However, a significant result of this declaration is the supplementation of a new social value, i.e., safeguarding the global environment [9]. Historically, this declaration had a positive impact on "ocean governance" by drawing attention to cooperation and an inclusive nature of concrete decision making and implementation. Awareness as regards to marine protection emanated in the following years and is observed from the designation of Particularly Sensitive Sea Area (PSSA) and Special Status Area (SSA) concepts, with regard to areas, which are particularly sensitive in nature and demand special attention. The PSSA concept can be traced back to the Swedish proposal at an International Conference on Tanker Safety and Pollution Prevention (TSPP/CONF/5), which called for special protection for *areas of particular value because of their renewable natural resources* [10]. The Swedish proposal emphasized that the concept of PSSA should be complementary to the existing MARPOL 73/78 regime as regards to "special areas." Resolution 9 as adopted at this conference endorsed the proposal with some modifications to the original text [11]. The SSA under the International Maritime Organization (IMO) can be termed as *sui generis* in nature [12] although the lists of PSSA and SSAs have been amalgamated into the same resolution by IMO.

2.2 North Sea Special Status Area

The Second International Conference on the Protection of the North Sea took place under the chairmanship of the British Minister of the Environment with participants corresponding to that of the ministers of the North Sea Coastal States [13]. A 16-Section Ministerial Declaration was adopted where Section XV dealt with *the reduction of pollution at source*, which was rather vague and imprecise in content. Then again, the ministers agreed to initiate action, within the IMO, for designating the North Sea as a Special Area for the purpose of Annex V of MARPOL 73/78, which basically dealt with prohibition of disposal of garbage as a source of *pollution from ships*. Oil pollution did not embody the initial agenda of the ministers since the initial objective was to phase out land-based pollution. Moreover, it can be deduced that North Sea commercial sea traffic during the early 1990s was at its inaugural phase.

Nevertheless, the designation of the North Sea as a Special Area in terms of oil and chemical pollution by the IMO was advocated in the Third International Conference on the Protection of the North Sea. Although the restrictions of oil pollution were not discussed distinctively at the conference, intensive control measures with regard to tankers were considered elaborately in 1990 [13]. Apparently problems and measures in terms of oil and chemical as a vessel-source pollution gained its international attention in the wake of the *Exxon Valdez* (1989) disaster in Alaska. Eventually, the North Sea received its rightful designation as an SSA, whereby oil discharge by oil tankers or generic vehicles acceding 400 gross tonnages was declared as prohibited in the Northwest European waters from the late 1999. This was a part of the 1997 amendments to MARPOL 73/78. The Northwest European waters cover inter alia the North Sea where more stringent discharge standards for the discharge of oily waters are applicable.

3 Oil Discharge in the North Sea

One-third of global marine oil transportation passes through European waters, which comprise not only oil tankers but also various other cargo ships [14]. These pose a constant threat of small- to medium-scale oil pollution from illegal dumping of oily wastes with at least 3,000 major events per year around Europe. Without efficient and strict controls as a deterrent (and to subsidize costs), oil tanker crews release noxious residuals at sea. It is estimated that at least 3,000 major illegal hydrocarbon dumping incidents take place in the European waters per year, amounting to total amounts of between 15,000 and 60,000 t in the North Sea [14]. These activities give rise to spills of oil, some of which are the result of maritime accidents, while others are termed as illegal.

3.1 Operational Discharge vs Illegal Discharge

Vessel-source oil pollution may occur in multifarious ways. A tanker may sink, be a part of a collision, be grounded, or have technical difficulties for which oil may leak out into the sea. This is the cliché concept of what embodies the principle of oil pollution. Major accidents such as the *Torrey Canyon* (1967, Southwest Coast of the UK), the *Amoco Cadiz* (1978, Portsall Rocks), the *Exxon Valdez* (1989, Prince William Sound's Bligh Reef, Alaska), and more recently the *Hebei Spirit* (2007, South Korea) have certainly left landmarks as oil tanker disasters that resulted in enormous oil spills with catastrophic consequences to the marine environment. As long as transportation across the sea continues, there will inevitably be oil discharges. It must also be stressed that oil pollution may be caused either through operational discharge or through an accidental oil spill. Operational discharge is considered intentional because it was done knowingly and intentionally as a part of the operation of the ship. But the question of fact is how do we distinguish "illegal discharge" from "operational discharges"?

Discharge of oily waste at sea may not always be designated as illegal. It is acknowledged that a ship is permitted to leave a permanent stream of oily water in its wake for several hours, or even several dozen hours, as long as the concentration of oil in the discharged waste does not exceed 15 parts per million [15]. This accounts for an intentional discharge, and the inherent analysis is that if the amount constitutes more than 15 parts per million, then it would invoke the concept of the so-called illegal oil pollution. Then again, it can also be argued that an "intentional oil pollution" can be defined as an unlikely and unrealistic scenario, whereby the vessel in question discharges oil with the full intention to destroy the marine environment. This is as opposed to the small amount of oil released which acceedes the given international standards, and it may or may not be done with the specific intention to cause harm to the environment. This may be coupled with the lack of proper surveillance. Nevertheless, the observation is that "illegal oil pollution" has not been defined in any of the international conventions. The only definition that is observed in major international conventions that deal with oil pollution is a definition which establishes the criteria which constitute pollution at sea where the discharge of oil is the central character.

Article 3 (paragraph 2) of the International Convention on Oil Pollution Preparedness, Response and Co-operation, 1990 (OPRC 1990), defines an "oil pollution incident" in the disjunctive mode [16]. Threat to the marine environment may or may not be consequential following a maritime incident of the vessel in question. This definition is shrouded in ambiguity and gives rise to pragmatic legal questions.

Then again, the subtle difference between operational discharge and illegal discharge has never been substantiated by any respective authority.

3.2 Illegal Oil Pollution in the North Sea

The Department of Transport of the United States of America has divided dangerous substances and materials into nine classes, whereby oil and oil products fall in class 3 [17]. They formally present environmental, health, and safety hazards and are internationally accepted. Oil and oil products are flammable and are considered as toxic to aquatic life. The most sensitive areas are calm shorelines, marshes, sea grasses, and mangroves, which can provide quiet zones for oils and hydrocarbons to accumulate. Corpses of oil-contaminated birds are found along the German North Sea coast where pollution would cause significant ecological damage and is directly observed in certain coastal areas [18]. The North Sea and adjoining Wadden Sea shared by Denmark, Germany, and the Netherlands host several important seaports such as the harbors of Rotterdam, Hamburg, or Antwerp and are a relevant connection between the Atlantic Ocean and the Baltic Sea. Approximately 420,000 ship movements in the North Sea are registered annually [19, 20]. Since 1999, the North Sea has received the SSA. It is assumed that chronic pollution, i.e., illegal oil discharges, is still prevailing. It has been estimated that between 15,000 and 60,000 t of oil is released illicitly into the North Sea every year [21]. To tackle this growing trend, the North Sea Coastal States have established cooperation to control and reduce illegal oil releases. This cooperation led to the Bonn Agreement 1969, which was established to deal with the protection of the North Sea marine environment from oil pollution [22]. The contracting parties have conducted control flights over the North Sea international waters with the aim of detection of oil spill (whether accidental or illegal) and discharges of other harmful substances. Moreover, aerial surveillances are performed sporadically on varying routes with significant accentuation on the predominant traffic regions [23]. The aerial surveillance spill statistics simultaneously serves as an assessment basis to protocol temporal changes in the level of illegal oil pollution [24]. Findings corresponding to oil-contaminated birds that were not correlated with recorded ship accidents [25], together with the oil spills observed by aerial surveillance [22], provide evidence that chronic oil pollution discharged illegally is still a persisting problem.

4 The Role of IMO in the Prevention of Illegal Oil Pollution

The International Maritime Organization has a long track record of ascertaining the appropriate solution within the appropriate time frame [26]. In order to prevent pollution from illegal oil discharges, the North Sea Coastal States have to establish international rules and standards, and when these rules and standards, as far as vessel-source pollution is concerned, are established, the standard applied must have the same effect as generally recognized international rules and standards established through competent international organization or diplomatic conference [27]. Although the concept of a competent international organization is not clearly defined in any of the conventions, when it narrows down to oil pollution in the North Sea, it is presupposed that IMO is the pertinent body that has the competency of an international organization. It is perhaps trite to point out that the law of international organizations is mainly developed through the practice of those organizations. As is understood, IMO's original mandate was initially concerning maritime safety. However, as the custodian of the 1959 Oil Pollution Convention, the organization, soon after it began operating in 1959, assumed responsibility for pollution issues. Relevantly, the pollutant that has the longest history of international attention is definitely oil, and the first time oil pollution was the subject of an international conference was in 1926, after the United States of America recognized the international nature of this problem. The International Convention for the Prevention of Pollution of the Sea by Oil (OILPOL), 1954, was signed in London. OILPOL was the first convention concerned with operational oil pollution from merchant ships. However, OILPOL proved to be inadequate and an international conference was held by IMO to deal with this situation in the year 1973. This resulted in the adoption of MARPOL 73/78 by IMO, which to date, along with its amendments, deals with illegal oil discharges as a part of vessel-source pollution.

When it comes to complimenting IMO's accomplishments in trying to protect the North Sea from illegal oil discharges, it has not only addressed the North Sea as an SSA, but it has also designated the Wadden Sea, which is located in the South Eastern part of the North Sea, as a Particularly Sensitive Area (PSSA). This was agreed at a meeting by the Marine Environment Protection Committee (MEPC) of the IMO in 2002. The proposed area for PSSA designation extends along the North Sea coasts of the Netherlands, Germany, and Denmark from Den Helder in the Netherlands to Blaavandshuk in Denmark [28]. This attempt transparently describes IMO's persistent efforts in trying to minimize operational or illegal oil pollution in the North Sea.

4.1 A Critique of MARPOL 73/78

The goal intended to be attained by IMO via MARPOL 73/78 is the elimination of intentional pollution by oil and other harmful substances from ships and to minimize the accidental discharge of such substances. The general provision in Article 6 of Annex 1 contains the obligation of parties acting as Flag State, Port State, or Coastal State, to cooperate in the detection of violations and the enforcement of the provisions of the convention, using all appropriate and practicable measures of detection and environmental monitoring, adequate procedures for reporting, and accumulation of evidence. Contrary to the United Nations Convention on the Law of the Sea 1982 (UNCLOS), MARPOL 73/78 does not provide that a Port State can take proceedings when a violation takes place on the high seas or in areas under the jurisdiction of another state. So in principle MARPOL 73/78 does not deviate from the exclusive jurisdiction of the Flag State. However, a Port State may inspect a ship that enters a port or offshore terminal under its jurisdiction, which in some circumstances may lead to the detention of that ship. A Coastal State can institute proceedings under its own laws in respect of any violation that occurred within its area of jurisdiction. Article 5 read together with Article 6 provides that a ship may, in any port or offshore terminal of a Port State which is party to the convention, be subject to inspection by Port State control officers for the purpose of verifying whether the ship has discharged any harmful substances in violation of the provisions of the regulations. However, the officers appointed or authorized by that Port State are bound to special rules on inspection of ships. A Port State may also inspect a ship when it enters the ports or offshore terminals under its jurisdiction, if a request for an investigation is received from any party together with sufficient evidence that the ship has discharged harmful substances into the sea. The report of the investigation is then passed on to the requesting party and the Flag State for appropriate action.

Regulation 11(b) is an *exception clause* to Regulations 9 and 1 consolidated in Annex I, which provides an accountability basis, i.e., penalty for discharge of oil, and simultaneously embodies the principle of *due diligence* as a defense. *Due diligence*, however, has not been given the much needed legal interpretation, which in this case could be translated as *good seamanship*. Nevertheless, this is balanced with Article 11(b) (i) where the right is withdrawn if proven that it is done "with *intent* to cause damage, or *recklessly* and *with knowledge* that damage would probably result..." [29] which is quite contrary to the principle of *good seamanship*. A sound interpretation would deduce the fact that the obligation of the owner or master can only be substantiated by proving the existence of *mens rea* (guilty mind) in the incident which proceeded by intention and knowledge of the imminent damage [30]. This paves the way for the analogy that IMO by dint of incorporation of certain terms in Annex I has ventured in-depth in the realm of illegal oil discharge, whereby the legal principles embedded therein would determine the question of law. In addition, Regulations 15 and 34 of Annex I provide for various restrictions and controls in relation to discharge of oil from machinery spaces of all ships and from cargo spaces of oil tankers coupled with methods for the prevention of oil pollution from ships in and outside of special areas. Subparagraph 2.2 of these regulations infers that the defense of "due diligence" is unavailable when it is proven that the owner or master acted intentionally, recklessly, and with the knowledge of probable damage resulting from the act itself and the burden of proof lies with the person evoking this defense.

4.2 European Union Directive and North Sea Coastal State Legislation

Illegal oil pollution has taken the shape of penal sanction in cases where it has been difficult to distinguish between illegal discharge and accidental discharge. There is an observed paradigm shift from the notion of civil liability laid down by IMO towards a stringent criminal liability where the wordings are supplemented with indeterminate terms and disjunctive wordings. This is exemplified in European Union legislation, i.e., Directive 2005/35/EC as amended by Directive 2009/123/EC, where the purpose of this Directive is to incorporate international standards for ship-source pollution into community law and to ensure that persons responsible for discharges of polluting substances are subject to adequate penalties, including criminal penalties, in order to improve maritime safety and to enhance the protection of the marine environment from pollution by ships [31, 32]. The EU Directive is applicable for ships arriving in and ships departing from ports in EU countries, which inevitably includes the North Sea areas. The North Sea Commission has already viewed the North Sea as a major economic entity of EU, and with the promulgation of the EU Directive, the special areas of the North Sea now have the legal protection of IMO and the EU Commission.

The only reference to IMO has been made in Article 6 of the Directive as regards to enforcement measures with respect to ships within a port of a Member State. The Directive has been broadly discussed in the maritime industry, not only in Europe but in the international shipping community at large. The main point of criticism is that it seems to apply higher standards in European waters than internationally agreed under MARPOL 73/78. Under the Directive, it might now be possible that even in case of accidental discharge of oil, one may be financially and criminally prosecuted. The problem is that the Directive does not only apply to vessels flying European flags but to all vessels visiting European ports. Additionally, the group of the potential liable persons is in the view of many quite too large and in any case contradictory to MARPOL 73/78, which only refers to the master, the crew, and the ship owner. The inevitable question is whether the Directive undermines the role of IMO in preventing illegal oil pollution or should IMO acknowledge the contents of the Directive and compliment the mission of eradicating illegal oil pollution that the European Union (EU) has set out to achieve.

4.2.1 North Sea Coastal States Shift Towards Stringency

Some of the North Sea Coastal States display the trend of criminal liability and penal prosecution of seafarers in respect of illegal oil pollution incidents in the territorial sea, even if there is no seminal proof of “willful behavior.” The Perben Law 2004, of France, imposes severe penal sanctions in relation to marine pollution owing to voluntary and involuntary discharges. Voluntary discharges, under this law, shall be punished with a fine of € 1 million and imprisonment up to 10 years. The “involuntary or negligent” pollution shall hold the sanctions with imprisonment up to 2 years and fines up to € 200,000. The Belgium Ship Pollution Prevention Act (SPPA), dating from 1995 and amended in 1999, has been modified in 2007, in order to implement the Directive 2005/35/EC on ship-source pollution and on the introduction of penalties for infringements and to be in agreement with the ratification of Annex VI of MARPOL 73/78. In 2007, Article 5 of the SPPA was modified in order to comply with the Directive 2005/35/EC. Pollution resulting from damage to a ship or its equipment, as described in MARPOL 73/78, Annex I, Regulation 11, under (b), and Annex II, Regulation 6, under (b), no longer falls under the exceptions to the discharge rules in the territorial sea and the internal waters, including the ports of Belgium or any other EU Member States.

In this regard, the role of IMO is described as demarcating "what ought to be" from "what must not be" in terms of illegal oil pollution requiring adoption of international cooperation and mutual assistance in preparing for and responding to major oil pollution incidents. It is mostly guided by the "polluter pays" principle and has left it as a state's prerogative to determine on the substantive and procedural laws. Although prescriptive in nature, the umbrella convention, i.e., UNCLOS, makes an effort to heighten the role of IMO's work by giving reference to MARPOL 73/78 in Article 217 by stating that the Flag State should provide for immediate investigation and institute proceedings in respect of violation of rules of MARPOL 73/78, irrespective of where the violation occurred or where the pollution caused by such violation has occurred or has been spotted. Moreover, Article 218 states that the Port State may undertake investigations and, where the evidence so warrants, institute proceedings in respect of any discharge from the vessel outside the internal waters, territorial sea, or EEZ of that state in violation of MARPOL 73/78. IMO has to date remained silent on addressing this progressive rigidity of the EU Directives in prosecuting illegal oil discharges. One could question whether this silence of IMO can be inferred as a form of affirmation. Because the preamble of Directive 2005/35/EC enunciates that it is supplemented by detailed rules on *criminal offenses* and *penalties* as well as other provisions set out in Council Framework Decision 2005/667/JHA of 12 July 2005 to strengthen the *criminal law framework* for the enforcement of the law against ship-source pollution. The liability facet of ship-source oil pollution is covered by the CLC Convention of 1969 and amended by the CLC 1992, the elementary features of which is *strict liability* of the tanker owner who is obliged to pay for damage resulted from *persistent spill*. A significant compromise reached in the event of drafting the CLC is the notion of *channeling of liability* where the liability for oil pollution would be channeled through to the "registered owner" who is burdened with compulsory insurance [33]. However, this tends to devise a liberty for the other parties, and though the "registered owner" may initiate recourse against those other parties, this had to be done after satisfying the claimant(s). Sometimes it does not suffice to cover the entire pollution damage, and in the long run, IMO's "polluter pays principle" is frustrated.

In analyzing Section 7 of the preamble of the Directive 2005/35/EC, it is understood that the EU policy makers believe that these Civil Liability Conventions do not provide adequate "dissuasive effects" to inhibit the parties involved in transporting hazardous cargoes and oil from exercising "substandard practices" and focus on the need for a more rigid regulatory system. Article 1 transparently renders the right to incorporate international standards for ship-source pollution into community law and to ensure penalties as referred in Article 8. Then again, Article 4 imposes an obligation on the Member States to ensure ship-source discharges into any areas referred in Article 3(1) as an infringement if committed with intent, recklessly, or by serious negligence. Article 3 establishes the right to impose those penalties far beyond community waters, i.e., internal waters, territorial sea, straits used for navigation, exclusive economic zone, and the high seas. So, an implementation of the Directive into North Sea Coastal States respective legislation would certainly solidify their international commitment in assisting IMO to help retain North Sea as an SSA. The international shipping industry can render IMO the benefit of the doubt of this silence in terms of EU's radical shift from civil liability to criminal prosecution. The EU Directive has not been well received by the international community because the ambit of this provision extends towards any person working on board, i.e., seafarers for infringement with parallel liability. "Minor mistakes" or "human error" which may result in accidental discharges has not been addressed in the Directive, leaving scope to unlawfully detain and punish any natural or legal persons involved in such "human error." But IMO via MARPOL 73778, Annex I, Tables I, II, and III, has made it succinctly clear about the prohibition of oil discharges in SSA, and considering the number of ship traffic in and around the North Sea, a thousand "minor mistakes" can lead to a major oil disaster in the North Sea. And if one "human error" is overlooked, then, it does not set the appropriate example. However, even if it is accepted that major shipping corporations try to escape liability via "insolvency" alibi, the focus of criminal liability is shed on the master and crewmembers that are left on the frontline while the ship-owning corporation hides behind the corporate veil. So, accountability in terms of illegal oil pollution in any area of the North Sea is literally vis-à-vis criminal liability vs civil liability. The EU Directive guides the former, while the latter is the prescriptive law as incorporated by IMO.

4.2.2 Directive 2005/35/EC as Distinguished from MARPOL 73/78

The EU Directive does not furnish any strict dichotomy as between "operational" and "accidental" discharge in terms of imposing criminal sanction. It seems that any type of discharge, which exceeds the international standards, is considered as an illegal discharge. As such it embodies illegal oil pollution as a part of vessel-source pollution. "Accident" under the traditional legal spectrum refers to an unforeseen, fortuitous, or unexpected chain of events [34], and "operational discharges" are considered to be "intentional," and this is mainly where the test of criminal liability comes into play. But no matter how much comprehensive and tight worded the Directive maybe in terms of protecting the European waters, which include the North Sea SSA and the Wadden Sea PSSA, the main point of criticism is that it seems to apply higher standards in European waters than internationally agreed under MARPOL73/78. This potentially may undermine the role of IMO in preventing illegal oil pollution with reference to North Sea SSA. A further clarification would reveal that the Directive is in direct conflict with other international regimes, which gives reference to the works of IMO, namely, MARPOL 73/78.

Article 230 (2) of UNCLOS enforces monetary penalties with the exception of the presence of "willful and serious" act.

In contradiction, the EU Directive contemplates the presence of either "willful" or "serious" act, which is cast in disjunctive mode. Then again, it is not certain as to whether "serious negligence" covers cases of accidental discharges. In the same context, the Directive contradicts with MARPOL 73/78 in so far as the offense must be committed "recklessly and with knowledge" as incorporated in Regulation 4.2.2.2 of Annex I. Evidently the EU Directive is in conflict with MARPOL 73/78 since both these elements must coexist simultaneously. This brings into the notion that the EU commission could foresee certain situations, which the policy makers of IMO could not. But the role of IMO when it comes to the North Sea relates to maritime capacity building and acts as a contributor towards ensuring safer shipping and cleaner oceans. So, when the shift moves from civil liability to corporate criminal liability, considerable attention should be given to the fact that the MARPOL 73/78 treaty attributes a uniform set of rules from which the contracting states cannot depart and the EU Directive puts Member States in conflict with their obligations to IMO owing to the fact that it enforces criminal liability within territorial waters for "serious negligence" and obviates any defendant from exercising MARPOL 73/78 defense under Regulation 11(b) of Annex I. Serious negligence under the EU Directive framework is vague, subjective, and ill defined. The analysis is that "serious negligence" could also be applied to a minor mistake that does not emanate from recklessness and could result in major illegal oil discharges in the SSA of the North Sea. The standard for determining the so-called serious negligence hangs in the balance. There is a growing consternation that relates to the subjectivity inherent in the qualifier "serious" with respect to "negligence," and it is apprehended that the term "serious" may be observed as the seriousness of the pollution rather than the act, which ignited it.

If the seriousness of the devastation of oil pollution is considered, then it correlates to the essence of what IMO intended to achieve to begin with. However, the obscurity of specific terminologies has led to the criminalization of a vulnerable group and absolute disrespect for the privileges rendered to them in the event of an accidental discharge of pollution. But then again, coastal areas that have been struggling through a long history of North Sea Conferences to achieve the status of "Special Area" and finally acknowledged by IMO must cooperate and implement policies which can deter all or any type of illegal discharge within its perimeter. Otherwise, to some extent, it defeats the very purpose and the concept of SSA. Compromise could be reached at the international and regional level, and to that extent, if IMO and the EU could consider that illegal oil discharge problems of the North Sea are interrelated and that they should be considered as a whole, then it can be assumed that civil and criminal liabilities could take a hybrid form of less stringency in nature.

5 Conclusion

In relation to the evolution of the governance of ship-source pollution, customary and conventional law prior UNCLOS exemplified an initial concern regarding oil pollution from ships. This early concern as demonstrated in international conventions such as the High Seas Convention of 1958 failed to bind states to follow international standards and provided little guidance regarding principles to be applied when legislating and enforcing ship-source pollution. The hypothesis is that states not only had wide discretion in deciding how to control pollution from ships but also had certain liberty to pollute the seas. Since the advent of UNCLOS, the international shipping community has observed a comprehensive framework to deal with all sources of marine pollution, including ship-source pollution. This was lucidly established in Part XII of the Convention. In fact, under the convention, states including the Coastal States of the North Sea are under an international obligation to prevent pollution from ships and to promote harmonization of standards by acting through the IMO. In this regard, IMO has clearly identified and defined particular sensitive areas of the North Sea and labeled them with the title of SSA. This is mirrored in Resolution MEPC. 37(28) of the Marine Environment Protection Committee empowered by Article 38 of the Convention on the International Maritime Organization by dint of which the committee adopted amendments to Regulation 5(1) of Annex V of MARPOL 73/78 to designate the North Sea as a special area [35]. Subsequently, IMO rolls towards providing a civil liability regime against illegal oil discharges, thus creating a clear nexus between the former and the latter.

Currently, the EU is not a member of IMO since IMO membership is open only to states [36]. However, all 27 EU Member States are members of the IMO, and thus, the EU, as a whole, has a significant power in order to play a significant role in the international decision-making process within the IMO. In the setting of illegal oil pollution, it can be stated that the EU States are supportive of an international legal regime that relate to pollution prevention and safeguarding the North Sea special areas. Whether or not the EU has an intension of playing a role in the decision-making process of the IMO is less clear and undetermined; however, with the adoption and subsequent implementation of the third maritime safety package, the EU now has one of the world's comprehensive and advanced regulatory frameworks for shipping [37]. This leads to the conjecture that the EU's approach is of a regional or even unilateral character, which potentially could undermine the authority of general international law. In the light of preventative measures against illegal oil discharges, this unilateral aggressive move on the part of EU could be seen as overshadowing the legislative authority of IMO. Scholars persistently argue that civil liability can also serve a prophylactic function, and hence, a properly structured system for civil liability would exert a powerful influence [38]. This influence apparently relates to prohibiting discharges of oil pollutants because less monitoring with higher penalties is always beneficial. The civil liability regime for ship-source oil pollution enables national victims of oil spill damage to make financial claims against domestic and nondomestic tanker owners and, in certain circumstances, the global oil cargo industry which is a positive aspect [39]. The IMO's involvement in promoting civil liability regime for the North Sea SSA has been rationalized as an effective means of incorporating the polluter pays principle which is an "...economic policy and principle used for allocating or internalizing 'economic costs of pollution prevention and control measures to encourage rational use of scarce environmental resources and to avoid distortions in international trade and investment' by subsidizing the environmental costs" [40]. In an effort to understand this legal doctrine, it can be said that it embodies two considerable components, one of which is the equal right of access, which involves "access to information, participation in administrative hearings and legal proceedings and the application of non-discriminatory standards for determining the illegality of domestic and transboundary pollution" [40]. Apart from making the actual polluter pay, it can have a deterrent effect and help to avoid such consequences from illegal acts, in addition to contributing to the better enforcement of environmental regulations. This is how the work of the IMO for the North Sea SSA can be summarized and concluded as "well balanced."

The OPRC Convention (adopted in 1990 by IMO), in its preamble, considers the polluter pays principle as a general principle of international environmental law, on the one hand and, on the other hand, takes account of other IMO conventions covering liability and compensation. In other words, the polluter pays principle as envisioned by IMO and on the basis of these conventions gains certain legal influence as "a general principle of international environmental law." Then again, since the *Erika* (December 1999, Coast of France) and *Prestige* (November 2002, Coast of Galicia) disasters, the EU plays a central role on the prevention of vessel-source pollution both operational and illegal. The singular and joint pollution (bilateral and multilateral in scope) liability schemes and protection plans as enunciated by the EU Member States for the North Sea waters are unique in its features. To add to these noteworthy safeguard and liability regimes, the environmental standards, particularly in regard to marine pollution, the establishment of a civil liability and compensation mechanism by IMO is acting as a "double protection" for the North Sea. Whether this two-facet protection leads to redundancy is subjective. From an international law perspective, EU Member States can act individually in the IMO for a check and balance of its initiatives for the North Sea waters. IMO, as any other international organization, has its deficiencies, i.e., the slow entry into force of IMO conventions once these are adopted, the inadequate implementation of these conventions even after entry into force, and the overall incapability of IMO in enforcing compliance with the relevant rules [41].

Despite its deficiencies, IMO in accordance with the objective provided under Article 1 of the Convention on the IMO continues to provide machinery to ameliorate the efficiency of navigation and prevention and control of marine pollution from ships. Moreover, the legal instruments endorsed by IMO reflect its neutrality and flexibility in dealing with SSA of the North Sea. As regards to subject matters generic in nature, IMO simultaneously encourages the removal of discriminatory action and unnecessary restrictions by governments affecting shipping engaged in international trade so as to promote the availability of shipping services to the commerce of the world without discrimination. Hence, the effectiveness of the IMO aiming at the prevention of oil pollution spills has more legal significance insofar as it tries to strike a balance between the international shipping industry and the protection of the sensitive areas of the North Sea. The role of IMO as an international organization is essentially to offer an organized framework for international cooperation. Anticipation of a clash between international and regional conventions is not within the mandate of IMO. The main focus remains constant via incorporation of amendments that has given special attention to sensitive maritime zones and the prevention of illegal oil pollution in the waters of the North Sea.

It is not within the agenda of IMO to promulgate redundant policies to uphold its international role, rather from a purely legal perspective; the goal of its liability rule is victim compensation. By comparing different legal regimes, it can be observed that the situation of the victims is in general improved although not completely satisfactory since the risk of under compensation still exists in case of catastrophic oil spills. But "satisfactory compensate" is subjective, even when it narrows down to indemnifying coastal areas of the North Sea that has acquired the status of SSA. In all cases IMO's role in terms of protecting the North Sea SSAs can be summarized as unbiased as opposed to the unilateral approach of the EU. Whether the EU Directive overrides the role of IMO and whether IMO will change its position are at this point unpredictable. There is a certain confidence that like any other international organizations, the IMO has effortlessly tried to reach a compromise by striking a balance between the shipping industry and protection of the North Sea, which is undoubtedly a prudent move [42, 43].

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Oil Pollution in the Waters of the Danish Sector of the North Sea

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Abstract This chapter deals with cooperation, organization, responsibility, statistics, preventive measures, equipment, etc. in relation to maintaining a clean marine environment in the Danish sector of the North Sea including the coast and harbours. In addition to international conventions, national legislation regulates responsibilities and organization with regard to aerial surveillance and oil spill response. Through multilateral agreements such as the Bonn Agreement, cooperation takes place with other North Sea countries with regard to aerial surveillance, oil spill response, operations, exercises, etc. Besides this international cooperation, there are a range of national collaborations between a number of national authorities and units which also takes place, not only in relation to ships but in relation to oil rigs as well, with an additional set of rules drawn up for the latter. Implementing preventive measures on the marine environment are also discussed in this chapter, together with measures such as vessel traffic zones which have yet to be established in the busiest maritime areas in the Danish part of the North Sea. The section on aerial surveillance and oil pollution statistics examines the numbers of incidents and numbers of oil slicks from ships and platforms. A steady decrease in mineral oil spills from ships has occurred over the last 10 years. During that period only one event requiring action to combat an oil spill has taken place in the Danish sector of the North Sea.

Keywords Aerial surveillance, Danish legal framework, Danish national agencies, Danish North Sea, Maritime transport, Oil pollution, Skagen

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Contents

1 Introduction

The Danish sector of the North Sea has always played an important role for Denmark and for the people living along the west coast of Jutland. The sea is used for a multitude of maritime activities including extraction of seafloor resources, commercial fishing, leisure boating, offshore wind parks as well as oil and gas pipelines.

The sea area off Skagen, highlighted in Fig. 1 (top centre), is a bottleneck for sea traffic inbound and outbound between the Baltic Sea and the North Sea which has increased steadily in the last decade, thereby reflecting intensifying international cooperation and economic prosperity. On the basis of AIS data, a picture of the ship intensity in Danish waters is shown [1].

Since the mid-1990s, the Baltic Sea Region has, as a whole, witnessed enormous growth in maritime transport. Despite the decline in the shipping industry in 2008 caused by the economic recession, the Baltic Sea is still one of the most heavily trafficked seas in the world, accounting for up to 15% of the world's cargo transportation [2]. Thousands of sizeable ships pass between the North Sea and Baltic Sea through the Skagen each month, including large oil tankers, ships carrying dangerous and potentially polluting cargoes, as well as international cruise ships.

Looking into the future, a huge growth in the sector is predicted [3]. The number and size of ships are expected to increase substantially in the coming years, including those transporting oil. The massive growth in the shipping sector is

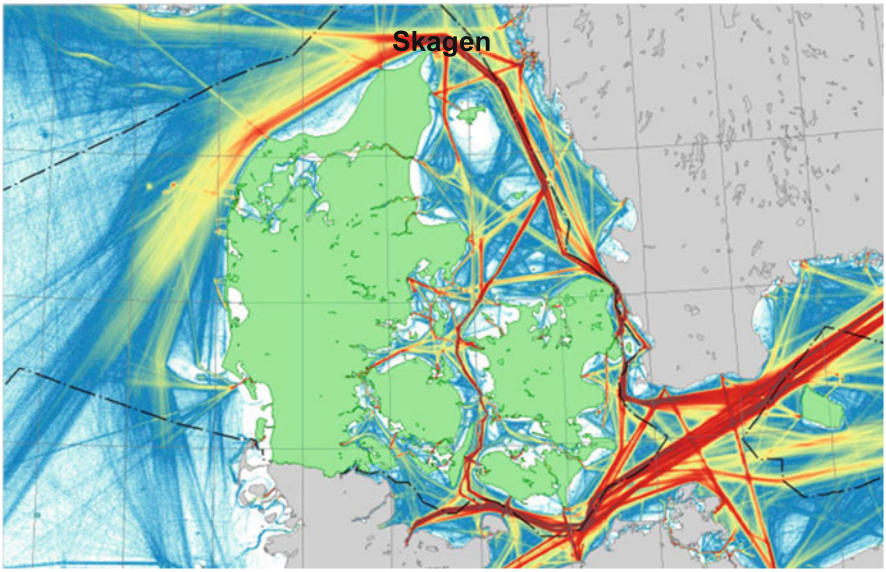

Fig. 1 Intensity of ship traffic in Danish waters, using AIS data (Automatic Identification System). *Source*: Danish Ministry of Defence 2010, page 67 [1]

mainly due to the expansion and construction of oil terminals on the shores of the Gulf of Finland and regional economic growth.

The enormous volume of shipping around Skagen is accompanied by a large risk of accidents including groundings and collisions. Many accidents result in oil spills. A large oil spill in the coastal area of the Danish sector of the North Sea could have serious ecological effects, not just in Danish waters but also potentially those of Norway, Sweden and Germany, for example. Oil spills can have devastating impacts on vast areas of nature as well as on sectors such as fishing, tourism and recreation. Clean-ups after an oil spill can also result in extensive financial costs in both the short and longer term.

2 Responsibility for Aerial Surveillance and Combating Oil Spills and Chemical Pollution at Sea

On 1 January 2000, the Danish Ministry of Defence took over from the Danish Ministry of the Environment the responsibility for aerial surveillance as well as oil spill and chemical pollution response and enforcement of marine environmental legal regulations in terms of collecting evidence (in cooperation with the police) associated with pollution of the sea from ships. In general the operative parts of the tasks are delegated to the Defence Command Denmark.

2.1 The Danish National Legal Framework for Marine Environmental Preparedness

The field of marine environmental preparedness is regulated under the Danish Act on the Protection of the Marine Environment, 2013 [4]. This section examines the aspects of that act as it relates to oil and chemical pollution in Danish waters.

The Danish Act on the Protection of the Marine Environment falls within the remit of the Danish Ministry of Environment and regulates the general protection of the marine environment against all forms of pollution of the sea. In connection with the transfer of responsibility for combating oil and chemical pollution thereon from the Danish Ministry of Environment to the Danish Ministry of Defence, this section reviews some of the Danish Act on the Protection of the Marine Environment in order to reflect the current responsibilities.

2.1.1 The Danish Ministry of Defence's Responsibility

The discharge into the sea of oil, chemicals and waste is generally punishable under the Danish Act on the Protection of the Marine Environment. The Danish rules are based on those set out in the MARPOL Convention [5] and therefore similar emissions regulations in the North Sea must apply. Regarding oil, any discharge within the territorial sea is prohibited, while outside the territorial sea only the discharge of very small amounts of oil is authorized in accordance with well-defined criteria. The Danish Act on the Protection of the Marine Environment further defines that oil in the legal sense should be understood as mineral oil. The term "mineral oil" means any of various colorless, odorless, light mixtures of higher alkanes from a non-vegetable (mineral) source. This is in contrast to, for example, coconut oil or rapeseed oil which is referred to as vegetable oil.

The Danish Ministry of Defence's tasks in the marine environment include surveillance of the sea, oil pollution response as regards oil and chemical pollution. In case of marine pollution originating from ships, the Danish Ministry of Defence can issue notices of detention or notices of enforcement designed in order to reduce pollution or risk of pollution from the ship.

Defence Command Denmark enforces the provisions of the Danish Act on the Protection of the Marine Environment in cooperation with the police. In case of discharge of mineral oil, Defence Command Denmark can search the ship, interrogate the crew and issue an administrative fine. Other illegal discharges than mineral oil are reported to the police.

2.1.2 The Danish Act on the Protection of the Marine Environment, Section 34

The complete task complex for the Danish Ministry of Defence's marine environmental preparedness is based on the Danish Act on the Protection of the Marine

Environment, Section 34. According to this section, the Danish Minister of Defence, in cooperation with the emergency service[1] and other authorities as authorized by the Minister, is responsible for combating oil and chemical pollution at sea and the coastal part of the territorial sea. In practice, “the coastal part” is defined as the sea area which goes into the so-called normal water level line. The wording “other authorities” aims to open up for the possibility for cooperation with, for example, municipal authorities.

2.1.3 Municipal Responsibility the Danish Act on the Protection of the Marine Environment, Section 35

According to the Danish Act on the Protection of the Marine Environment, Section 35, subsection 1, it is the municipal council which, in case of oil or chemical pollution, conducts the rehabilitation of coastlines and control of pollution in ports. The coastline in this regard is defined as the landward side above normal water level line, in practice above the current waterline. The local council is, according to the Danish Act on the Protection of the Marine Environment, Section 35, Subsection 2–4, the responsible body for making contingency plans. The Danish Minister of the Environment and the Danish Minister of Defence should be informed about the content of these contingency plans as well as the corresponding amendments and supplements.

In accordance with the Danish Act on the Protection of the Marine Environment, Section 35, subsection 5, the Danish Ministry of the Environment is responsible for setting up the overall collective emergency preparedness.

2.1.4 The Danish Act on the Protection of the Marine Environment, Section 35, Subsection 6

The Danish Act on the Protection of the Marine Environment, Section 35, Subsection 6, allows the Danish Ministry of Defence, in the case of particularly serious and extensive pollution, to determine that rehabilitation of coastlines and control of pollution in ports should be chaired by the Danish Ministry of Defence or other authorities which the Minister authorizes. The provision only allows the Danish Ministry of Defence an opportunity to take charge of the rehabilitation of coastlines and control of pollution in ports from a coordination point of view. This is merely a method to achieve coordination-oriented management and not a short or long takeover of the responsibility of the area. The Danish Ministry of Defence only conducts the insertion of the capabilities that may be available for the referred task

[1] The Danish Emergency Management Agency (DEMA) is a Danish governmental agency under the Ministry of Defence (see http://brs.dk/eng/Pages/dema.aspx.

but is not responsible for the procurement of these. The responsibility rests with, respectively, the local councils and the port boards in accordance with the Danish Act on the Protection of the Marine Environment, Section 35, Subsections 1 and 3.

2.1.5 Options

In addition to the general provision which confers the Danish Ministry of Defence's responsibility for combating oil spills and pollution at the sea, the Danish Act on the Protection of the Marine Environment also contains a number of provisions that give the Danish Ministry of Defence the tools which are needed in order to solve the overall task. The law allows, for example, the possibility for the Danish Ministry of Defence, without a court, to make any inquiries of a ship which are necessary to prevent or eliminate pollution at the sea if an oil spill from the ship has already happened or if there is a danger of polluting of the sea.

The Danish Ministry of Defence may also, in this situation, prohibit a ship to continue its voyage or other activities or to order that a ship's further sailing must follow certain guidelines. Finally, the Danish Ministry of Environment has the possibility to prohibit a ship calling at Danish ports in case the ship chooses to ignore the injunction as the Danish Ministry of Environment has given in accordance with the Danish Act on the Protection of the Marine Environment. The Danish Act on the Protection of the Marine Environment authorizes Danish Ministry of Defence to detain the polluting ship as security for costs for reasonable measures taken to prevent or minimize pollution.

2.2 The Rule of International Law Based on the Marine Environment

There are a number of rules of international law on the marine environment which, together with the Danish national regulations, provide a framework solving the marine environmental task. The international regulation consists mostly of international conventions ratified by Denmark and thus it has committed to comply with the rules. A wide range of international rules arising from the conventions are incorporated in the Danish Act on the Protection of the Marine Environment provisions. The most important international marine conventions relevant to the North Sea are discussed below:

2.2.1 United Nations Convention on the Law of the Sea (UNCLOS), 1982

The United Nations Convention on the Law of the Sea (UNCLOS), 1982 [6], is informally described as the "sea constitution". This is because the convention was created when, in 1982, the countries concerned decided to merge the customary international law which was in force at the time as regards the oceans and their use. The so-called 1958 conventions, namely, the Convention of 29 April 1958 relating to the territorial sea and the contiguous zone, the Convention of 29 April 1958 relating to the high seas, the Convention of 29 April 1958 relating to the continental shelf and the Convention of 29 April 1958 about fishing on the high seas and conservation of the living resources, together with an optional protocol of 29 April 1958 concerning the compulsory settlement of disputes concerning the interpretation or application of the Conventions of 29 April 1958 about the law of the sea, are largely incorporated into UNCLOS but are still in force. UNCLOS defines each maritime area (e.g. the territorial sea, the exclusive economic zone, the high seas, etc.) and identifies the possibilities of their use including in what extent the coastal states may exercise jurisdiction over these areas. UNCLOS has thus had an important influence on the resolution of the marine environment task, and parts of the Convention on the Law of the Sea are incorporated into the Danish Marine Environment Protection Act 2013 [4].

2.2.2 The MARPOL Convention

The International Convention for the Prevention of Pollution from Ships (MARPOL 73/78) is administered by the International Maritime Organization, IMO [5]. It may be viewed as a form of a "Marine Environment Protection Act" which, amongst other things, regulates technical specifications for ships in order to prevent pollution of the sea. The convention also contains detailed rules on when and in what way ships are allowed to carry out discharges into the sea.

2.3 Multilateral Agreements in Relation to the Marine Environment

In addition to the above-mentioned international conventions, Denmark has signed a number of multilateral agreements with neighbouring countries around the North Sea. The agreements primarily relate to aerial surveillance and oil spill response in dealing with combating marine pollution, but some also contain some elements of cooperation on prosecution. Some agreements have been prepared as conventions, while others are less formal cooperation agreements. The most important of these agreements are reviewed below.

2.3.1 The Bonn Agreement

The Agreement of 9 June 1969 on combating oil pollution in the North Sea (the Bonn Agreement) [7] includes mutual assistance in combating oil and other harmful substances in the North Sea. Furthermore, the agreement includes a commitment of active cooperation through coordinated aerial surveillance [8] of the North Sea. The Bonn Agreement has been signed by Denmark, Sweden, Norway, Great Britain, Ireland, France, Belgium, the Netherlands, Germany and EU.

2.3.2 The Copenhagen Agreement [9]

The "Nordic Convention of 16 September 1971 on cooperation of measures to combat oil pollution at sea", revised 29 March 1993, was changed to the "Agreement between Denmark, Finland, Iceland, Norway and Sweden about cooperation concerning pollution control of the sea after contamination by oil or other harmful substances" [9]. The agreement relates primarily to cooperation in combating pollution of the member states' waters. According to Article 6, the parties should in the best possible way assist each other to ensure collection of evidence associated with illegal discharges of oil and other harmful substances.

2.3.3 Trilateral Agreements: DENGERNETH [10]

In the southern sector of the North Sea, pollution may present a danger to coastal regions of Denmark (including Greenland and the Faroe Islands), Germany and the Netherlands. Bilateral agreements were therefore concluded between the Netherlands and Germany (NETHGER, 1991) on the one hand and between Denmark and Germany (DENGER, 1993) on the other hand to establish close cooperation in response to pollution of the sea.

Subsequently, the competent parties, e.g. the Danish Defence Command, the Ministry of Transport, Public Works and Water Management of the Netherlands and the Federal Ministry of Transport and Building and Urban Affairs of Germany, agreed to extend their existing cooperation to include information exchange on the threat of marine pollution and aerial surveillance in order to prevent and detect pollution. The parties also agreed to establish one composite trilateral arrangement of cooperation instead of having separate bilateral instruments concerning cooperation in combating marine pollution as well as cooperation in aerial surveillance.

The agreement "Danish-German-Netherland Joint Maritime Contingency Plan on Combating Oil and Other Harmful Substances" (DENGERNETH) is fully operational but had not, at the time of writing, been signed by all parties. The plan is an operational agreement which describes in detail the cooperation in aerial surveillance and oil spill response in the border area between Germany, Denmark and the Netherlands.

The plan shall apply as necessary and appropriate to any marine pollution or threat of pollution within the DENGERNETH Response Region, which is or could become of sufficient severity to initiate joint action. The DENGERNETH plan also applies to the Wadden Sea which is a conservation area. Regional sub-plans for Wadden Sea areas may be concluded within the framework of the DENGERNETH plan.

In order to establish a high degree of readiness, annual exercises shall be carried out between the three countries. Instead of these trilateral exercises or in addition, combined exercises in accordance with relevant regulations of the Bonn Agreement may be conducted.

3 National Organization and Responsibilities

Prevention and control of maritime environmental pollution is a shared responsibility involving the state as well as the municipal and private actors.

3.1 Geographical Responsibilities and Allocation of Responsibilities

The allocation of responsibilities between the current emergency responses is as described in sections 2.1.2 and 2.1.3 overall as set out in the Danish Act on the Protection of the Marine Environment [4] Section 34 and Section 35.

In accordance with Section 34, the Danish Ministry of Defence, in cooperation with the emergency service and other authorities as authorized by the Danish Ministry of Defence, is responsible for combating oil and chemical pollution at sea and the coastal part of the territorial sea.

3.1.1 Drilling Rigs, Production Platforms (Oil and Gas), Subsea Pipelines and Similar Installations

Notwithstanding the above, regarding the Danish Ministry of Defence's responsibility for the area, this does not include fixed offshore installations at sea, such as production platforms and drilling rigs, which are covered by the Danish Ministry of the Environment. The responsibility for the immediate response of pollution from drilling rigs, subsea pipelines and related installations as well as the initiative to mobilize equipment to combat lays with the concessionaries, and the initiative to mobilize equipment to combat spills lays with the concessionaries. However, mobilization and initiation of spill combat may be effectuated in cooperation and dialogue with the Environmental Protection Agency. The costs incurred shall be borne by the concessionaires.

3.1.2 The Macondo/Deep-Water Horizon Oil Spill

During the Macondo incident on 20 April 2010, a huge fire engulfed a deep-water horizon petroleum-drilling rig that had exploded in the Gulf of Mexico, killing 11 platform workers and injuring 7 others. After burning for hours, the rig sank on 22 April, resulting in the spread of a large oil slick from the location of the former rig. Over a period of 100 days, attempts were made to stop the oil's gushing and to control its spread. Finally, on 15 July, British Petroleum (BP) succeeded in fitting a tight-sealing containment cap, which stemmed the leak. US government data indicate that 4.9 million barrels of oil leaked before the well was capped.

As a result of the accident in the Gulf of Mexico in 2010, initiatives has been launched in the EU (EU Offshore Directive [11]) and by the oil and gas industry [12] in order to analyse the accident and evaluate whether existing standards and procedures within the offshore oil and gas drilling industry are adequate for risk mitigation and whether the setup of equipment for mechanical recovery is suitable.

3.1.3 Oil Spill Contingency Plans (OSCP)

The oil spill contingency plans (OSCP, see, e.g. ITOPF 2014 [13]) must ensure that the operator has an adequate amount of collection equipment available and that this can be mobilized within a specified maximum response time, in a tiered response, adjusted to different hypothetical spill scenarios described in the contingency plan.

The risk for unintended spillage of oil and chemicals must be held as low as reasonably possible, following the ALARP principle, by taking adequate precautionary actions relative to the risk involved in offshore oil and gas exploration and production.

OSCPs for Offshore Operators in Denmark

In 2014 there is a total of five production units in the Danish licence area (see Fig. 2 [14]) where DONG Energy Exploration and Production is the operator of the Siri/Hejre production unit, HESS Denmark is the operator of the South Arne production unit and Maersk Oil is the operator of the three production units, the Dan asset, the Halfdan asset and the Tyra asset. From the production units discharge of treated produced water from fixed point of discharge takes place. In addition, periodic discharges from mobile drilling rigs take place in connection with exploration, drilling of wells and during well service.

The offshore operators in Denmark are responsible for drawing up contingency plans in case of unintended spillage to the sea from an offshore installation will make it possible to fight oil spill. The contingency plans developed by the offshore operators must be approved by the Danish Environmental Protection Agency (Danish EPA).

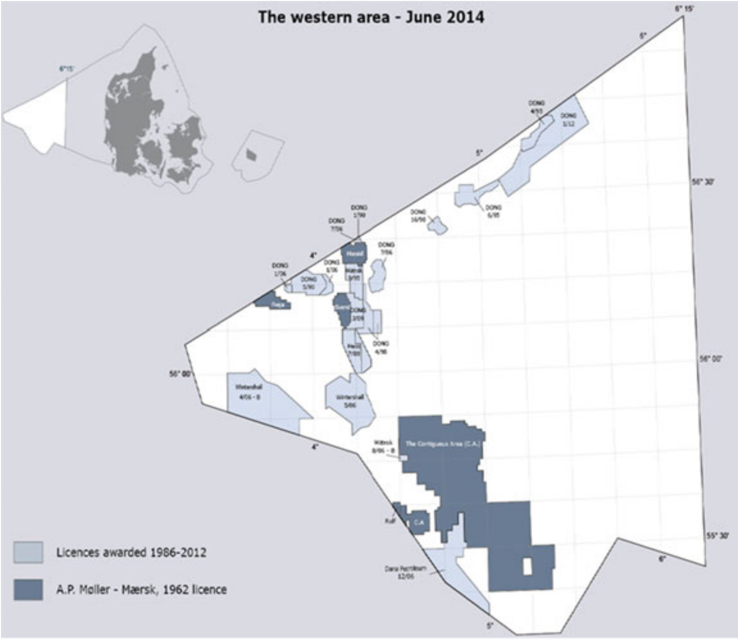

Fig. 2 Danish licence area, west. *Source*: Danish Energy Agency 2014, page 46 [14]

The contingency plans will ensure that the operator has an adequate amount of collection equipment available and that this can be mobilized within a specified response time, specified in a tiered response. In the Danish sector there are tiers 1, 2 and 3, where equipment in the fastest response (tier 1) can be operational within hours of a spill incident, which enhance the probability of gaining a high recovery rate for the spill.

The operator must have equipment for mechanical and chemical response. Chemical response (dispersants) will only be used in extreme emergencies, and any use of dispersant requires permission from the Danish EPA.

It is a requirement that exercises in spill recovery must be held at regular intervals. The Danish EPA may join these drills. The operator covers the cost in connection with an oil spill. The Danish EPA will, in the case of oil spills, reconcile the clean-up efforts with the operator in order to ensure that an attempt to collect the mechanical fightable oil or chemicals will be carried out.

Coordination During Spill Identification and Spill Recovery

All spills must be reported electronically to the Danish Defence Command and Danish EPA. Any spill of oil or chemicals judged to be either physically combatable or above a limit of 5000 l must be reported immediately by phone to the Danish EPA as well as the Danish Defence Command.

Information on spill size and location enables the Danish Defence Command to support the offshore operators with supplementary information and match the spill observations with information from recent aerial surveillance and information from satellite images. Also information is received from offshore installations in order to match information from satellite and aerial surveillance. Support by the aerial environmental surveillance and satellite service of the European Maritime Safety Agency (EMSA, http://www.emsa.europa.eu) thereby may serve to identify and support and focus the effort during recovery of a combatable oil spill or chemical spill by enabling tracking of the extension of the spill in km^2 and assist discern the thickness and the spreading and drift of a spill.

3.1.4 Aerial Surveillance

Danish Sea Environmental Aircraft

The Danish Defence Command undertakes aerial surveillance in the Danish waters, including the area of platforms, using the Royal Danish Air Force's CL-604 Challenger as a sea environmental aircraft. The Challenger performs nearly 200 flight hours in the Danish sector of the North Sea every year, at a speed of about 280 knots. With this speed a large area is covered.

German Sea Environmental Aircraft

In addition to the aerial surveillance performed by Danish sea environmental aircraft, German sea environmental aircraft also perform aerial surveillance to some extent, especially close to the Danish platforms.

EMSA

The aerial surveillance is further supported by the satellite service provided by EMSA CleanSeaNet Service [15]. In 2014 the Defence Command received more than 250 satellite images provided by EMSA covering the Danish part of the North Sea.

Tour d'Horizon [16]

All members of the Bonn Agreement agreed on performing a flight mainly along the offshore installations, of at least 600 nautical miles. The aircraft crew will concentrate on all detectable pollutions from various sources. Roughly the area between 52° north and 63°north is to be surveilled. These flights are carried out according to an agreed yearly scheme.

Coordinated Extended Pollution Control Operations (CEPCOs) [16]

A CEPCO can be defined as a continuous sequence of aerial surveillance flights supported by sea-borne assistance – and where possible also with data from satellite observations – to ensure a permanent presence (e.g. over a period of 24 h) in a sea area with high shipping intensity. This high level of deployment is only possible when several (neighbouring) contracting parties cooperate intensively to ensure continuity and optimal coordination of the surveillance activities. The aims of the operation are, inter alia:

1. To enhance the enforcement of discharge provisions at sea
2. To increase the deterrent effect of aerial surveillance efforts
3. To improve the cooperation between the participating authorities

3.1.5 Oil Pollution Response

Combat Readiness in the Form of Environmental Equipped Ships

The Danish Defence Command is the responsible authority in relation to the supervision and control of pollution of the Danish waters. Furthermore the Danish Defence Command is responsible for the deployment of the required pollution control in the event of a pollution incident at sea and to coordinate efforts. In addition to the use of their own assets in the event of an oil pollution combat situation, the Danish Defence Command can also arrange that other authorities or private parties/civilian actors become involved in the pollution response at sea in Danish waters. The Danish Defence Command may further, in accordance with international agreements, request assistance from other countries.

Combating Methods Used in Connection With Oil Spills in the Danish Sector of the North Sea

Denmark has its own capacity for oil pollution response.[2] The combat method is primarily mechanical collection where the booms confine the oil and then picks it up with skimmers.

The premise is that all oil spills which can be fought must be fought. Generally, dispersants (chemical control) is not used in the Danish sector of the North Sea. In special cases, the Danish Ministry of the Environment may authorize the use of chemicals to combat an oil spill. The specific requirements for methods and equipment, and how quickly action needs to take place, are described in each operator's contingency plans.

[2] In case of the oil and gas operators, parts of the response equipment are provided by OSRL in the UK, who are contracted by the operators.

International Cooperation Regarding Oil Spill Response

Denmark participates in several regional conventions and agreements which in case of a major oil spill ensure that the countries concerned will aim to support each other. For example, OSPAR [17] countries cooperate on the use of equipment across borders, if the need arises in case of a large oil spill. In addition, Denmark has entered into operational agreements with Sweden, Germany and the Netherlands.

OSPAR: International Cooperation to Protect the Marine Environment

The OSPAR Commission is responsible for the 1992 Convention for the Protection of the Marine Environment of the North East Atlantic (OSPAR Convention) [17], which includes the North Sea. Signatories to the Convention are Denmark, the Netherlands, Norway, the UK, Germany, France, Ireland, Iceland and Spain. The first four countries represent close to 100% of the total production of oil and gas in OSPAR.

The OSPAR Commission works to protect ocean and marine biodiversity. The framework of OSPAR's work is determined by a number of recommendations and legally binding decisions.

3.2 *Marine Environment Organization*

Marine environment organizations can be divided into two main areas: (1) organization for oil and chemical pollution response at sea (the Danish Ministry of Defence's responsibility) and (2) organization for oil pollution response on the coast and in harbours (the municipal council's area of responsibility).

3.2.1 Organization for Oil Pollution and Chemical Pollution Response at Sea

The Danish Defence Command is responsible for oil and chemical pollution response at sea. In case of pollution at sea, the Danish Defence Command coordinates the operational deployments at sea via the Maritime Assistance Service (MAS).

3.2.2 Organization for Oil Pollution Response and Chemical Pollution Response on the Coast and in Harbours

The municipalities have in accordance with the Danish Act on the Protection of the Marine Environment [4] responsibility for rehabilitation of the coastline and pollution response in harbours. The municipal council provides a contingency plan for implementation of rehabilitation of coastlines in case of significant pollution of coastlines in the municipality and for pollution response in ports.

In case of beach rehabilitation after very extensive oil pollution, the situation typically will be that the local authorities will have the management of the actual rehabilitation task within their own municipality while the overall coordination of resources will be led by the Danish Ministry of Defence.

3.3 Sailing Equipment for Oil Spill Response

3.3.1 Danish Naval Assets

At the time of writing, Denmark has two environmental vessels, the *Gunnar Thorson* and the *Gunnar Seidenfaden*, which were built in 1981. They are 56 m long with a displacement of 1,660 tonnes. They can reach a speed of 12 knots and their tank capacity for recovered oil is 311 tonnes. These two vessels, which have a crew size of 16, can both be used without limitations in the North Sea.

Denmark also has two smaller environment vessels, the *Mette Miljoe* and the *Marie Miljoe*, which were built in 1980. They are 30 m long and can reach a speed of 9 knots and their tank capacity for recovered oil is 64 tonnes. Both vessels, which have a crew size of 6, are designed for coastal navigation which means that the ships are not allowed to operate further offshore than 45 nautical miles and they are allowed only to operate within a defined line along the Danish west coast.. This means that the ships only have a limited ability to cover the Danish sector of the North Sea.

In addition to the environmental vessels, three barges are attached to the marine environmental vessels and can be deployed in conjunction with them. The collected oil from an operational area can be pumped into the barges and these can accommodate 300 tonnes each.

Denmark will in the coming years build new response vessels to replace the current ones. While plans for new vessels are not detailed, they will continue to fulfil the role of current vessels for marine environmental protection and environmental monitoring and for oil spill recovery,

3.3.2 Rescue Boats

The Royal Danish Navy has 14 closed and 18 open fast sailing rescue boats. These vessels have the capability to be used to counter oil pollution at sea. The response time of the rescue boats along the Danish west coast is 20 min every day of the year.

The rescue boats can be used for field exploration, transportation tasks and collection of oil samples from the sea.

Rescue boats can be deployed within a distance of 20 nautical miles from their starting point, and the endurance is maximum 8 h. The rescue boats participate in organized exercises in local areas where launching booms in shallow water are one of the challenges.

3.3.3 The Danish Naval Home Guard

The Danish Naval Home Guard (NHG) participates actively in the resolution of the marine environment task. This is partly done by towing and laying booms and towing barges. The booms are laid either from the coast or from an NHG unit where booms are stored. These booms may come either from the shore or from own unit, where booms are stored.

The volunteers in the NHG practice and educate themselves in close cooperation with personnel from the Danish Navy in solving the marine environment task. NHGs practise their efforts with both single vessels and as a larger coordinated cooperation effort with several vessels, nationally as well as internationally.

NHG vessel's response time is 1 h in relation to major environmental disasters. The vessels are strategically placed around Danish waters so that no matter where pollution is found, an NHG vessel will often be one of the first assets reaching the action area. The NHG vessels' main task is to launch and tow booms.

All NHG vessels are thus an important part of the marine environment preparedness because the reaction time in relation to pollution, no matter where in the Danish waters it occurs, will be relatively short due to the placing of the vessels.

3.3.4 Cooperation with Private Stakeholders

The practical element of the task of cleaning up after a marine environmental pollution accident is a task that can be solved by all of the community's available capabilities.

The result is that, when needed, the Danish Defence Command has the opportunity, at short notice, to hire private stakeholders/civil actors. The private actors will, amongst other things, be able to deliver vessels which are able to provide tug assistance and recover oil spill at sea.

Maersk Oil and Gas/Esbjerg Guard Ship Company

The Danish Defence Command has signed an agreement on mutual assistance with Maersk Oil and Gas in relation to oil spill preparedness. Maersk Oil and Gas is able to combat oil pollution at sea using available equipment which consists of equipment for confinement and recovery

The Esbjerg Guard Ship Company (ESVAGT) and chartered offshore supply vessels are designed to bring the containment and collection equipment and perform the task for Maersk Oil and Gas. The equipment is operated by personnel from ESVAGT, in cooperation with the crews of the mobilized units selected for the action. ESVAGT's units are in accordance with the agreement on a 24 h alert which means that ESVAGT only can be used as a follow-up response. Nevertheless, the capacities in ESVAGT framework are an essential resource in the event of a pollution incident in the North Sea.

ESVAGT has two emergency teams with containerized equipment. Each team has skimmers, booms, power pack for inflating the booms and specially educated personnel. Ships for transporting equipment and personnel are appointed/chartered in each case.

3.4 Other Partners

3.4.1 The Danish Emergency Management Agency

The Danish Emergency Management Agency's primary task is defined in the Emergency Management Act [17]; with subsequent amendments, it only includes responsibilities at the shore and in the associated water areas like lakes and rivers.

The Danish Emergency Management Agency does not have an independent functional or economic responsibility in relation to pollution response at sea. However, it does assist at contractor base on the basis of the Emergency Law, Section 8, the defence – the Danish Defence Command – with contributions in relation to the solution of tasks in accordance with the Danish Act on the Protection of the Marine Environment. The work will involve tasks related to oil pollution response in shallow water and in places where the naval vessels cannot enter.

3.4.2 The Local Authority's Preparedness

As noted previously, local councils have, in accordance with the Danish Act on the Protection of the Marine Environment, the responsibility of coastline clean-up related to oil pollution above the normal water level line. In practice, it is the coast above the current water's edge. The question about the organization of the individual municipality's readiness to perform its duties in accordance with the Danish Act on the Protection of the Marine Environment is not further regulated. It is thus the individual municipality which makes the decision about the mobilization's size and design. After consultation with the municipal organizations, the Environment Minister draws up guidelines for the content of municipal emergency plans in accordance with the Danish Act on the Protection of the Marine Environment, Section 36 [4].

3.4.3 Nord

The Danish Defence Command has an agreement with the company Nord relating to the transport and processing of oil and chemical waste collected by the Navy's marine environmental ships.

3.4.4 The Police

The police are, in accordance with the Danish Act on the Protection of the Marine Environment [4], Section 35, not assigned specific tasks or skills in relation to the marine environment. They will, however, be included in the authority cooperation which is established through extensive pollution in order to ensure the best possible performance of police operations such as traffic control, roadblocks, press office and issuing of warnings and directions to the civilian population related to oil spill response. The Danish Defence Command may, by appointment, use the police's command and control facilities when a major pollution response must be coordinated locally in Danish waters.

4 Preventive Measures on the Marine Environment

The purpose of implementing preventive measures on the marine environment is to promote shipping safety for the maritime traffic. It will indirectly help prevent pollution of the marine environment. In Denmark it is considered essential that, on the one hand, there should be a focus on maintaining adequate preparedness if an accident were to occur and pollution of the environment is a fact and that, on the other hand, there should also be a focus on promoting risk reduction measures which will reduce the risk of an accident at sea and consequently pollution.

4.1 The Safety of Navigation in the Danish Sector of the North Sea

At the time of writing, no traffic separation schemes, vessel traffic services nor shipping lanes are established in the Danish sector of the North Sea. In this regard, there are currently no specific plans in the pipeline.

4.2 Hailing of Ships

With regard to surveillance and enforcement of the marine environment, the routine hailing (contacting) of ships passing through Danish waters is performed. When performing a hail, a maritime surveillance centre or a naval unit will call up a ship in order to obtain information about the ship's owner, cargo, insurance company and content of the oil record book. All calls are completed by informing the ship that, in accordance with the MARPOL 73/78 Convention [5], it is not legal to discharge anything other than clean water in Danish waters.

5 Oil Spill Statistics

5.1 Incidents in the Period 2010–2014

5.1.1 Collision Between Golden Trader and Vidar

Within the five-year period 2010–2014 (inclusive), there was only one serious incident in the Danish sector of the North Sea. On 10 September 2011, the Maltese flagged bulk carrier *MV Golden Trader* and the Belgian flagged fishing vessel *Vidar* collided in the North Sea, off the Danish Coast.

Several days after the collision, the Swedish Accident Investigation Authority informed the Marine Safety Investigation Unit of a severe pollution incident, which had been reported on the Swedish western coast. Analysis carried out during the course of the safety investigation confirmed that the oil washed ashore had leaked from a breached heavy fuel storage tank fitted to the *Golden Trader*. It was estimated that the total amount of heavy fuel oil lost on board was approximately 450 m^3.

The immediate causes of the collision were determined to be an inaccurate interpretation on board *Golden Trader* of the developing close quarter situation and potential navigational practices on board *Vidar*.

5.1.2 Spill of Crude Oil During Bunkering from the Syd Arne Platform

Between 2010 and 2014, no major oil spill incidents occurred at the platforms inside the Danish EEZ. However, prior to that period, a major spill incident took place at the Syd Arne platform area in December 2008. During bunkering of crude oil from storage facility on the seafloor beneath the Syd Arne production platform to a tanker, an oil spill was observed. When the spill was observed, pumping was stopped and the authorities were informed. A Danish sea environmental aircraft on a reconnaissance flight was directed to observe the oil spill and estimated the oil volume to more than 650 m^3 in this area. The spill was recovered by two strike teams that were mobilized from Esbjerg Harbour to collect the oil. No dispersants were used. A minor additional spill happened due to back-flushing in the bunkering system.

Danish and German environmental aircrafts, as well as data from side-looking airborne radar (SLAR), served to focus and enhance the recovery rate during the mechanical combat of the spill. Spill recovery was, at one stage, hindered due to failure of skimmer pump. Estimated recovery rate was app. 20% of the calculated spill size, as approximately 28,000 l seawater with crude oil was collected and brought ashore before weather conditions and spreading and thinning of the oil hindered the collection of oil. A root cause investigation and precautionary action was taken to avoid similar spill incidents during bunkering of crude oil offshore. Furthermore, a tier 1 response, as described in the section "OSCPs for Offshore Operators in Denmark", within few hours is now possible due to equipment on a standby vessel, which served to enhance recovery rates of spills.

5.1.3 Other Incidents

During the period 2010–2014, a plurality of groundings, collisions and loss at sea have taken place in the Danish sector of the North Sea, but these events had no or only a minor impact on the marine environment.

5.2 Observations of Possible Oil in the Danish Sector of the North Sea

5.2.1 All Observed Spills in the Danish Sector of the North Sea Using Bonn Agreement Data

During the 10-year period from 2000 to 2010, the number of observed slicks confirmed as oil spills [8] ranged from 33 slicks in 2000 and 2009 to as high as 164 in 2008 using both aerial surveillance and satellite surveillance data (see Fig. 3). The use of satellite surveillance from 2004 onwards means that it is possible to identify slicks during the hours of darkness, a time when intentional oil spills may occur, and has broadened the geographical coverage of surveillance activities beyond what is possible using aerial surveillance only.

However, the number of slicks does not necessarily provide a complete picture of what has been happening in the Danish North Sea Region. Figure 4 compares the number of flight hours per year against the number of observed slicks for the 20-year period from 1990 to 2010. There was wide variability both in the number of flight hours conducted and in the number of observed slicks, and this is reflected also in the ratio of flight hours to observed slicks, a way of identifying whether there has been any specific trend over time (see Carpenter, 2007 [18])

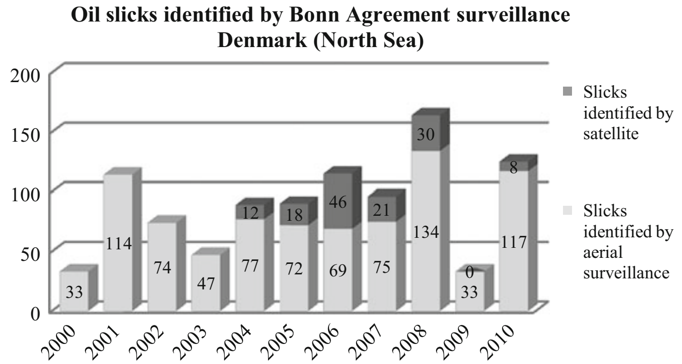

Fig. 3 Oil slicks observed by aerial and satellite surveillance in the waters of the Danish sector of the North Sea, 2000–2010

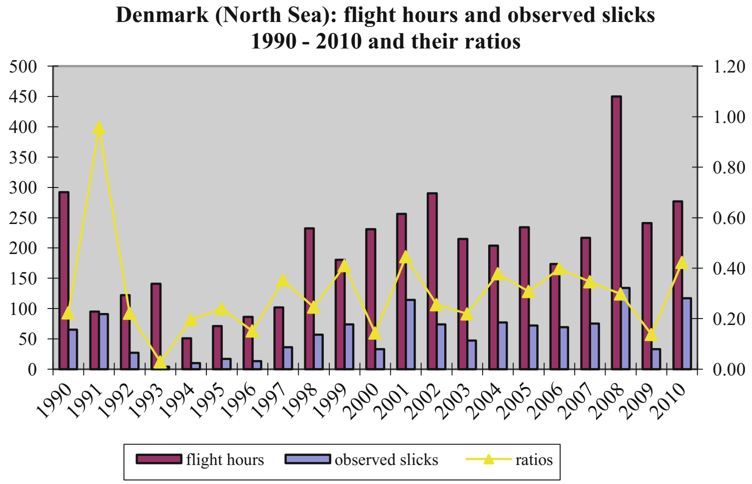

Fig. 4 Number of flight hours and observed slicks between 1990 and 2010 in Danish North sea waters and the ratio of slicks to flight hours

In 1990 there were 292 h of aerial surveillance flights conducted in the Danish North Sea Region. This subsequently fell to only 51 h in 1994, rising to a high of 450 h in 2008. The number of observed slicks in the same years was 65, 10 and 134 slicks, respectively. Also for those same years, the ratio of slicks to flight hours is 0.22, 0.03 and 0.30. The highest ratio of slicks to flight hours occurred in 1992 where 91 slicks were observed during just 95 h of aerial surveillance flights, giving a ratio of 0.96. However, across the whole 20-year period, the next highest ratio is 0.45 in 2001, all other years being lower than that value.

What Figs. 3 and 4 illustrate is that there continues to be wide variations year on year in the Danish North Sea Region but that, with increases in the number of flight

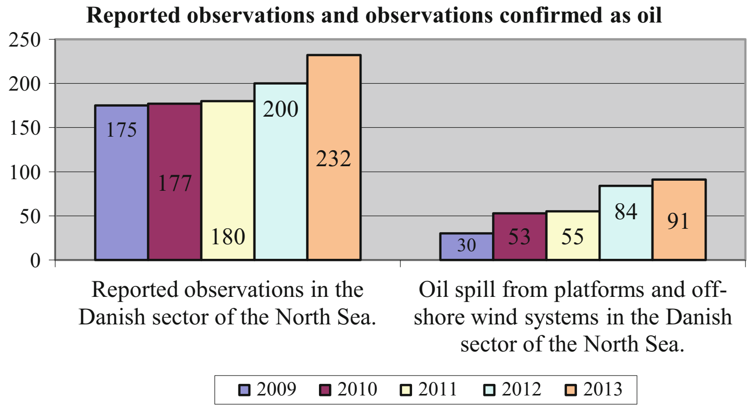

Fig. 5 Observed and confirmed oil spills from platforms and offshore wind systems in the Danish sector of the North Sea

hours and the use of satellite surveillance, it is possible to more accurately identify slicks and also the source of those slicks.

5.2.2 Observed Spills from Oil Platforms

During the period 2009–2013, there was an increase in reported observations of possible oil spills from oil platforms in the Danish sector of the North Sea of 33%, from 175 to 232 possible spills (see Fig. 5). At the same time, reported observations of oil and chemical spills from oil rigs and offshore windmills increased by 203% from 30 to 91. It is estimated that the reason for the increase in oil spills from platforms and offshore wind systems in the Danish sector of the North Sea is due to better cooperation between the land-based authorities and the operators of offshore installations in relation to effective reporting of spills. Hence, the increase in incidents does not reflect a significant real-term increase in the volume of oil and chemical spills. Several quite small spills, some of which reflect nearby-major-spill incidents, are now included in the statistics, which makes it possible to identify the causes of incidents and to enhance procedures to avoid any incidents that may lead to unplanned discharges to the sea.

5.2.3 Observed Discharges from Shipsy

Between 2009 and 2013, there has been a steady decline in observed discharges confirmed as coming from ships in all Danish waters. Ninety-five discharges from ships were observed during 2009 in Danish waters, while in 2013 only 39 discharges were observed. This is a reduction of 68%.

In 2012 and 2013, less than 10 oil spills are estimated to originate from ships in the Danish sector of the North Sea in each of the years.

6 Conclusions

Monitoring for, and handling of, oil pollution in the waters of the Danish sector of the North Sea remains a priority in a region which is one of the most highly trafficked maritime regions in the world. Despite the economic recession of the late 2000s, the area, which is the gateway between the North Sea and the Baltic Sea, is expected to see continued growth in shipping traffic. This brings with it an ongoing risk of accidental (and potentially deliberate) oil and chemical pollution from shipping.

The Danish sector of the North Sea Region is regulated at multiple levels, from international conventions such as UNCLOS and MARPOL, by regional agreements such as the OSPAR Convention and the Bonn Agreement, by EU legislation such as directives such as the EU Offshore Directive and also through bilateral and trilateral agreements with its neighbouring countries (Germany and the Netherlands). Responsibility for aerial surveillance and for combating oil spills at sea lies with Danish Defence Command.

This chapter sets out the range of legislative measures under which surveillance and pollution handling activities occur in the region. It also sets out the responsibilities of the various stakeholders, from the Danish Defence Command to the municipal authorities, and of private companies and civil agencies. It discusses the range of surveillance activities taking place in the region under the aegis of the Bonn Agreement, for example, and the range of equipment available to handle spills ranging from Danish naval assets to equipment operated by private companies.

What this chapter shows is that continued high volumes of shipping traffic, and continued production from offshore oil and gas platforms in the Danish North Sea, means that there also continues to be oil spills in the region coming from both ships and oil platforms. However, ever more accurate surveillance methods and the use of satellite surveillance, for example, can be interpreted to mean that the sources of spills can be determined more accurately, giving the potential for the companies responsible to be held accountable for helping clean up spills and for the costs of their environmental impacts.

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Oil Pollution In and Around the Waters of Belgium

Ronny Schallier and Ward Van Roy

Abstract Although the waters of Belgium only form a minor part of the North Sea, they contain some of the busiest shipping routes in the world with the Dover Strait and some of the biggest European ports in the immediate vicinity. It is therefore recognized as a key maritime risk area, also in terms of ship-source oil pollution. This chapter first discusses the significant, stepwise decrease of illegal oil discharges from ships in and around the waters of Belgium based on national aerial surveillance data since 1991 but also gives indications as to why the ecological quality objectives have not yet been met despite this decline. It further gives an overview of the accidental oil pollution incidents in this key risk area over the last 30 years and reflects on the high level of accidental marine pollution risk. Finally, the various measures are discussed that have been and will be undertaken in terms of oil pollution prevention, enforcement, preparedness and response with the aim to (further) reduce the oil pollution pressure in this environmentally sensitive area.

Keywords Aerial surveillance, Decrease in illegal oil discharges from ships, Ecological and socioeconomic importance, Key risk area, Oil pollution prevention, Preparedness and response, Shipping accidents, Southern North Sea, Waters of Belgium

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Contents

1 Introduction

1.1 Ecological Importance of Belgian Waters and Shores

Of all North Sea coastal States, Belgium has by far the shortest coastline (ca. 65 km). The waters of Belgium, or Belgian marine areas, can be subdivided into the territorial sea (12 nautical miles) and the exclusive economic zone. They contain a total surface of nearly 3,500 km^2 [1] which is merely 0.5% of the entire North Sea area. Nevertheless this small Belgian part is considered very important from both an ecological and a socioeconomic point of view [2].

The waters of Belgium consist of a very shallow part of the southern bight of the North Sea, with a sea floor that gradually decreases towards the northwest up to a water depth of 40–45 m, and which is characterized by the presence of a complex system of trenches and elongated, shallow sandbanks. The strong semidiurnal tidal currents in the area, with tidal amplitudes between 3 and 4.6 m and currents of more than 1.2 m s^{-1} and the low fresh water discharge of the river Scheldt, result in well-mixed nearshore waters [3, 4]. This dynamic marine environment contains very diverse and abundant benthic populations, such as, amongst others, the highly diverse coastal sand mason (*Lanice conchilega*) beds and offshore gravel beds, which make them important feeding and nursery areas for higher trophic levels such as fish and birds [5–7]. As such, Belgian coastal waters are very important spawning grounds and nursery areas for a.o. sole. They also form a nursery area for other commercial fish species such as plaice and cod [4].

The waters of Belgium form an important wintering and foraging area for seabirds [8, 9]. During winter months, the Belgian coastal waters regularly harbour internationally important numbers (i.e. more than 1% of biogeographical population) of great crested grebes (*Podiceps cristatus*) and the great black-backed gull (*Larus marinus*), together with important numbers of the red-throated diver

(*Gavia stellata*) and the common scoter (*Melanitta nigra*). In spring and summer months, the coastal zone forms an important foraging area for internationally important numbers of terns (sandwich tern *Sterna sandvicensis*, common tern *Sterna hirundo*, and little tern *Sternula albifrons*) which mainly breed in the port of Zeebruges [10]. Finally, the Belgian part of the North Sea functions as important migratory corridor used by more than a million seabirds during the migration period [11].

In order to sustainably preserve the most valuable marine habitats and seabird areas, a series of marine-protected areas have been designated: a Special Area for Conservation or SAC called 'Trapegeer-Stroombank' area (EC Habitat Directive area) containing a Ramsar Zone and three Special Protection Areas or SPAs (EC Birds Directive areas) have been created in the Belgian coastal waters (Fig. 1). Finally, a large additional Habitat Directive area called the 'extended

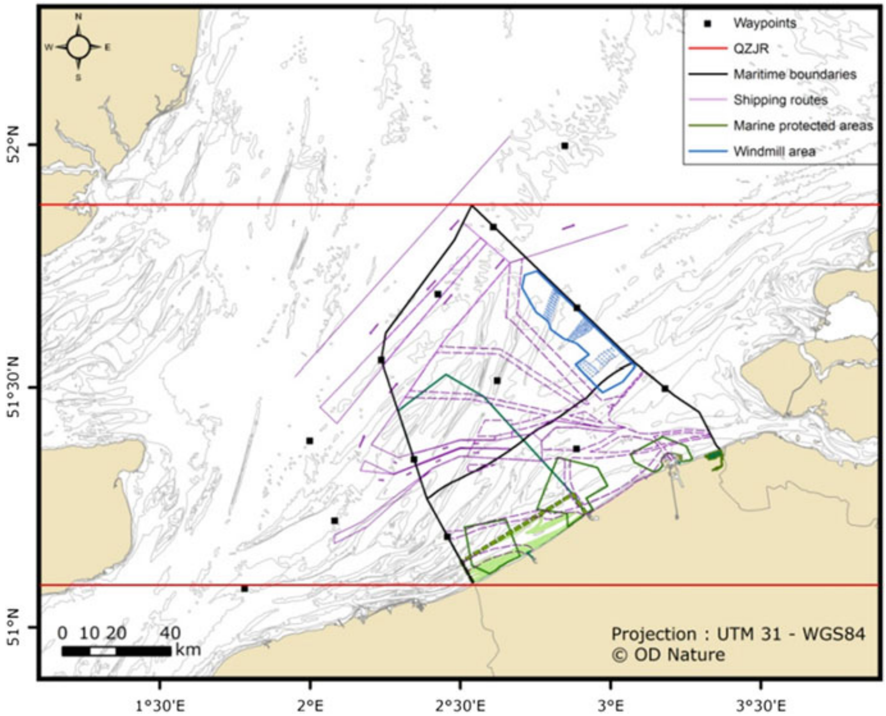

Fig. 1 Overview map of Belgian surveillance area. The *black squares* are the 'waypoints' used for flight routing and reporting. The *horizontal red lines* reflect the Quadripartite Zone for Joint Responsibility (QZJR). The *black lines* correspond to the Belgian maritime boundaries, which consist of the territorial sea and the EEZ. The *purple lines* reflect the shipping routes, with the *solid lines* corresponding to the primary shipping routes (NHTSS and WHTSS) and the *dotted lines* corresponding to the secondary shipping routes. The *green lines* and areas correspond to the various marine protected areas in the waters of Belgium. The *blue line* reflects the Belgian offshore wind farm area with indication of the current wind turbines (*blue dots*)

Trapegeer-Stroombank' area has recently been announced to the EC and is therefore recognized as a Site of Community Interest [10].

The Belgian coastline mainly consists of fine sandy beaches and dunes. It also contains three important intertidal nature reserves consisting of sheltered coastal salt marshes and mudflats [1]: the 'Zwin', the 'IJzermonding' and the 'Baai van Heist' – a reserve which has both a coastal and a marine part.

1.2 Socioeconomic Importance of Belgian Waters and Shores

With its gently sloping sandy beaches, the Belgian coastline attracts plenty of tourists, mainly in the summer season. With an average of 15 million commercial overnight stays per year and around 19 million of annual day tourists, the coastal tourism is a crucial touristic sector in Belgium in the summer period [12, 13].

The waters of Belgium also contain important fishing grounds. Beam trawl fishery is the dominant type of fishing activity in the area, with both flatfish beam trawl fisheries and, in coastal waters, shrimp beam trawl fisheries [14]. Both the Belgian and Dutch southern fishing fleet are active in the area.

Industrial activities at sea have for years been mainly limited to sand and gravel extraction activities, since there are no offshore oil and gas installations on the Belgian continental shelf. But a very recent and growingly important industrial activity is the construction and exploitation of offshore wind farms (Fig. 1), driven by demands for increased renewable energy [15]. By the end of 2013, three offshore wind farms have been constructed in the Belgian EEZ consisting of 135 wind turbines with total installed offshore wind energy capacity of 571 MW, which placed Belgium in the third place in Europe in 2013 – only preceded by Denmark and the United Kingdom [16]. And plans exist for the construction, in the next few years, of four additional offshore wind farms in the designated offshore energy zone in the Belgian EEZ.

Maritime transport and shipping however remains the most important economic activity in and around the waters of Belgium. The Belgian part of the North Sea is situated just northeast of the Dover Strait and in the immediate vicinity of the two biggest ports of Europe, Rotterdam and Antwerp. They contain some of the busiest shipping routes in the world, with more than 150,000 ship movements per year – or 400 ship movements a day – in the central Traffic Separation Scheme that goes through the Dover Strait [17] and almost 60,000 ship movements in other maritime traffic routes in the Belgian waters [18]. Although most ships are merely in transit through Belgian waters, being en route towards the wider North Sea or the Channel, the number of ships calling into Belgian ports, and thus the economic importance of the Belgian ports, is very high. In 2013 the total maritime traffic volumes in the Hamburg-Le Havre range (i.e. the range of most important German, Dutch, Belgian and French ports between Hamburg and Le Havre) mounted to 1,109 million tonnes. The share of the four Belgian sea ports (Antwerp, Ghent, Zeebruges and Ostend) therein was 262 million tonnes, or 23.6% [19].

1.3 A Key Risk Area for Ship-Source Pollution

The very dense maritime traffic in the waters of Belgium is forced into narrow shipping lanes due to the shallow sandbank system in the area, and further offshore it follows the central Traffic Separation Scheme that connects the southern North Sea with the Dover Strait. Moreover, the surrounding waters contain two important maritime traffic junctions, the junction at the Sandettie bank in the south and the Noordhinder junction in the north. This dense and complex maritime traffic situation in and around Belgian waters creates a major maritime safety risk as well as a major risk for deliberate and accidental marine pollution from ships. The North Sea coastal States have therefore jointly recognized this area as a key risk area for ship-source pollution, which in the framework of the Bonn Agreement has led to the designation of a zone of joint responsibility of Belgium, France, the United Kingdom and later extended to the Netherlands [20] (Fig. 1). In this quadripartite zone of joint responsibility (QZJR), containing the waters of Belgium and the surrounding French, British and Dutch waters, the four mentioned countries have the obligation to perform regular surveillance.

This chapter will firstly further discuss the chronic problem of deliberate operational oil discharges from ships in and around the waters of Belgium (QZJR). Then the focus will shift towards the risk for accidental marine pollution in this key risk area, based on a historical overview of oil pollution accidents and on findings and conclusions of national and regional oil spill risk assessment studies. Trends in both types of oil pollution will be presented. Furthermore an overview will be given of the range of (most relevant) policy measures undertaken in terms of marine pollution enforcement, prevention, preparedness and response with the aim to substantially reduce ship-source oil pollution and its impact in the area.

2 Illegal Oil Discharges from Ships

2.1 Aerial Surveillance as Method for Monitoring Oil Pollution In and Around the Waters of Belgium

Illegal operational oil discharges from ships have been a chronic environmental problem in the greater North Sea for several decades, leading to severe chronic oiling of seabirds and sensitive coastlines [21, 22], also in Belgium [23]. The operational oil spills found at sea are the result of illegal discharges of engine room bilges and fuel oil sludge by merchant ships and other vessels, or oil cargo residues from tankers [24, 25]. Recognizing that the number of illegal oil discharges from ships remained unacceptably high, the North Sea coastal States jointly decided in 1987 to intensify airborne surveillance initiated in the framework of the Bonn Agreement, as an effective means to enforce international antipollution regulations at sea [26]. In this framework, Belgium has been performing surveillance flights over the North Sea since 1991, by means of a remote sensing aircraft (Britten Norman Islander) equipped with a Side Looking Airborne Radar (SLAR), performing randomly planned flight routes following predefined BA waypoints (Fig. 1). Belgium performs ca. 200–250 national flight hours per year in its surveillance area being the QZJR. The main objective of these flights is marine pollution control, i.e. the detection of illegal discharges from ships (violations of the MARPOL discharge regulations).

Aerial surveillance is also a well-accepted method for monitoring of oil pollution at sea [27–30]. Since the start of the Belgian aerial surveillance programme in 1991, regular pollution control flights have been performed in the Belgian Surveillance area. Oil slicks floating at the sea surface have systematically been monitored and documented since 1991 following standard Bonn Agreement pollution detection, observation and evaluation procedures.

The Belgian surveillance area represents a very interesting study area for trend analysis of illegal operational oil spills originating from ships, because it has no offshore oil and gas installations and the mineral oil pollution in this densely navigated area originates almost entirely from chronic illegal operational discharges from ships. The data collected in this area through the Belgian aerial surveillance programme, with the same remote sensing aircraft and with a relatively stable annual number of flight hours over the years, have shown to form an excellent dataset to analyse long-term trends in operational oil discharges [30].

2.2 *Significant Decrease in Chronic Oil Pollution Pressure*

Figure 2 shows the number of operational oil slicks that have been detected and observed by the Belgian aircraft in the Belgian surveillance area (QZJR) for the period 1991–2013, presented as number of slicks per flight hour above the sea. The figure shows that whilst the slick detection frequency was in the order of 0.2 or 0.25 slicks per flight hour in the 1990s (being 1 slick every 4–5 flight hours or ca. 50 slicks per year), this frequency decreased drastically to less than 0.1 slicks per flight hour in recent years (being less than 1 slick in 10 flight hours or <20 slicks per year). Figure 3 shows the total estimated oil volumes of these slicks per year. It illustrates the even more drastic decrease in annual oil volumes found in the QZJR between 1991 and 2013.

Belgium recently performed a detailed statistical analysis on its national operational oil slick database following 20 years of aerial surveillance in the QZJR, i.e. period 1991–2010 [30]. The analysis results confirmed a statistically significant and stepwise decrease in the annual number of oil slicks, their total polluted surface

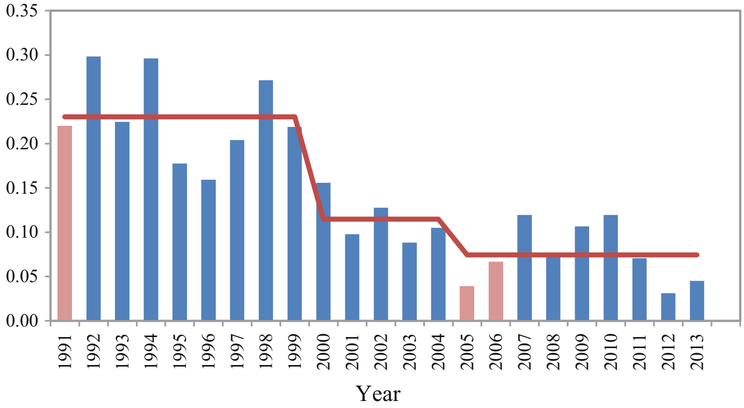

Fig. 2 Number of observed/detected operational oil slicks per flight hour (the years 1991, 2005 and 2006 are transition years with a reduced number of total flight hours – 1991, start-up year; 2005–2006, transfer and conversion of aircraft). The *red line* reflects the average number of observed operational slicks per flight hour for each of the three subperiods (1991–1998, 1999–2005 and 2006–2013)

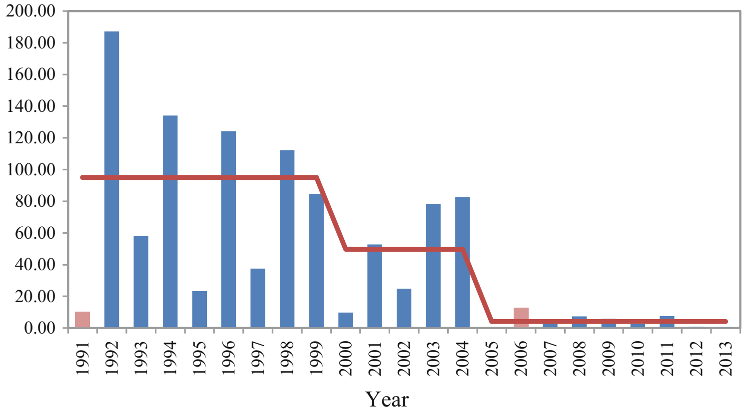

Fig. 3 Total estimated observed operational oil pollution volume per year (the years 1991, 2005 and 2006 are transition years with a reduced number of total flight hours – 1991, start-up year; 2005–2006, transfer and conversion of aircraft). The *red line* reflects the average total estimated observed operational oil pollution volume for each of the three subperiods (1991–1998, 1999–2005 and 2006–2013). The total oil volumes observed in 2005, 2012 and 2013 are below 1 m^3 and therefore not visible in the figure

(oiled area) and estimated volume throughout the study period. Two crucial turning points in the fight against deliberate ship-source oil pollution were identified: the first turning point being the year 1999 in which the designation by IMO of the northwest European waters (incl. the North Sea) as Special Area under MARPOL Annex I took effect and the second turning point being the years 2004–2005, during

Table 1 Overview of the detected and observed operational oil slicks over the three subperiods 1991–1998, 1999–2005 and 2006–2013, per volume category (minor slicks, <0.1 and 0.1–1 m^3; medium slicks, 1–10 m^3; and major slicks, >10 m^3)

	Subperiod 1	Subperiod 2	Subperiod 3
Oil volume category (m^3)	1991–1998	1999–2005	2006–2013
<0.1	191	113	76
0.1–1	128	32	24
1–10	53	23	11
>10	15	8	0

which the implementation of the Port Reception Facilities Directive 2000/59/EC became effective all over the EU and after which a general improvement of the ship waste handling facilities could be confirmed [31, 32]. In the Belgian study, it was found that the oil slick numbers and their surface had significantly decreased with ca. 50% when comparing the period before and after 1999, whereas the total oil volumes had not significantly decreased [30]. This indicates that most of the vessels and ship owners tended to respect the very stringent 'Special Area' discharge regulations from 1999 onwards but also that those who chose not to comply could still discharge considerable amounts of oil into the sea. Another somehow opposite trend was found however when comparing the oil slick data before and after the period 2004–2005. No (second) significant decrease was found in slick numbers or in their surfaces around this second turning point, but a highly significant decrease of almost 90% was found in observed oil spill volumes. This result demonstrates the impact at sea of the implementation of the Port Reception Facilities Directive. Apparently this Directive made it very difficult for ships to discharge large quantities of oil into the sea.

The exact amount of observed oil slicks for the period 1991–2013, per volume category and per subperiod, is added in Table 1. Furthermore three maps have been added which illustrate the spreading of the observed oil slicks in the area (Figs. 4, 5, and 6). These maps show the spatial distribution of the various operational oil discharges found in the area for each of the above subperiods: 1991–1998, being the period before the designation of the North Sea as Special Area under MARPOL Annex I took effect; 1999–2005, being the period before the Port Reception Facility Directive was effectively implemented throughout the EU; and 2006–2013, being the most recent period following the effective EU-wide implementation of the Port Reception Facility Directive.

These spatial maps are only qualitative of nature, meaning that they only visualize the location of the oil slicks found in the surveillance area over the years, and do not contain information on variations in frequency of overflights in the area. It is believed however that these maps give a good overview of the chronic oil pollution pressure in the area, since the surveillance area is very small and a typical pollution control flight in the area with a remote sensing aircraft along the predefined waypoints covers most of the area effectively – except for the British territorial waters that are only rarely overflown. The operational oil slicks plotted on

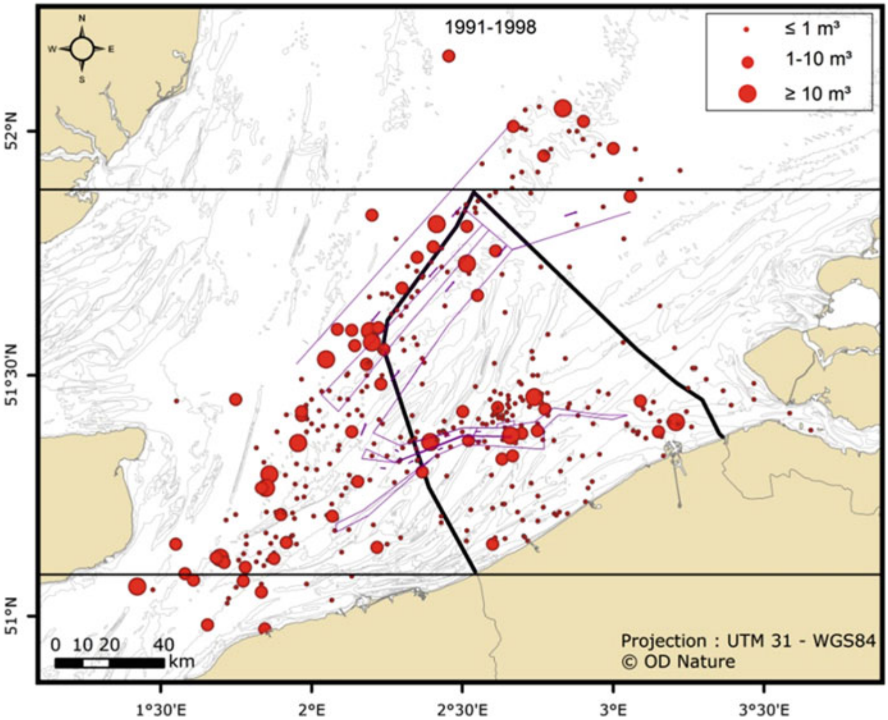

Fig. 4 Operational oil slick distribution map for the first subperiod (1991–1998)

the three maps are furthermore divided in various oil volume categories, with minor slicks (<1 m^3), medium slicks (1–10 m^3) and major slicks (>10 m^3).

It should be noted that with regard to the estimated oil volume data for the years 1991 till 2003, a special data processing approach has been applied as in Lagring et al. [30]: correction factors have been applied to recalculate the oil slick volumes for the slicks found before 2004 (when the 'old' Bonn Agreement colour code was still used to estimate oil volumes) in order to be able to use and compare oil volume data collected before and after 2004 – since from 2004 onwards, the new, better scientifically underpinned Bonn Agreement Oil Appearance Code is used for volume estimations [33, 34].

The three maps (Figs. 4, 5, and 6) supported by the oil slick numbers per volume category and per subperiod (Table 1) strikingly visualize the decreasing effect in and around the waters of Belgium of the various policy measures undertaken over the years to reduce chronic oil pollution from ships. What the maps also show is that the chronic oil pollution pressure from ships seems to have spatially shifted over the years. Whilst in the first subperiod (1991–1998) by far most of the slicks were found in the primary shipping lanes (Dover Strait; Noordhinder TSS; Westhinder TSS), this is less pronounced in the second subperiod (1999–2005). The opposite even seems to be found in the third map representing the most recent subperiod

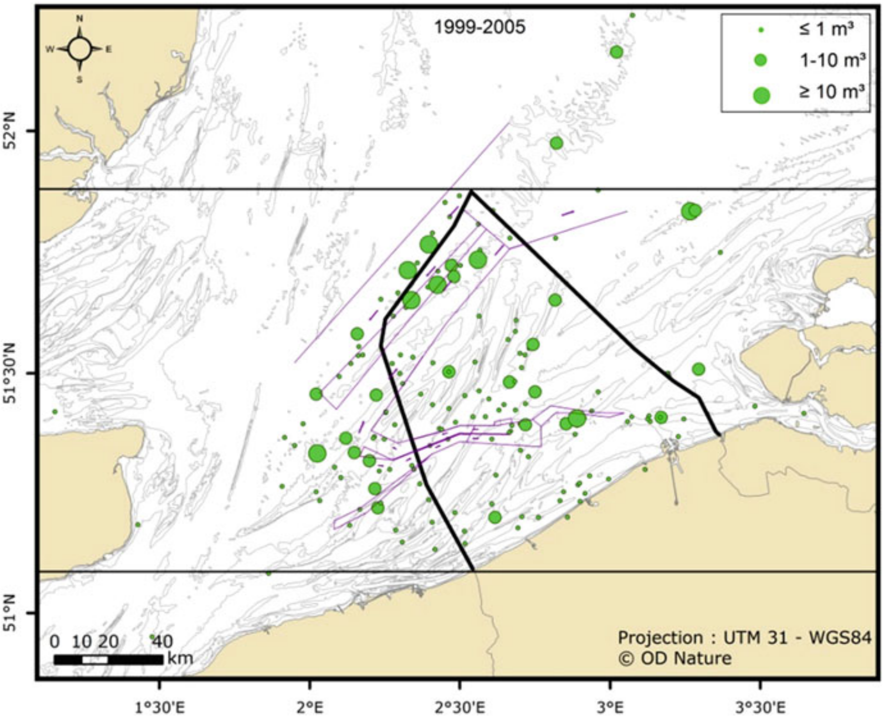

Fig. 5 Operational oil slick distribution map for the second subperiod (1999–2005)

(2006–2013), in which the remaining slicks tend to be located outside the primary shipping lanes and nearby secondary routes that are mostly used for short sea shipping between the United Kingdom and the West European mainland or between coastal ports. This remarkable shift in spatial slick distribution is probably an unfortunate effect at sea of the exception on the waste delivery obligation laid down in the EC Port Reception Facilities Directive [35]. Article 7 is one of the key Articles of this Directive, in that it contains the delivery obligation put on the master of the ship to deliver all ship-generated waste. However, Article 7.2 also allows an exception from this principal obligation in situations where it can be established that there is sufficient storage capacity for all ship-generated waste that has been and will be accumulated during the intended voyage of the ship until the port of delivery. In such cases, and this is generally the case for short sea shipping, a ship may proceed to the next port of call. In 2010 EMSA already concluded that due to different interpretations and application of the exception in Article 7.2 between EU Member States, the enforcement thereof can still be improved with the aim to further avoid discharges at sea [36].

From the above, it can be concluded that there is an overall, significant decline in chronic ship-source oil pollution in the Belgian surveillance area, as reported for other or wider marine areas in various other publications (e.g. [28, 29, 36, 37]).

It would be incorrect to attribute this overall decline in operational oil discharges from ships entirely to the two abovementioned key legislative measures. The decreasing trend should be seen in a wider context of preventive, deterrent and enforcement measures that have been taken over the years at various levels. There is little doubt that the two key regulatory measures – i.e. Special Area designation and Port Reception Facilities Directive – would not have had the same effect if these regulations had not been adequately controlled and enforced [30]. As a result of continuously improved regional cooperation between inspectors, police services and judicial authorities, for instance, ships caught red-handed at sea over the years by the Belgian remote sensing aircraft have not only been facing prosecution in Belgium but also in France, the United Kingdom and the Netherlands or even in Germany and Sweden, resulting in fines imposed on polluters in the order of magnitude of several 10,000–100,000s of Euro, up to a fine of 1.5 million Euro imposed on a MARPOL offender in a Belgian court of law, for a major illegal oil discharge performed in Belgian waters.

In terms of environmental impact, a similar decreasing trend in oiled seabirds on Belgian shores is perceptible [38] (unpublished data INBO). However, the OSPAR ecological quality objective regarding oiled seabirds – i.e. that the average proportion of oiled common guillemots should be 10% or less of the total found dead or

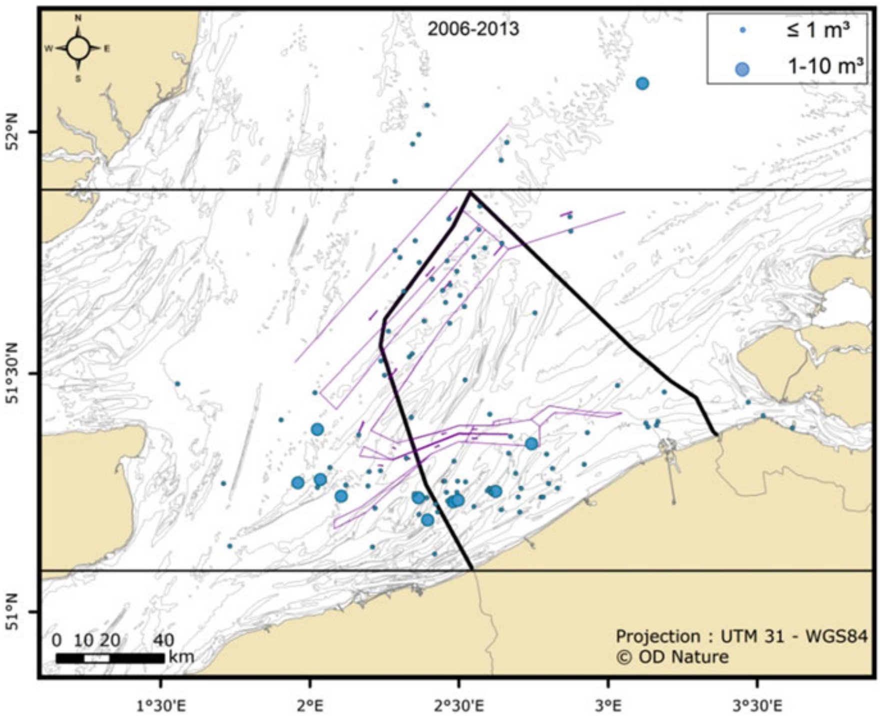

Fig. 6 Operational oil slick distribution map for the third subperiod (2006–2013)

dying in various North Sea areas over a period of at least 5 years [39, 40] – has not yet been reached in Belgium. The recent shift in location of operational discharges from primary to secondary routes in the area (Fig. 6), in particular the coastal secondary route which crosses the important wintering and migratory area for seabirds in the western coastal waters of Belgium, is probably the main reason why this ecological quality objective has not yet been met despite the overall decline in chronic oil pollution pressure.

For these reasons, Belgian authorities continue to make the surveillance efforts needed to further reduce the number of illegal oil discharges in the area, taking into account new means such as EMSA's CleanSeaNet satellite surveillance. In recent years, major efforts have also been made to accelerate and improve the follow-up and prosecution process in case a ship is caught red-handed, through inter alia the creation of a national coastguard centre on maritime security (MIK), the fine-tuning of national enforcement procedures and the appointment of specific environment magistrates.

3 Accidental Marine Pollution

3.1 Historical Overview of Shipping Accidents with (Risk for) Accidental Oil Pollution

As explained in Sect. 1.3, the waters in and around Belgium contain some of the busiest shipping routes in the world and are internationally known as a key maritime risk area, also in terms of accidental marine pollution from ships. Groundings are the most frequent type of shipping accident in the area with on average 5–10 groundings per year; collisions between ships represent the second most frequent type of shipping accident in the area, with on average 1–3 collisions per year [18, 41]. Contrary to the groundings, which almost never lead to pollution given the soft sandy sediments in the area, ship to ship collisions regularly result in accidental marine pollution [42, 43]. Table 2 gives an overview of the historic list of maritime incidents in the last 30 years (period 1985–2014) which resulted in accidental marine pollution, or a significant risk thereof, in and nearby the waters of Belgium (QZJR). Figure 7 contains a pie diagram derived from Table 2, which visualizes the 'weight' of each accident type. Based on these historic accident data, the following can be concluded:

- Since 1985, in total 28 maritime accidents took place in and around the waters of Belgium which resulted in accidental marine pollution by oil or to a significant risk thereof (in 23 and 5 cases respectively).
- Collisions are the main cause for accidental marine pollution in the area (representing nearly 2/3 of the accidents).
- Exactly half of the accidents, and most of the major ones (Borcea, Bona Fulmar, Tricolor, Vicky, etc.), happened outside the Belgian marine areas – i.e. in

Table 2 Historical overview (period 1985–2014) of shipping accidents with (risk for) accidental oil pollution in and nearby waters of Belgium and in Belgian coastal ports ([42, 43]; Statistics MUMM; info Borcea and Baltic Ace: *Source*: RWS Noordzee, The Netherlands)

Name vessel(s)	Year	Area[a]	Location	Cause	Vessel type(s)	Oil vol.[b]
Olympic Dream	1987	NL	Westerscheldt river	Fire	Oil tanker	(Risk)
Skyron/Hel	1987	UK	Dover Strait	Collision	Oil tanker + general cargo ship	120 m^3
Borcea	1988	NL	Waters off Zeeland	Structural failure	Bulk carrier	350–500 m^3
Serafina	1990	NL	Noordhinder junction	Overflow	Oil tanker	<300 m^3
'Westhinder' incident	1992	BE CS	Westhinder TSS	(Unknown)	(Unknown)	170 m^3
Cast Muskox/ Long Lin	1992	FR	Sandettie junction	Collision	Container vessel + general cargo ship	190 m^3
Amer Fuji/ Meritas	1992	BE TS	Akkaert bank	Collision	General cargo ship + bulk carrier	225 m^3
Davidgas/Athos	1992	NL	Noordhinder junction	Collision	Gas tanker + freighter	185 m^3
Aya/Wladyslaw Jagiello	1993	NL	Westerscheldt mouth	Collision	Ro-Ro + general cargo ship	15 m^3
British Trent/ Western Winner	1993	BE CS	Westhinder anchorage	Collision	Oil tanker + bulk carrier	10 m^3
Carina/Samia	1995	BE TS	Westhinder TSS	Collision	Container vessel + reefer	45 m^3
Spauwer	1995	BE TS	Flemish banks	Capsizing	Sand extraction vessel	<10 m^3
Bona Fulmar/ Teoatl	1997	FR	Noordhinder TSS	Collision	Oil tanker + chemical tanker	7,000 m^3 (petrol)
Mundial Car/Jane	1997	NL	Noordhinder anchorage	Collision	Ro-Ro + container vessel	20 m^3
Vigdis Knutsen/ St. Josse	1997	FR	(Not specified)	Collision	Oil tanker + fishing vessel	(Risk)
Adelaide/Saar Ore	2000	BE EEZ	Westhinder TSS	Collision	General cargo ship + bulk carrier	<10 m^3

(continued)

Table 2 (continued)

Name vessel(s)	Year	Area[a]	Location	Cause	Vessel type(s)	Oil vol.[b]
China Prospect/ Veerseborg	2001	BE EEZ	Westhinder anchorage	Collision	Bulk carrier + general cargo ship	(Risk)
Vera/Music	2001	BE EEZ	Westhinder anchorage	Bunkering incident	Bunker vessel + bulk carrier	20 m^3
Gudermes/St. Jacques II	2001	UK	Dover Strait	Collision	Oil tanker + fishing vessel	100 m^3
Heinrich Behrmann	2001	BE TS	Beach Blankenberge	Grounding	Container vessel	(Risk)
Tricolor/Kariba	2002	FR	Sandettie junction	Collision	Ro-Ro + container vessel	~500 m^3
Vicky	2003	FR	Sandettie junction	Collision	Oil tanker (colliding against wreck Tricolor)	190 m^3
Pauline	2007	BE port	Port Zeebruges	Technical failure	Ro-Ro	<10 m^3
Sapphire	2007	BE port	Port Ostend	Bunkering incident	Bunker vessel	100 m^3
High Progress/ advent	2009	BE EEZ	Westhinder anchorage	Collision	Chemical tanker + bulk carrier	(Risk)
Z700-Rapke	2011	BE TS	Vlakte van de Raan	Capsizing	Fishing vessel	<1 m^3
Baltic Ace[c]/Corvus J	2012	NL	Noordhinder junction	Collision	Ro-Ro + container vessel	45 m^3

[a]*BE TS* Belgian territorial sea, *BE CS* Belgian Continental Shelf area (till 1999), *BE EEZ* Belgian exclusive economic zone (from 1999; Belgian EEZ was created in 1999), *BE port* Belgian port, *FR* nearby French waters, *NL* nearby Dutch waters, *UK* nearby British waters

[b]In case oil was accidentally released, a volume estimate is given in this column; in case the incident was limited to a significant oil pollution risk (meaning no oil was released following the incident), this is reflected as '(risk)' in this column

[c]Minimum volume estimates for the period December 2012–December 2014 (salvage of Baltic Ace wreck scheduled in 2015)

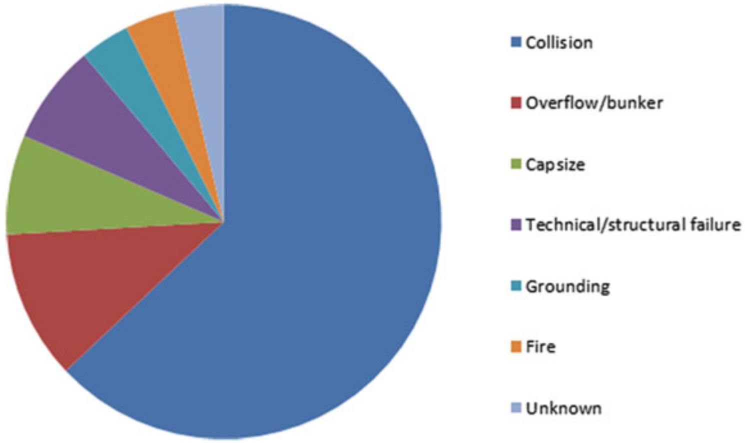

Fig. 7 Pie diagram of causes of maritime accidents resulting in (risk for) accidental marine pollution by oil in and nearby the waters of Belgium (period 1985–2014)

surrounding French, Dutch or British waters, in areas such as the Dover Strait, Sandettie and Noordhinder junctions – but polluted or formed an immediate threat for the Belgian waters.

- In total 43 vessels were involved in the accidents of which eight oil tankers – some of which were laden with more than 50,000–100,000 tonnes of oil [42, 44] (statistics MUMM; http://www.cedre.fr/en/spill/alphabetical-classification.php).
- By far most of the accidents took place between 1985 and 2003. After 2003, following the – interrelated – Tricolor and Vicky accidents, the number of accidents at sea with (risk for) accidental oil pollution drastically decreased to a total of three incidents for the period 2004–2014 (port incidents not considered).
- Most of the accidents resulted in minor to medium accidental oil outflows – i.e. of less than 100 m^3 or in the order of a few 100 m^3 of oil released in the marine environment.

Only three major accidental oil spills have been registered in and around the waters of Belgium since 1985, being the Borcea incident (1988), the collision between the tankers Bona Fulmar and Teoatl (1997) and the Tricolor incident (2002–2004). The Bona Fulmar/Teoatl accident resulted in the biggest spill: in total 7,000 m^3 of oil was released in the waters off Dunkirk (http://www.cedre.fr/fr/accident/bona_fulmar/bona_fulmar.php). But the environmental impact from this major spill was minimal because the oil type was unleaded petrol which completely evaporated within a day. In the Borcea and Tricolor case, much lower quantities of oil were released in the marine environment ($<1,000$ m^3), but the ecological impact of these spills was much higher due to the persistent nature of the oil type (heavy fuel oil or HFO) and the presence of very high numbers of wintering birds in the marine areas that were impacted. The Borcea incident resulted in ca. 5,000–5,500 impacted oiled seabirds stranding mainly along the Dutch coastlines [45]. The Tricolor incident resulted in almost 20,000 oiled seabirds stranding on the beaches of northern France, Belgium and southern Netherlands [44, 46–48].

3.2 Outcome of Recent Risk Assessment Studies

Recent national and regional risk assessment studies have led to an even more detailed description of the accidental oil pollution risk in and around the waters of Belgium. North Sea region-wide risk assessment studies have shown, for instance, that ca. 160 million m^3 of crude oil passed the Dover Strait in 2004 alone, which was a bit less than half of the total volume of oil transported in the entire North Sea that year [49–51]. Another, UK spill risk assessment study focused on the risk related to the increasing HFO transportation through the Dover Strait [52]; the total annual volumes described in that study were in the order of 30–40 million m^3 for HFO transported as cargo on board tankers and in the order of 10–20 million m^3 for HFO used as fuel. Realistic maximum cargo oil outflow risks following collisions with oil tankers have been estimated as ca. 15,000 m^3 [53], whereas a realistic maximum outflow of fuel oil resulting from (more frequent) collisions between other types of vessels, also taking account of increasing ship sizes, is thought to be in the order of 1,000–3,000 m^3 [43, 54].

Not surprisingly the first phase of the most recent regional, Bonn Agreement area-wide assessment study BE AWARE [55] led to the conclusion that the southern North Sea, including the waters of Belgium, contains the highest maritime-related accidental spill risk at present and in the near future and that this risk mainly originates from ship to ship collisions. The BE AWARE project is discussed in more detail in the chapter by Bjerkemo and Huisman in this volume [56].

With the abovementioned figures in mind, it can easily be concluded that in a ‘worst-case’ accident scenario in or around the waters of Belgium (for instance, a collision involving an oil tanker and resulting in an accidental release of a persistent oil type in the order of 10–15,000 m^3), the overall impact will probably be much higher than in previous spills and is likely to significantly impact a wide variety of sensitive marine and coastal habitats and species in the area as well as important socioeconomic sectors such as fisheries and coastal tourism.

Recent national offshore wind farm risk assessment studies [57] have furthermore calculated that the overall accidental marine pollution risk in the Belgian EEZ increased by 8.5% due to the increased collision risk between ships and the numerous wind turbines located in the offshore wind farm area (see Fig. 1). The regional BE AWARE study [55] confirmed that the increase of risk in the southern North Sea will for the coming years be mainly caused by the steep increase of the collision risk with wind turbines.

3.3 Oil Pollution Prevention, Preparedness and Response

Recognizing the high maritime safety risk in Belgian waters, a series of important risk-reducing measures have been taken over the years by the competent authorities in Belgium, i.e. mainly the Flemish Agency for Maritime Services and Coastal Affairs. There is little doubt that these preventive actions have substantially contributed to the drastic decrease in accidental marine pollution in Belgian waters over the last 10 years as explained in Sect. 3.1. Key risk-reducing measures are ([41, 58] (http://www.vts-scheldt.net/); oral comm. R. Gyssens, head MRCC, and E. Bogaert, head VTS section, Flemish Shipping Assistance Division):

- The activation in 2003 of a new 'Oostdyck' radar tower of the Scheldt radar chain, built 24 km off the Belgian coast, which drastically improved the vessel traffic monitoring of maritime traffic in the French-Belgian offshore border area
- The establishment since 2008 of a common Flemish-Dutch nautical management, as laid down in the common nautical Treaty of 2005, of the shipping traffic to and from ports along the river Scheldt ('VTS-Scheldt')
- Recent adaptations of the traffic management route systems at the Wandelaar pilot station, VTS extension in the Wandelaar approach in the Belgian territorial sea and more stringent obligations to take pilots on board
- The integration of AIS in the radar image for the entire VTS working area and modernization of communication systems
- The introduction of safety zones around offshore wind farms and the construction of an AIS relais station in the most northern wind farm
- The extension of the coastal station MRCC Ostend as Belgian SAR and MAS station and performant coordination centre for all incidents at sea

Despite these extensive risk-reducing measures, however, shipping accidents and subsequent risks for accidental marine pollution can never be completely avoided. In view of this remaining accidental marine pollution risk and of the ecological and socioeconomic vulnerability of the Belgian marine areas and coastline, the Belgian authorities developed a dedicated contingency plan for the North Sea and acquired a national oil pollution combating stockpile, allowing response to oil spills up to 1,000 m^3 [59]. The national stockpile, owned by the Federal Public Service for the Environment, consists of different kinds of complementary oil pollution combating systems (containment booms, skimmers and pumps, storage tanks, dispersant spraying units, etc.) that can handle oils with viscosities ranging from very low up to very high in different typical operational situations: the open sea, the shallow coastal waters and the shoreline. The national responsibility for dealing with marine pollution incidents is a federal competency. Given the overall shallow water depth in the Belgian marine areas, the federal response strategy mainly focusses on mechanical recovery and less on chemical dispersion – which is only a second response option in Belgium as laid down in national law. Given its very short coastline, Belgium has only a limited stock of response equipment in comparison to most other North Sea coastal States. The national stockpile is mainly intended for a rapid initial response. In case of a major accidental oil pollution event, Belgium will call upon international assistance, mainly from other North Sea coastal States in the framework of the Bonn Agreement and from European stockpiles such as the EMSA response vessels located in the southern North Sea. Because of this obviously important international cooperation tier in the southern North Sea region, Belgian response units participate on a regular basis in subregional pollution response exercises, together with response units from neighbouring countries and EMSA.

In order to further optimize the crisis management structure in case of a major incident at sea, Belgium completely revised its national contingency plan for the North Sea over the last years. This very recent and important revision was undertaken in the framework of the Belgian Coastguard Structure, being a general cooperation structure between federal and Flemish competent authorities for the North Sea (http://kwgc.be). This new national contingency plan, called 'General Emergency and Intervention (GEI) Plan North Sea', defines the organization of an overall, multidisciplinary response structure to the various emergency situations and incidents that may happen at sea and which require a coordination or management from the Belgian authorities, such as maritime emergencies, SAR and medical evacuations, and also marine pollution by oil or other harmful substances. The Governor of West Flanders acts as coordinator of the GEI Plan North Sea. The overall crisis management structure as laid down in the GEI Plan North Sea is in line with the tiered approach and the concepts of crisis command structures reflected in IMO guidelines.

Belgium also recently extended its national contingency plan with a dedicated part on places of refuge, containing plans for the accommodation of ships in need of assistance. These plans have been drafted in implementation of Art.20 of the European Monitoring Directive 2009/17/EC, and also taking into account the international guidelines on places of refuge – mainly IMO Res.A.949 (23) [60, 61]. For situations of ships in need of assistance as referred to in the European Monitoring Directive 2009/17/EC, the Governor of West Flanders acts as competent authority, whereby he can take urgent decisions and measures on behalf of the Belgian Coast Guard partners – who temporarily delegated their competences to the governor for the situations as foreseen in the Directive.

The Belgian national organization has been successfully tested on several occasions in real incidents, such as the incident with the Tricolor and Vicky in 2002–2003. The current crisis management structure, as laid down in the new national contingency plan, has only been put to a test on two recent occasions, in the light of the incidents with the MSC Flaminia (2012) and the Baltic Ace (2012–present). Although important lessons learnt can always be drawn, the national coordination structure proved to work very effectively.

4 Conclusions

The positive conclusions that can be drawn from this overview on the problem of oil pollution in and around the waters of Belgium is that the environmental pressure from the illegal oil discharges has decreased significantly owing to the wide variety of policy measures initiated both at national and international level and that also the number of accidental marine pollution cases has dramatically decreased owing to a series of crucial risk-reducing measures. However, with regard to chronic oil pollution, the ecological quality objectives have not yet been met in the area, and therefore national surveillance efforts will continue to further reduce illegal oil discharges, amongst others by focusing surveillance not only on the primary shipping lanes but also on secondary shipping routes used for short sea shipping and by further improving the enforcement chain. As regards the high remaining accidental marine pollution risks, the national authorities continue to optimize maritime safety in the area, e.g. taking account of the recently increased risk caused by the construction of vast offshore wind farms in the waters of Belgium. Belgian authorities furthermore endeavour to increase the national level of preparedness. But despite the thorough revision of the national contingency plan and the acquisition of a national stockpile of response means, Belgium cannot face the accidental oil spill risks alone – especially given the enormous number of ships that are transiting the area each year. Belgium therefore attaches great importance to international cooperation and continues to strive towards a further improvement of the subregional cooperation with the neighbouring coastal States, recognizing the need to jointly face the important accidental oil pollution risks. After all, a major accidental oil spill will most probably affect the interests of all four coastal States bordering this key southern North Sea area.

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Oil Pollution in the Dutch Sector of the North Sea

Kees Camphuysen and Ben Vollaard

Abstract Oil pollution is a serious issue in the Netherlands ever since merchant and military vessels with diesel engines gradually replaced vessels operating sails and steam engines in the early twentieth century. Arguably, the southern North Sea became one of the most heavily oil-polluted sea areas in the world as a result of chronic oil pollution. Major shipping incidents resulting in massive oil spills have, however, been rather rare within the area. In the early twenty-first century, the number of detected oil spills has markedly declined and levels of chronic oil pollution are currently rather low. Most detections of oil slicks are still concentrated around the major shipping lanes and off major ports such as Rotterdam and IJmuiden (leading to Amsterdam).

Keywords Aerial surveillance, Bonn Agreement, Chronic oil pollution, Historical overview, Major oil spills, North Sea, Oil pollution, Recent trends, Remote sensing, Shipping accidents

Contents

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1 Introduction

The Netherlands is situated in the most southern part of the North Sea (a shallow shelf sea in the Northeast Atlantic). Shipping lanes running along the Dutch coast form important maritime connections between major shipping harbours in Germany (Hamburg and Bremen), the Netherlands (Amsterdam and Rotterdam) and Belgium (Antwerp). These connections, together with the intense shipping to and from Scandinavia and into the Baltic via the Dover Straits, result in Dutch waters ranking high in the list of the busiest shipping lanes in the world. Oil pollution is a serious issue in the Netherlands, ever since merchant and military vessels with diesel engines gradually replaced those operating sails and steam engines. Early in the twentieth century, the first steps were taken to reduce marine oil pollution, largely for economic reasons, but with little success. This chapter provides a historical account of oil pollution in Dutch waters, followed by an analysis of recent data on the occurrence of oil slicks in the southern North Sea.

2 The Study Area

The Netherlands has a dynamic and soft coastline with sandy beaches (interspersed with artificial dykes to enforce weak sections of the coastline) bordering the southern North Sea in the west and southwest of the country (mainland and delta coasts) and a chain of Wadden Sea islands (each with a sandy beach on the North Sea side) separating the shallow, intertidal Wadden Sea from the North Sea in the north. The Dutch sector of the continental shelf (~51–56°N latitude, 2.5–6.5°E longitude) has a surface area of approximately 57,000 km^2 (see Fig. 1). The northern tip of this area just reaches the relatively shallow Dogger Bank area. In most parts of the Dutch sector, the relatively turbid waters (as a result of river run-off) are only between 10 and 40 m deep. Prevailing currents run parallel to the Dutch coast and mostly in a south to north (northeast) direction. The prevailing winds are also from the southwest [1], so that oil slicks and oiled seabirds arriving at the shoreline most likely originate from spill areas to the south and southwest of the

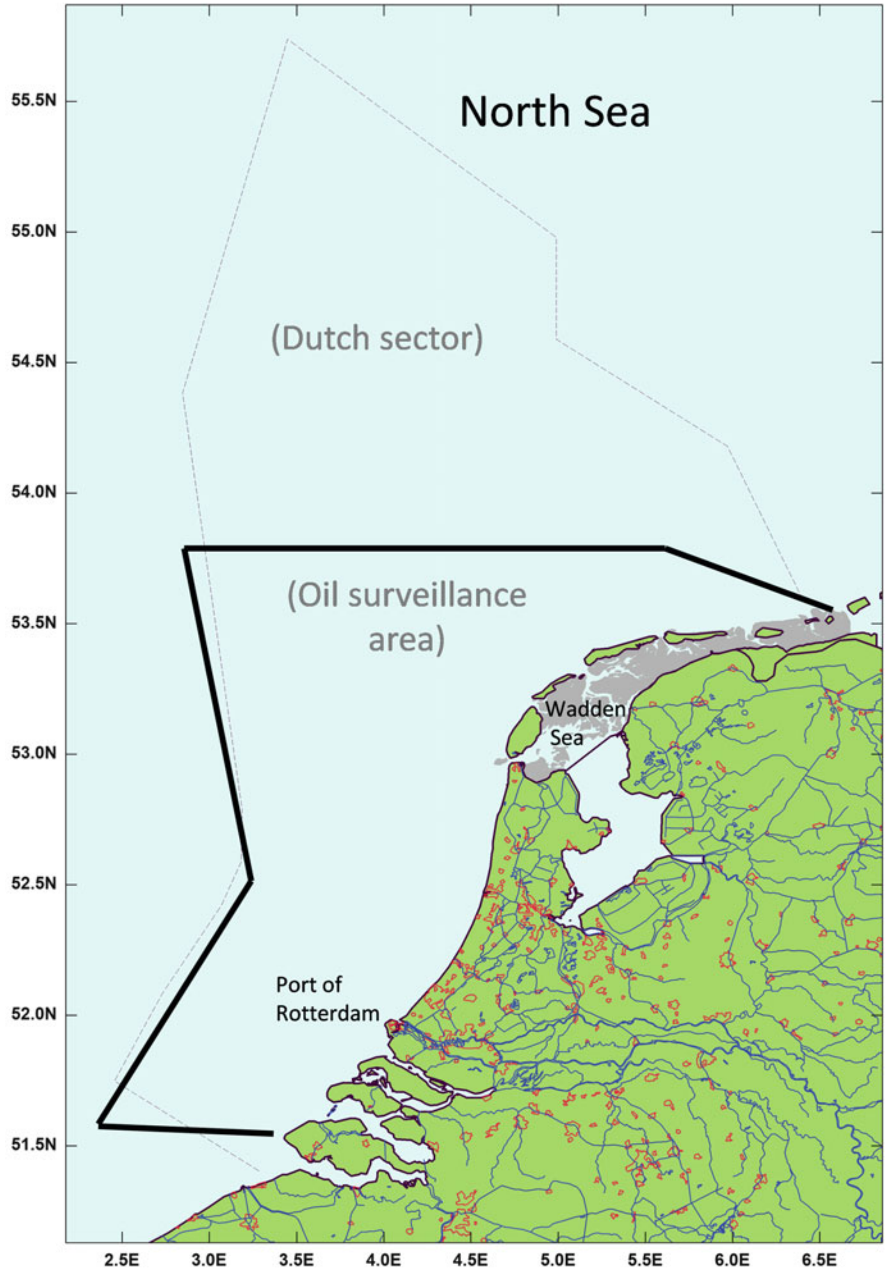

Fig. 1 Sectors of the North Sea under Dutch jurisdiction. *Note*: In Fig. 1, the surveillances for oil pollution are mainly delineated with a *solid black line* and these were used for statistical analysis of the data. Relatively little surveillance time is devoted to the northern part of the Dutch sector. Most of the west and north coasts of the Netherlands are sandy beaches, interspersed with dykes. The mudflats (shown in *grey*) and salt marsh areas within the Wadden Sea in the north (a sea area with numerous connections to the North Sea between the islands) are particularly sensitive to oil pollution

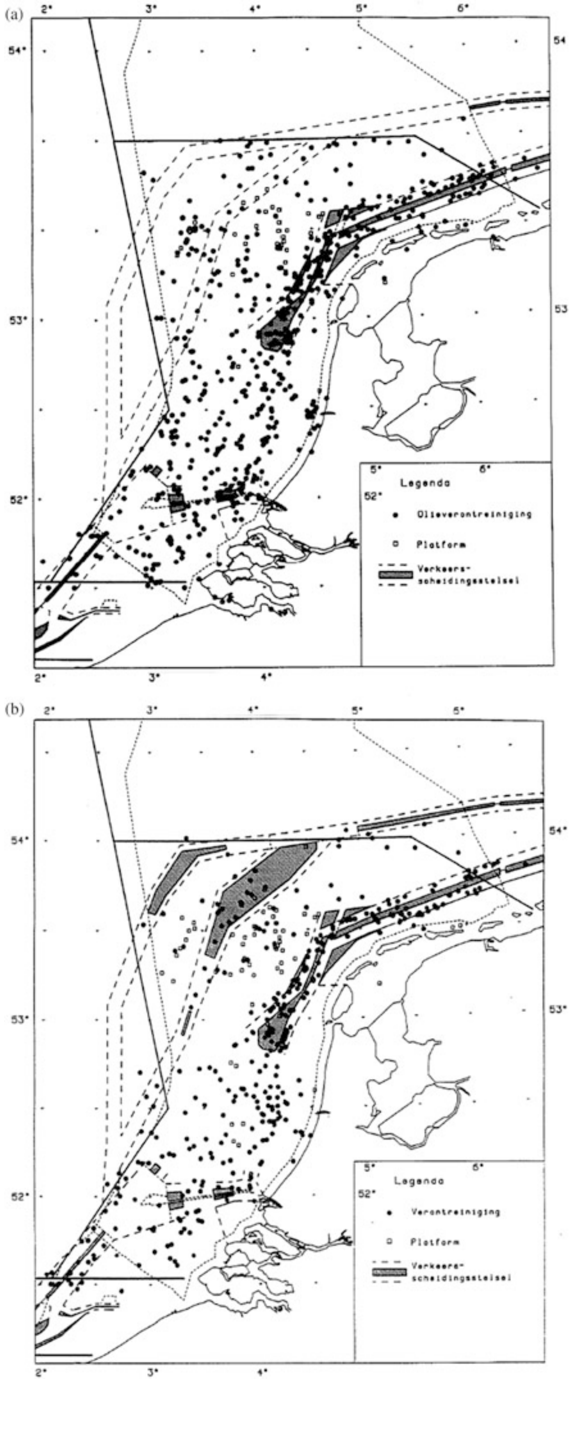

Fig. 2 Examples of the spatial pattern of detected oil slicks in the Dutch sector of the North Sea for 1989 (see (**a**)) and 1990 (see (**b**)), including oil slick reports from all sources. *Note*: Shown in (**a**) and (**b**) are the boundaries of the studied sector or the North Sea, the shipping lanes, shipping separation systems and offshore installations (*white squares*). *Black symbols* represent detected slicks. From annual reports produced by the Ministry of Transport and Public Works [35, 36]

Dutch coast. Oil slicks and oiled seabirds at over 30–40 km to the north of the Netherlands are, generally speaking, unlikely to reach the coast, except during prolonged northerly storms.

At the Dutch continental shelf, in order to regulate dense ship traffic, a complex system of shipping lanes, deep water routes and shipping separation systems has been established (see Fig. 2). Vessels intending to visit the large harbours of Antwerp, Rotterdam and Amsterdam often anchor off the coast near Vlissingen/ Westkapelle (delta area), off Hoek van Holland (mainland coast of Zuid-Holland) and off IJmuiden (mainland coast of Noord-Holland). About 150 oil or gas production platforms, all connected by underwater pipelines to transport oil/gas from the wells towards processing plants on land, are situated in the Dutch sector of the North Sea, and a particularly high number are situated around 53°–54°N latitude, 3°–4°30′E longitude.

The southern North Sea is an important economic and ecological area. Pollution of the sea by oil and other harmful substances may threaten the marine environment and the economic interests of bordering coastal states. In view of the dense ship traffic routes and the many oil and gas installations in the North Sea, any incident with a vessel at sea is of immediate concern. The Bonn Agreement was established to respond to oil pollution of the North Sea by active cooperation and mutual assistance of neighbouring states [2]. The contracting parties have also agreed to conduct surveillance of their respective zones of jurisdiction, to detect and if needed combat pollution and to prevent violations of international anti-pollution regulations, such as MARPOL 73/78 [3]. Aerial surveillance plays an essential role in this task. Since 1969, the North Sea Directorate[1] (*Directie Noordzee*) within the Ministry of Transport and Public Works has been responsible for 'operational detections' and cleanup operations of oil pollution within the Dutch sector of the North Sea [4, 5]. Oil detections by third parties were reported to a central, constantly manned post (the Control and Information Centre in Hoek van Holland, currently Netherlands Coastguard Centre, Den Helder), and decisions for an aerial inspection of the reported pollution, or even a cleanup operation, are taken.

Contracting parties under the Bonn Agreement [2] have agreed a cooperative approach to aerial surveillance. Surveillance activities for oil pollution (since 1969 and in particular since 1992), now conducted by the Netherlands Coastguard, are concentrated on the main shipping lanes. Offshore areas and the northern part of the Dutch sector (with little activity) are less frequently visited. The primary objective of routine patrolling is to detect combatable oil slicks at an early stage, to catch ships and platforms red-handed and to gather sufficient evidence for a prosecution. In this chapter, we will describe the different steps made to improve the effectiveness of these surveys. These steps included the development and use of more advanced (e.g. remote sensing) equipment and a better survey design. A statistical analysis of the data was possible only for the most recent data sets [6–8].

[1] In 2013, due to reorganisation, this is now the Ministry for Infrastructure and the Environment, Rijkswaterstaat Zee & Delta.

3 Terminology

It is common usage to discuss oil pollution in terms of either chronic oil pollution and/or specific oil incidents. Daily operations in shipping and offshore (production water discharges) are regulated through the MARPOL and OSPAR Conventions [3, 9] with regard to the quantity of oil particles in the discharged water (in ppm's), whereas another type of oil pollution is caused by accidents (colliding vessels, hull failure or groundings). Oil *incidents* are typically from a known (often named) source and are usually the result of accidents at sea (e.g. groundings of *Torrey Canyon* or *Amoco Cadiz*, *Sea Empress*, *Prestige*), or a sufficiently large amount of oil is spilled as a single event but the source remains unknown (so-called mystery spills). Oil incidents are not necessarily very large spills, although all the more famous named examples had considerable volumes of oil leaking into the marine environment. Chronic oil pollution, on the other hand, is the sum of all smaller and larger releases of oil into the oceans through atmospheric transport, water run-off from land (including rivers), natural seeps and leakages as well as deliberate discharges of oil from ships or offshore installations. In many cases, as soon as the source is identified, we tend to speak of an oil incident, even though some of these spills may be small and some of these are the result of operational discharges.

The detections of oil slicks during aerial surveys are in fact detections of slicks of lipophilic substances, not necessarily slicks of mineral oils [10]. The most frequently encountered forms of pollution include mineral oil (including bilge oil, crude oils, condensates and light oils), vegetable oil (e.g. rapeseed oil, palm oil), fish oil and chemical pollution. It is often impossible to tell different substances apart and visual inspections of 'oil slicks' often refer to the colour and the shape of slicks. Oil appearances will generally follow some common patterns. Thinner oils, sheen, rainbow and metallic, will normally be at the edges of the thicker oils. Heavy oil will tend to be mainly true colour and have very sharp defined edges [11]. Visual observation of the pollution and polluter provides essential information about the size, appearance and coverage of the slick that are used to calculate the initial estimate of volume. Visual inspections can only be conducted in daylight. Even at daytime, the observation can be influenced by several factors: cloud, sunlight, weather, sea, angle of view, height, speed and local features as well as the type of oil [11]. The well-trained and skilled operators in the surveillance aircraft will therefore fly a pattern to observe the pollution and suspected polluter from different angles.

4 History of Oil Pollution in Dutch Waters

4.1 When It All Started: Oil Pollution in Dutch Waters, 1915–1968

Within the Netherlands, the first accounts on marine oil pollution were published early in the twentieth century [12–14]. It was reported that oiled seabirds had washed ashore on the mainland coast (village Noordwijk, Zuid-Holland) and suggested that this might have been the result of a tanker being destroyed in the course of war at sea [13]. It was also noted, however, that oiled seabirds had been reported before (in Britain), also *prior* to the First World War [12]. It was soon found out that the 'oil nuisance' would not only not disappear in the 1920s, 1930s and in later decades but that the problem would rapidly grow out of hand [15–17]. These simple and early reports were just the first accounts of marine oil pollution in the Netherlands. Many similar accounts would be published over the 100-year period following these publications, and oiled seabirds were usually involved.

Systematic surveys to monitor the frequency of occurrence of oil slicks at sea were non-existent in this period. A review of the results of beached bird surveys [18] (e.g. systematic searches for oil seabirds along the coast) found numerous accounts of oiled seabirds washing ashore but listed only four shipping incidents, including:

- *1920*: Two 'American vessels' ran aground just north of the Wadden Sea islands (near Terschelling), causing a 'massive oil spill'. Countless numbers of seabirds were affected [14].
- *1933*: A mystery spill, a large quantity of oil washed ashore near Breskens in Zeeland [19].
- *1960*: Leakage of oil following a collision of two tankers on Vlissingen's roads in Zeeland [20].
- *1966:* The oil tanker *South America* ran aground on Maasvlakte (off the port of Rotterdam, Zuid-Holland) in late March, leading to widespread oil pollution on beaches further to the south, along beaches in Zeeland.

Particularly large numbers of oiled seabirds (indicative of offshore spills or leakages of oil) were reported in January 1921, winter 1921/1922, January–February 1928, winter 1929/1930, March 1934, April 1935, October–November 1936, November 1938, February 1946, March 1949, winter 1949/1950, December 1954, May 1958, January 1960, February 1961, April 1965 and December 1967 (original sources cited in [18]). Most these incidents occurred in winter (November–April), but this must be seen as a reflection of the abundance of sensitive seabirds such as auks (Alcidae) wintering in the Southern Bight, not as a genuine seasonal pattern in the occurrence of oil at sea.

The earliest concerns with regard to marine oil pollution had an economical rather than an ecological background. Experiments were conducted to assess the effects of oil pollution on fish, fish eggs and aquacultures (oysters) and to verify claims of economic damage inflicted by oiling [21]. They listed five main concerns with regard to marine oil pollution: (1) oil-contaminated fish cannot be sold, (2) mortality of numerous seabirds that alight into oil slicks at sea, (3) a slower process of oxidation of (human) faeces and other waste products dumped into the ocean, (4) the impossibility to bath in the sea and the adverse effects on coastal tourism and (5) and a perceived increased risk of fire from oil-soaked campshot and other woodworks in harbours. Some thirty years later, in a 'manual to prevent contamination of the seas with oil' published for sailors by the Royal Dutch Ship-owners organization [22], three of these issues were repeated (contaminated fish, seabirds and beaches), but the conclusion was added that so much oil was washing ashore that an 'untenable state of affairs' (*een onhoudbare toestand*) was reached.

The earliest reports were apparently dealing with incidental cases of oil pollution, but it became clear that oil pollution was increasing and that this trend was most pronounced in coastal areas near major shipping lanes [17, 21]. Early suggestions to reduce the problem included the use of oil-water separators on board of ships but also to dump any residues of oil cargoes at 'sufficiently large distances away from land' (>50–100 miles from land [22]). Out of sight, out of mind was an attitude that is still followed by some authorities today. More eager cleanup operations in nearshore oil incidents than on the open ocean [23] or decisions to tow a sinking oil tanker away from the coast rather than to contain the accident under controlled, nearshore conditions (the accident with the *Prestige* plus see [24]) are recent examples of that old idea.

4.2 A Period of Technological Developments: Monitoring Oil Pollution in 1969–1991

Right at the start of this period, in January–February 1969, a mystery spill occurred north of the Wadden Sea islands that arguably led to the highest mortality of wintering seabirds ever witnessed within the Netherlands [25]. At least some 30,000–40,000 sea ducks (*Somateria mollissima* and *Melanitta nigra*) were affected. The increased attention for oil pollution and oil incidents led to a rather more comprehensive list of incidents at sea in this period:

- *1969*: Mystery spill just north of the Wadden Sea islands, causing a mass mortality under wintering sea duck populations [25].
- *1969*: Oil tanker *Texaco Westminster* with defects on board, 500 t oil in sea.
- *1970*: Oil tanker *Pacific Glory* spills 900 t of oil following a collision in the Southern Bight [4, 26].
- *1971*: Oil tanker *Elisabeth Knutsen* spills 100 t of oil following a collision with another vessel [4, 26].

- *1974*: 'Tanker accident' in late December near the port of Amsterdam (IJmuiden), numerous casualties under wintering sea duck and auk populations (R. Luntz, personal communication).
- *1975*: Oil tanker *Olympic Alliance* spills 8,000 t of oil in the Southern Bight following a collision with another vessel [4, 26].
- *1975*: Oil tanker *Pacific Colocotronis* was damaged in heavy weather; some 2,000 t of Sahara crude oil was spilled off Den Helder (mainland coast) [27, 28].
- *1976*: Discharge of 200t of oil by *Athenian Victory II* [26].
- *1977*: Blowout of the *Bravo* platform in the *Ekofisk* field in the Norwegian sector, releasing 3–4000 t d^{-1} over a period of eight days. Exceptionally high numbers of oiled auks on the Dutch Wadden Sea islands may be related to this incident [18, 29].
- *1978*: The Dutch coast was polluted by oil over a distance of more than 100 km in July. Analysis of oil samples showed that this stranded oil was 'very similar' to that released by the oil tanker *Eleni V* which collided with the *Rosaline* off the coast of East Anglia (England) on 6 May 1978 [30].
- *1982*: Collision between the oil tanker *Katina* and the ore carrier *Pengall* off Hoek van Holland in June. 'Considerable' pollution.
- *1982*: Collision of the oil tanker *Benetank* with another ship, oil in the Westerschelde (delta area).
- *1982*: Container vessel *Erato*, collision with container vessel *Yumpa*, lots of oil in the Westerschelde area.
- *1983*: Cargo ship *Vostosc II* near Vlissingen; collision with wreck leads to leakage of bunker oil.
- *1985*: Mystery spill just off the mainland coast in May leading to hundreds of carcasses of severely oiled seabirds [18].
- *1987*: Mystery spill within the Wadden Sea in January led to mass mortality of sea ducks [31].
- *1988*: Oil spill of a slightly damaged ore carrier *Borcea* off the delta area in January. At least 5,000 seabirds were contaminated and killed [32].
- *1990*: Oil tanker *Rose Bay* has a collision in the English Channel with a fishing vessel; considerable amount of oil was spilled.
- *1991*: Bulk carrier *Clipper Confidence*, collision with chemical tanker *Norgas*; considerable amount of oil spilled.

Oiled seabirds washed ashore every winter and often in high numbers (see chapter on beached bird surveys, this volume [33]), indicating that chronic oil pollution was a serious problem. In a multiyear overview published in the late 1980s, the exceptionally high oil rates found in birds stranded in the Netherlands were highlighted [18]. For 1969–1985, considering the most oil-sensitive seabirds, the proportions of oiled carcasses amounted to 92% ($n = 615$ birds found in total) in divers (Gaviidae), 60% ($n = 2{,}574$) in grebes (Podicipedidae), 87% ($n = 561$) in northern gannets (*Morus bassanus*), 96% ($n = 10{,}963$) in scoters (*Melanitta* sp.), 84% ($n = 7000$) in black-legged kittiwakes (*Rissa tridactyla*), 89% ($n = 4{,}115$) in razorbills (*Alca torda*) and 89% ($n = 14{,}554$) in common guillemots (*Uria aalge*).

Such high oil rates, as a result of chronic oil pollution rather than of major oil incidents, were easily among the highest values in the world [24, 34].

The unwanted effects of marine oil pollution were well known by scientists and conservationists alike, for more than half a century, but also the general public and established national authorities became increasingly aware of the oil problem. It was not before the 1960s, however, and in particular after the grounding of the oil tanker *Torrey Canyon* at Land's End (SW England) that serious attention was given to the oil problem in most countries bordering the sea, the Netherlands included. In the period of international negotiations leading to the enforcement MARPOL Convention (1973) and its 1978 Protocol [3] (the combined instrument entered into force on 2 October 1983), in the 1970s and early 1980s, novel techniques were developed to detect oil slicks during aerial surveys and from satellites. At the offshore platform *Meetpost Noordwijk* off the mainland coast, remote sensing techniques were experimentally tested and refined under strictly controlled conditions. When aircraft used for aerial surveillances were fitted with these novel technologies, not only did the number of detections increase sharply, but oil slicks could now also be detected at night or during relatively poor weather.

Within the Netherlands, incidental reports of oil slicks at sea were supplemented by visual observations from an aircraft operated by the government (Rijkswaterstaat) since 1975. A systematic aerial survey was started in 1976 (visual observations only), while remote sensing techniques were introduced in 1982. Only since March 1983 were remote sensing techniques deployed along a fixed route covering much of the Dutch sector of the North Sea as part of a systematic search for oil pollution [5]. Detection techniques became gradually more advanced and the flight path of the systematic surveillances changed occasionally, so that reliable time series were difficult to construct. Examples of the spatial patterns in oil slick detections are provided in Fig. 2. It was clear, however, that most of the detected oil slicks were found near or at the shipping lanes north of the Wadden Sea islands, often with a second cluster of detections off Rotterdam harbour. It became also evident that oil slicks occurred year-round and not just in winter, as the beached bird surveys seemed to indicate (see chapter on beached bird surveys, this volume [33]).

Since the monitoring flights were established in the late 1970s, at least somewhere between 400 and 700 (occasionally over 1,000) oil slicks were found per annum (see Fig. 3). Detection rates were lower in windy conditions, and therefore, more cases of marine pollution were missed in autumn and winter than in summer and spring, when the prevailing weather is often calmer. On average, between 1983 and 1991 when the aircraft conducting aerial surveys was using remote sensing equipment, some 1.13 ± 0.51 slicks per hour flight were detected (mean $\pm$ SD, $n = 3{,}514$ detections; see Table 1), without any clear trends over time.

The source of the pollution could be identified on 1,244 occasions (1982–1991; Table 1). In most cases, the slicks were ship related (57.6%), and these involved virtually exclusively discharges of oil rather than accidents (e.g. leakages as a result from collisions or otherwise). Some 28.5% of the observed slicks originated from fixed production platforms and/or wellheads, and 13.9% were caused during

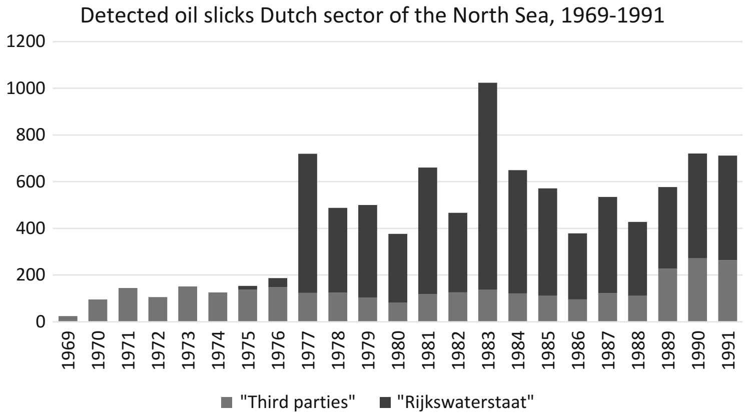

Fig. 3 Detections of oil pollution (n) in the Dutch sector of the North Sea, 1969–1991. *Note*: All reported oil slicks are included, separating those reported by 'third parties' and those found during aerial surveys of Rijkswaterstaat (either during systematic surveys or during other flights). From monthly and annual reports produced by the Ministry of Transport and Public Works [37, 38]

Table 1 Detection of oil slicks in the Dutch sector of the North Sea, 1982–1991

		During aerial surveillance			Identified sources			
	All	No.	Hours	No./hour	Ship	Rig	Platform	Total
1982	466				88	6	11	105
1983	1,024	802	334	2.40	82	18	45	145
1984	649	501	388	1.30	50	14	24	88
1985	571	401	370	1.10	59	26	11	96
1986	378	233	263	0.90	58	9	23	90
1987	535	310	281	1.10	76	28	30	134
1988	427	276	317	0.80	77	9	20	106
1989	577	338	371	0.90	*61*	*7*	*67*	*135*
1990	721	362	373	0.97	79	21	60	160
1991	712	291	411	0.70	87	35	63	185
Total	6,600	3,514	3,108	1.13 ± 0.51	717	173	354	1,244
					57.6%	13.9%	28.5%	

Note: Table 1 includes all reported detections (far left) during aerial surveys with remote census equipment (number of detections, hours of flight and detections h^{-1}) and identified sources of pollution. A detection means that by means of radar (SLAR) a disturbance of the generic wave pattern at sea surface was found. Only by visual observation can a detection be confirmed as being a mineral oil slick. From Ministry of Transport and Public Works Annual Reports [37, 38]

drilling operations from oil rigs. The offshore industry on the Dutch sector of the North Sea developed rapidly in the course of the 1970s and 1980s. By 1991, some 96 fixed installations were established (including wellheads and production platforms, with and without accommodation, mostly for gas), while on average 15 rigs per month were active.

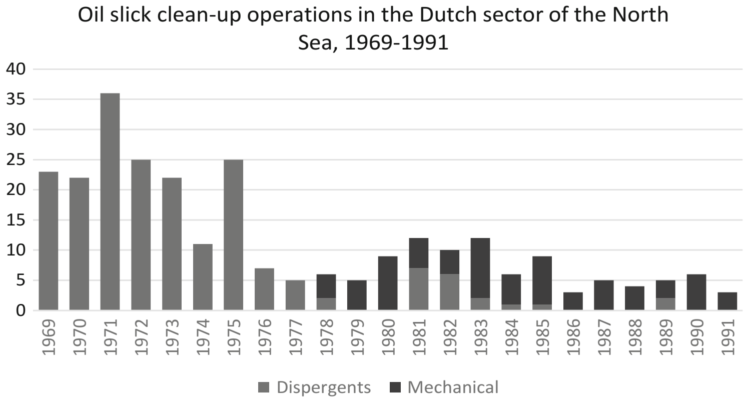

Fig. 4 Cleanup operations (n) in the Dutch sector of the North Sea, 1969–1991. *Note*: Initially, oil slicks were sprayed with dispersants only. New mechanical techniques to combat oil pollution were introduced in the late 1970s, and these techniques were preferred in later years. From monthly and annual reports produced by the Ministry of Transport and Public Works [37, 38]

In the 1970s and 1980s, good progress was made with the development of remote sensing techniques, but the cleanup side of oil pollution incidents was a matter of debate at the same time [5, 39, and see also 40, 41]. The use of dispersants (spraying oil slicks and thereby bringing oil into the water column) was increasingly seen as a poor solution of the problem, and mechanical methods to remove oil from the sea surface were developed and further refined. The actions of water and wind were appreciated more (many light slicks would 'disappear' in no time by simple wind action), making the use of dispersants often superfluous. Cleanup operations were started on only a small number of occasions (ca. 5–10 per annum since the late 1970s), and the use of dispersants was largely phased out (see Fig. 4).

4.3 Monitoring Oil Pollution in Recent Years: 1992–2011

Several oil incidents could be highlighted for this period, but perhaps by far the most dramatic incident occurred in winter 2002–2003 with the car carrier *Tricolor* that sank in the French EEZ in the Channel. The wreck and its bunker tanks were more or less intact after a collision had brought the ship down to the seafloor, until an attempt to remove the oil from the wreck led to a considerable leakage of oil, right in the middle of the wintering period of a large number of sensitive seabirds.

- *1992*: Mystery spill just north of the Wadden Sea islands in February, causing a mass mortality under wintering seabirds [42].
- *1992*: Collision of the oil tanker *Long lin* and the bulk carrier *Cask Muscox* near Zeebrugge (Belgium) caused considerable oil pollution also in Dutch waters.

- *1992*: A mystery spill of palm oil in the English Channel leading to widespread contamination of the shorelines within the UK and in the Netherlands.
- *1998*: A mass stranding of seabirds in the North Sea in December 1998. Hundreds of birds washed ashore alive in Zeeland (SW Netherlands), along the mainland coast and on Texel. Two strandings were temporarily (10 days) and geographically separated (ca. 120 km apart) but were apparently caused by a single source of pollution. At least 1,100 seabirds were affected by an extremely sticky substance, soon identified as polyisobutylene $(C_4H_8)_n$ [43,44].
- *2002*: The *Tricolor* spill in December 2002–January 2003 caused mass mortality of wintering seabirds in N France, Belgium, the Netherlands and in the UK [45–49].
- *2003*: Leakage of bunker oil by *Assi Euro Link* after colliding with *Seawheel Rhine* some 50km NW of the Wadden Sea island Terschelling caused considerable pollution and seabird mortality [50].
- *2007*: Mystery spill of an unidentified green, oil-like substance in January 2007 on the mainland coast and on Texel. Numerous seabirds are killed and a considerable contamination of the beaches occurred. A chemical analysis of the substance remained inconclusive, but high concentrations of sulphur and smaller amounts of strontium, arsenic, copper, 4-tert-butylphenol (CAS 98-54-4) and 4-(1,1-dimethylpropyl)phenol (CAS 80-46-6) were found.
- *2010*: Mystery spill of polyisobutylene $(C_4H_8)_n$ off the Dutch coast affecting seabirds in March 2010 [51].

It should be noted that several of these spills did not relate to mineral oil but to other lipophilic substances. Further non-oil-related but nevertheless notable shipping incidents included a leakage of around two tonnes of lead sulphide in the sea by the cargo ship *Nordfrakt* 10 km west of the mainland coast near Noordwijk in October 1992, a fire on board the chemical tanker *Sloman Traveller* 18 km N of the Wadden Sea island Vlieland releasing chloride gases in the atmosphere in December 2001 and the loss of around 700 drums of heavily toxic Wolman salt (arsenic pentoxide) by the cargo vessel *Andinet* NW of the Wadden Sea island Texel in December 2003. The fairly prominent position of incidents not related to mineral oil is remarkable, if the official statistics of the aerial surveys are consulted. Of 6200 slicks recorded during 1992–2000, 57.1% remained unidentified. Mineral oils (38.5%) were most frequently found, while ‘chemicals’ were involved in only 0.1% of the cases. Vegetable (or animal-related) oils were found to comprise 2.5% of the slicks (1.8% ‘other pollutants’; $n = 6{,}200$ [38, 52]).

For 1992–2011, considering the most oil-sensitive seabirds found in the Netherlands, the proportions of oiled carcasses amounted to 77% ($n = 354$) for divers, 24% ($n = 580$) for grebes, 56% ($n = 827$) for northern gannet, 59% ($n = 2{,}150$) for scoters, 47% ($n = 2{,}309$) for black-legged kittiwake, 62% ($n = 3{,}304$) for razorbill and 60% ($n = 14{,}379$) for common guillemot. These oil rates are still high but significantly lower than in earlier decades and were gradually declining over time [23, 53].

5 Statistical Analysis of Recent Trends in SLAR Detections[2]

The Netherlands started remote sensing surveillance operations in 1983 in a Cessna. A Coast Guard Dornier 228-212 aircraft was introduced in June 1992, and this machine patrolled the Dutch part of the North Sea on a daily basis ever since. From now on, oil spills from shipping and offshore oil and gas extraction were systematically monitored by remote sensing techniques including airborne radar. On board this aircraft are advanced navigation systems, coupled with remote sensing equipment (Terma Elektronik), FLIR, video and photo cameras and airborne radar (SLAR). The number of flight hours gradually increased since 1983 from 600 to 1,200 annum^{-1} and has remained fairly constant since the mid-1990s.

The Netherlands is unique with its relatively intensive nightly surveillance activities (about 30% of all flights). Apart from collecting statistics on illegal oil discharges for all hours of the day, nightly surveillance is mainly conducted to secure a rapid response in case of an emergency at sea and to enforce traffic regulations around the clock. For about a third of the surveillance flights, satellite images are also used to guide the aircraft to potential oil spills. The images are provided by the European Maritime Safety Agency (EMSA), through their CleanSeaNet program [54], and are available within 30 min after a satellite pass. For further information on EMSA CleanSeaNet, see chapter in this volume [55]. The combination of satellite and airborne remote sensing technology allows monitoring of vast sea areas at day and night, under all sky conditions and under most weather conditions. As a result of these much more standardised techniques, a statistical analysis of the data to detect general trends is now well possible and is provided below.

The advanced instruments on board the aircraft are an important source of information and a visual evaluation of detections is impossible at night or under adverse weather conditions. As a result, the sum of all detections is referred to as ‘spots’ (unidentified slicks, possibly pollution, but type of substance unknown). After radar has detected a spot in daylight, the aircraft swerves back for a visual inspection and for an investigation of the size and thickness of the spot.

5.1 Annual Trend

Figure 5 shows the trend in the probability of detecting spots by airborne radar during 1992–2011. Clearly, the trend is downwards, as it is in the German and Belgian parts of the North Sea [56,57]. All Bonn Agreement contracting parties

[2] Sections 5 and 6 draw heavily on Vollaard (2014) [8].

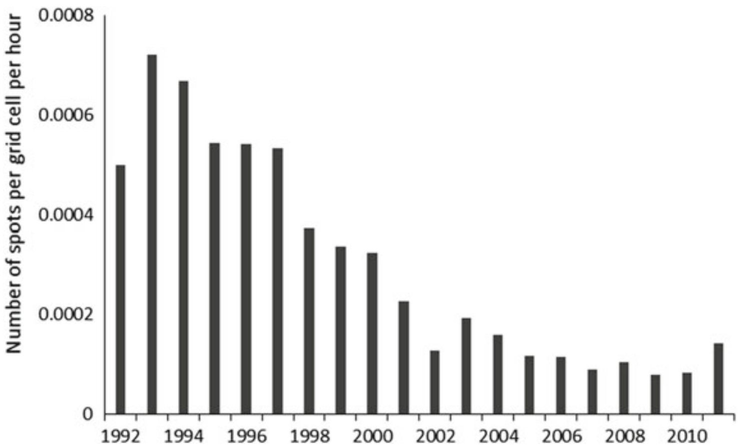

Fig. 5 Radar-identified spots per grid cell-hour, Dutch continental shelf, 1992–2011. *Note*: Incidence is defined as the number of yearly identified spots per grid cell per hour. The grid cell size is 2.5 by 2.5 km. On average, a year has 1.2 m grid cell-hours. From Vollaard [8]

report similar trends since 1999, and this is reflected in the annual reports produced by the Bonn Agreement Secretariat [58]. The decline has been interpreted as a decline in oil pollution and is attributed to a range of factors including changes in ship design, better facilities for legal disposal in the harbour, strengthened port state control and greater environmental awareness of shipping crews [58]. Shipping intensity remained roughly stable during 1992–2011 when measured by the number of seagoing vessels visiting the harbours of Rotterdam and Amsterdam (tonnage increased because of the trend towards larger vessels).

5.2 Spatial Patterns

Figure 6 shows the incidence of radar-identified spots in the Dutch part of the North Sea during 1992–2011. The areas with the highest incidence are concentrated in the three major shipping lanes along the coast and in the approaches towards the harbours of Antwerp, Rotterdam, Amsterdam and IJmuiden. This confirms that the data relate primarily to discharges from shipping rather than oil spills from other sources, such as oil and gas exploration. Figure 2 shows that the area with the most oil and gas platforms, the southwestern part of the Frisian Front (around coordinates 575,000, 5,900,000), has a relatively low incidence of observed spots.

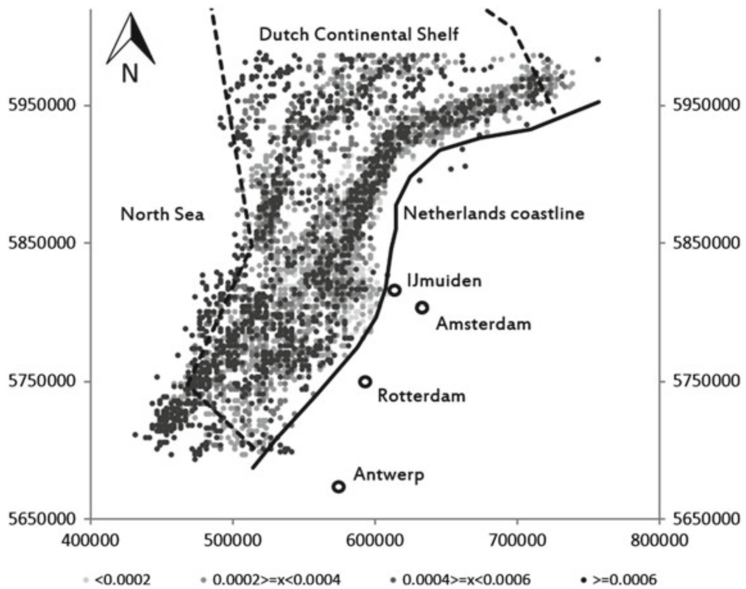

Fig. 6 Mean yearly incidence of radar-identified spots, Dutch continental shelf, 1992–2011. *Note*: Incidence is the number of yearly identified spots per grid cell-hour. UTM31N coordinates on the axes. The major shipping lanes and main port approaches are clearly visible, suggesting a relationship with shipping. From Vollaard [8]

5.3 Seasonal Patterns

Figure 7 shows the estimated probability of detecting a spot by month of the year. When estimating the monthly pattern, we account for seasonal trends in air temperature, wind and water temperature in the North Sea area. Both during 1992–1999 and 2000–2011, the spring period jumps out as the period with the highest probability that airborne radar picks up a spot. Not coincidentally, this is also the period of algal blooms [59].

5.4 Diurnal Patterns

Figure 8 shows the estimated probability of detecting a spot by hour of the day. When estimating the hourly pattern, we account for hourly trends in air temperature, wind and water temperature in the North Sea area. The pattern can be interpreted as the trend in oil spots since all other anomalies on the water surface that the radar may pick up do not vary with the time of day. During 1992–1999,

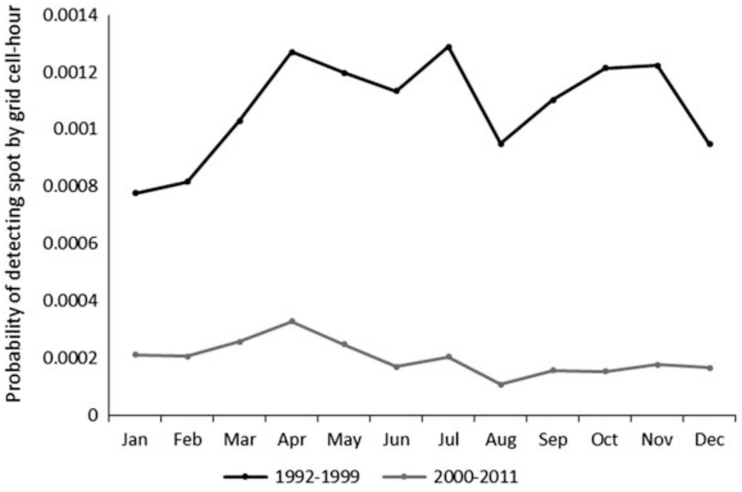

Fig. 7 Probability of identifying a spot, by month. From Vollaard [8], month-fixed effects in Equation (2)

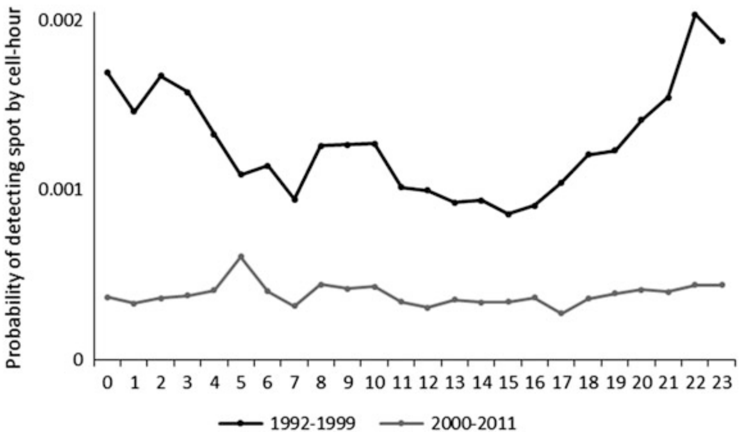

Fig. 8 Probability of identifying a spot, by hour of the day. From Vollaard [8], hour-fixed effects in Equation (2)

there is a very clear upswing in the detection probability from late afternoon until 10 pm. This implies that these hours are popular times for illegal discharges of oil: discharges that are concentrated in time accumulate because they do not disappear immediately. During 2000–2011, this particular diurnal pattern is much less articulated, given the strong drop in the overall rate of detected spots. We return to the timing of oil discharges in the next section.

6 Law Enforcement

The regulations of oily waste disposal from shipping are primarily enforced by aerial surveillance and port state inspections. Below, we focus on aerial surveillance. The chance of being convicted for an illegal oil discharge is remote. First of all, the coastguard aircraft is not in the air for 85% of time, and when in the air, it takes about 5 h to cover all of the relevant area. Oil spills may disappear for the radar before the area is surveyed. This holds for small discharges of oily waste in particular, by now the majority of the spills, since these tend to disappear for the radar much quicker than large discharges [60]. The chance that a discharge is detected is limited to the flight hours conducted: reports of oil spots by third parties such as other ships or civilian aircraft crossing the North Sea are exceedingly rare, and cases of a whistle-blower reporting an illegal discharge to the authorities, not unheard of in the USA, seldom occur in the Netherlands.

Second, even when Coast Guard aircraft observe an oil spill, it is difficult to link the spill with a particular vessel in the busy shipping lanes of the North Sea. The data collected by the aircraft show that in nine out of ten cases, the offending vessel cannot be identified. In other words, the offender needs to be caught in the act or just after the act.

Third, on the off chance that an offender is detected, the case may still be dropped because of a lack of evidence. In the Netherlands, for a prosecutor to proceed with a case, an aerial observer needs to have confirmed the illegal nature of the substance based on visual inspection from the air. In other words, all of the advanced monitoring technology can only be used to guide the aerial observer to a potential oil spill for a visual inspection. Airborne radar also produces false positives, including freshwater slicks, seaweed, algal blooms and subsurface sand banks [61]. The courts rely on the aerial observer's ability to identify the specific appearance of oil on the water surface. Clearly, the standard of evidence has large implications for the chance of being convicted. In low-visibility conditions, including the hours between sunset and sunrise, fog as well as heavy precipitation, the probability of conviction drops to zero.

Shipping has long been suspected of evading law enforcement by discharging at the night-time rather than the daytime. The Dutch data are unique in also covering the nightly hours, which allow for a test for the presence of temporal displacement [8]. The tendency to discharge at late hours, as was shown in Fig. 8, does not necessarily mean that those hours are chosen to evade law enforcement. Times of sunset and sunrise vary widely during the year after all. Only when the hourly pattern is such that the timing of discharges allows for the seasonal variation in times of sunset and sunrise can it be seen as strategic. Not earlier than 1999, with a further tightening of regulations in the North Sea area, did seasonal variation in discharges emerge. By that time, the level of discharges was much lower than in earlier decades, making the temporal displacement towards the night-time relatively small in absolute levels.

Over the period 2006–2012, some 10 to 15 vessels were identified annually as suspects of an illegal oil discharge. In only about half of the cases, the prosecutor proceeded with the case. All cases were settled before court. Surprisingly, a low chance of getting caught is combined with a low fine. In 2012, a Russian shipping company was fined for 45,000 euros for illegal oil discharges in both the North Sea and the Arctic Sea. According to people involved in the case, fines are generally even lower. In neighbouring countries, including Belgium and France, fines for the same offence can be easily 10 to 20 times higher [7].

7 Discussion

Within Europe, there is a long history of marine mineral oil pollution [62]. Mineral oil spills, including accidental spills and chronic oil pollution, can cause considerable damage in the marine environment and usually involve wildlife casualties. The economic damage can be considerable and it was in fact a mix of economic and ecological issues that has been the motivation to try and reduce or even eliminate marine oil pollution.

Within the southern North Sea, chronic marine oil pollution was a highly significant issue, at least until sometime in the 1980s. Beaches became contaminated with substantial amounts of oil on a regular basis (national newspaper reports) and oil rates of stranded seabirds were exceptionally high in an international context [18, 23, 34]. A central archive to document the presence or absence of oil on shorelines does not exist within the Netherlands, but a combination of newspaper clippings (e.g. those held by the Dutch Seabird Group, NZG/NSO archives) and notes made by the volunteers engaged in beached bird surveys organised by this same organisation shows that the incidence of oil on beaches has been reduced markedly in recent decades.

It is the lack of systematic documentation in most of the twentieth century, as a result of which it is hard to evaluate the rise and decline of marine oil pollution in any detail. The incentive to ring an alarm bell among naturalists (usually reporting stranded oiled seabirds) was much greater than that of anyone else. As a result, the earlier oil reports were almost always seabird related. Had there been a major spill, however, comparable with the oil pollution caused by shipping accidents such as those with *Torrey Canyon* (1967), *Amoco Cadiz* (1978), *Erika* (1999) or *Prestige* (2002), this would not have gone unreported. It could be seen as a miracle that major shipping incidents or uncontrolled blowouts from the oil and gas platforms built within the Dutch sector have not occurred in the past or in recent years. The shipping density in the area is immense, shipping lanes being used by thousands of vessels per annum through areas with numerous oil and gas installations (a simple blackout on board could easily cause disaster), but major accidents did not occur. Given the ecological conditions of the Southern Bight, notably in winter [63,64] and the associated sensitivity to oiling [65, 66], the Dutch could consider themselves extremely lucky in this respect.

The presence of numerous ships and the offshore industry was hard felt nevertheless, because of the *chronic oil pollution* introduced into these sea areas. Chronic oil pollution is usually reported as the result of a mix of hydrocarbons entering the seas from shipping (tankers and other vessels), offshore and coastal exploration and production, pipelines, atmospheric emissions from sea-based activities, coastal refineries and storage facilities, oil reception facilities, materials disposed of at sea and natural seepage. Even though the aerial and river run-off portions are usually depicted as representing large tonnages of pollution [67], it is clear that (illegal) discharges from ships and leakages from platforms and rigs were the main culprits leading to seabird mortality and polluted shorelines in the southern North Sea.

It took time to establish techniques to effectively monitor and detect slicks of oil at sea, and it took time to change the general attitude on board these ships to deliver unwanted residues and polluted water to harbour reception facilities rather than to dump it overboard. Initially, despite international regulations under MARPOL 73/78 Annex I [3], these harbour facilities were either absent or the cost of delivery was too high. This, combined with a rather small risk of getting caught red-handed while discharging oil, did not stimulate company management or captains to obey the rules. In later years, however, but again with a mix of underlying factors being responsible (education, environmental awareness increased, better facilities, more intense aerial surveillance, fines or at least prosecution, higher risk of detection), the frequency of illegal discharges declined. As a result, shorelines are now normally clean and they will be more or less clean throughout the year (ignoring some relatively minor pollution incidents). Also the oil rates in stranded seabirds declined significantly. While in the 1970s and 1980s newspaper headlines about oil 'incidents' (i.e. usually cases of pollution on beaches and numerous oiled seabirds encountered) were an annual and usually a winter event, such reports are now unusual and become rarer from year to year.

The improvement in the levels of chronic oil pollution has not been restricted to Dutch waters (between 2009 and 2013) [58]. The number of detected oil slicks per hour of surveillance has declined steadily since the early 1990s. Since the chance of being convicted for an illegal oil discharge is remote, even today [8], we must conclude that the observed decline in spillages of oil, with shipping densities being constant or even increasing, is primarily the result of 'better behaviour' on board these vessels. Earlier in the twentieth century, dumping unwanted goods into the oceans was a common practice, not only by captains at sea but even by coastal communities (sewage and other waste materials). 'Waste water' from land was released untreated into sensitive sea areas such as the Wadden Sea and the Southern Bight until the late 1970s. Directly after the two great wars in Europe, excess ammunition, including chemical weapons, were simply dumped into the sea, sometimes even at very short distances to the nearest coastline, on at least 80 locations within the North Sea and Northeast Atlantic Ocean [68, 69]. The common attitude was the following: waste materials would simply disappear into the great wide open of our oceans. That sailors had the exact same attitude was in fact hardly surprising. It was the environmental awareness, something that slowly kicked in after the 1960s, that will have made the greatest difference.

While wildlife hazards due to mineral oil incidents are widely recognised and frequently published, little factual information is available on the effects of 'other noxious liquid substances' on the marine environment [70]. Discharges and washing ashore of hydrophobic substances other than mineral oil or mineral oil products and their effects on marine wildlife have been documented with increasing frequency [44, 70–72], and the effects of some of these substances on shorelines and wildlife have been similar or worse than those of mineral oil [70]. It has been suggested, therefore, that the criteria used by GESAMP (1993, 2002) to classify substances into harmful and less harmful types should be evaluated, taking into account the experiences with these substances at sea [70].

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Oil Pollution in the Waters of the United Kingdom North Sea

Patrick Donner and Tafsir Johansson

Abstract Oil pollution in the United Kingdom (UK) waters of the North Sea primarily emanates from shipping activities and offshore oil production. Increased commercialisation of the shipping industry fills up the quota of oil pollution that is not resulting from oil exploration by offshore installations. The North Sea is a relatively small yet intensively used area, and it contains some of the most active and engaged shipping channels in the world. The result of such active engagement has left devastating consequences in the English Channel, which have sporadically occurred in the form of maritime casualties. This chapter is an effort to understand UK legislation, which has pragmatic approaches to addressing immediate responses as regards to oil pollution applicable to the areas adjacent to the North Sea. "Intervention" is a term often used when it comes to instantaneous action to limit or mitigate oil pollution which may have profound effects on the waters of the world. The need to develop close international cooperation is important and the existing legal regime is in great need of revision. As such and from a more private law approach, arrangements for monitoring and remedial action in the wake of an oil spill are addressed. The UK is just one of several states bordering the North Sea trying to make a difference in addressing oil spill and oil pollution through strict liability regimes. This delineates the disposition of the UK to address a complex problem of oil pollution in the North Sea, which is sensitive in nature. The degree of success is in further need of analysis.

Keywords English Channel, Illegal oil discharge, Intervention, MARPOL 73/78, North Sea, SOSREP (Secretary of State's Representative Maritime Salvage and Intervention), United Kingdom, Vessel-source oil pollution

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Contents

1 Introduction

International interests in the domain of environmental protection increased significantly in the aftermath of the Second World War [1]. Concerns of coastal states in relation to vessel-source pollution and oil spills have increased simultaneously [1]. Before the new millennium, scholarly authors began to examine on issues revolving around incidents with tankers that exemplified "oil spill" from the perspective of the environment and sensitive areas [2]. These incidents could have detrimental effects and leave a sea that possesses a sensitive ecology with irreparable damages [2]. The North Sea, in this setting, is an area which is deemed strongly susceptible to oil spills which, more or less, has been substantiated by evidence from maritime accidents involving releases of chemicals, radioactive substances and oil. The area of the North Sea is bounded by the coastlines of the United Kingdom of Great Britain and Northern Ireland (England and Scotland) (UK) and several European states. Relevantly, when it narrows down to safeguarding the marine environment in the North Sea, there exists a certain difference of opinion in the form of a hidden conflict amongst the given states [3]. The potential for conflict is founded on how much effort is put into preventing accidents, how accidents that do occur are handled, and how the consequences of such accidents are reduced [3]. Thus, conflicts that are mostly accident related depend more on the effectiveness of preparedness and response systems and regulation of activities than on the accidents per se.

Oil pollution as regards the North Sea emerges from shipping activities and offshore oil production. Offshore installations and seabed activities relating to oil exploration constitute a relatively small part in the total amount of the pollution compared to that of maritime casualties, accidental pollution or deliberate dumping of oil. Shipping, more specifically the ever-increasing transboundary commercialisation of various parts of the North Sea, is considered as the principal cause of oil pollution. The English Channel is an arm of the Atlantic Ocean and joins the North Sea to the Atlantic. Vessel-source oil pollution that has taken place in the English

Channel from numerous maritime casualties has triggered international concern and has given rise to the corresponding state responsibility of the UK Government. In the light of this topic, a sharp distinction is to be made between the roles of the international community and individual states because eventually, it narrows down to private law and the instruments that are incorporated by individual states of the North Sea. Maritime casualties in the North Sea have also invoked concerns as regards to illegal oil discharges that are unanimously frowned upon by the coastal states. In fact they are the typical reason for the occurrence of all legal matters and the originators of legislation, which have secured places in international law and, to that extent, in domestic legislation.

This chapter is an effort to understand the legal order for oil pollution in the waters of the UK North Sea. To follow the development of this chapter, it must be stressed that accidental oil spills and individual catastrophes are quite spectacular, even though scientists have demonstrated that pollution from other sources tend to damage the environment at a greater level. Even though the end result of oil contamination forms only a small part of the so-called general pollution of the marine environment, the end result of oil spills and oil wastes is extremely damaging for marine landscapes and ocean inhabitants, especially for sensitive areas similar to the UK waters of the North Sea [1].

2 A Review of Vessel-Source Oil Pollution in the UK Waters

The constantly increasing use of fuel oil with the resulting discharge of oil and oily mixtures brings ships and tankers prominently into the foreground as a significant direct cause of oil pollution near the coasts of major maritime nations [4]. "Oil" in its simple form has been defined as being a very wide range of hydrocarbon-based substances and refined petroleum products [5]. From a convention perspective, the definition of oil is observed as being wider and more demonstrative. "Oil" from an international perspective is interpreted as petroleum in any of its forms including crude oil, fuel oil, sludge, oil refuse and refined products [6]. Although these different forms are said to have different effects in the water, when in a juxtaposition, they are under the legal spectrum defined as simply "oil pollution". Oil pollution, from a broader perspective, is not solely confined to coastal waters [4]. It may occur within the national maritime zone of a state or in international areas which in international law are termed as the high seas. While navigation in the high seas is read together with the word "freedom", this so-called freedom of navigation has resulted in major oil pollution disasters, which have eventually affected the coastal states in one way or another. It may be safely asserted that shipping agencies dealing with the production, transportation, handling or use of oil must be considered as actual or potential sources of oil pollution. The term "oil pollution" derives from the notion of a pollution which is massive in proportion and the mitigation process of which is quite cumbersome and complex.

Vessel-source oil pollution may take place anywhere and is likely to occur in the event of dumping of oil, discharges from shipping and accidental spillage of oil. All vessels discharge oil during their operational lifetime and based on the type of operation; oil pollution has been categorised into legal and illegal oil pollution. While accidental spillage of oil is dependent on the occurrence of an unforeseeable event and may be dealt by response, protection and mitigation, the operational oil pollution aspect may be limited by rigid regulations. International law has also designated certain vulnerable sea areas as "special areas" where oil pollution is confronted with strict control and management policies. The International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 (MARPOL 73/78), has characterised the North-West European waters as a special area effective from 1 August 1999 [6]. This means that the UK waters of the North Sea bear the same title and are governed by international oil pollution instruments. While oil pollution in the wake of a maritime casualty is regulated by conventions that relate to intervention, operational oil pollution is administered by instruments, which contemplate both civil and criminal liabilities.

In terms of illegal oil pollution, MARPOL 73/78 provides a rigid measurement of permissible oil discharge in the North Sea [6]. Any discharge beyond the given limit is deemed to be illegal oil pollution. Furthermore, the London Convention on the Dumping of Wastes at Sea, 1972 (London Convention), prohibits the deliberate dumping of oil at sea. The London Convention, in fact, has a worldwide application. In addition, the regional Oslo Convention for the Prevention of Marine Pollution by Dumping from Ships and Aircraft, 1972 (Oslo Convention), is limited to the North-East Atlantic Area including the UK waters of the North Sea. However, the Convention for the Protection of the Marine Environment of the North-East Atlantic, 1992 (OSPAR Convention), came into force on 25 March 1998 and, for the State Parties to OSPAR, replaced the 1972 Oslo Convention and the 1974 Paris Convention on Pollution from Land-Based Sources [7]. The original Oslo and Paris Conventions were administered by the Oslo and Paris Commissions, and these also ceased to exist when the OSPAR Commission, commonly abbreviated as OSPARCOM, was created to administer the new convention.

Between the two facets of oil pollution, i.e. operational discharge and maritime casualty, the former can be controlled with international instruments relating to monitoring, certification, inspection and compensation. The latter, however, demands urgent response to limit the damage that has occurred. The "response sector" understands the difficulties that pertain to the North Sea and has not been able to find ways to improve their performances significantly. The Torrey Canyon oil spill on the southwest coast of the UK in the spring of 1967 is, to date, considered as one of the world's most serious oil spills. This has made the UK, its North Sea counterparts and the international community aware and decisive about accidental oil pollution relating to the pristine waters of the North-East Atlantic area. While there may exist a zero-tolerance policy for operational discharges, the same cannot be enacted for the accidental facet of oil pollution, and it, therefore, has become a primary concern, not only to the scientific and social researchers but also to coastal states including the UK.

The *Torrey Canyon* disaster of 1967 revealed certain doubts with regard to the powers of states, under public international law, which relate to accidental incidents in the high seas [8]. Questions were raised as to the extent to which a coastal state could take measures to protect its territory from pollution where a casualty threatened that state with significant oil pollution in the wake of an accident, especially if the measures necessary were likely to affect the interests of foreign shipowners, cargo owners and even flag states [8]. The general consensus was that there was a need for a new regime, which, while acknowledging the need for state intervention on the high seas in cases of grave emergency, clearly restricted that right to protect other legitimate interests. Although an impermeable convention with unassailable wordings can bring operational oil discharges close to zero, the same cannot be said in terms of a convention dealing with intervention in cases of collision or stranding of a vessel. Accidental oil pollution may invoke liability, but it cannot have the same ramifications of operational oil pollution. While the aftermath of the accident can be dealt with via technical assistance, the immediate response or intervention part dealing with the maritime incident requires far greater effort. Then again, the end result of both operational oil pollution and oil pollution from accidents includes the common effect of contamination to the world's greatest resources. Hence, the UK as a stakeholder of the North Sea waters was compelled to put in a place substantial legal instruments to mitigate oil pollution issues ab initio and ad finem.

3 Oil Pollution, North Sea and UK Legislation

It has been more than 30 years since the shipping community first embraced international rules and standards for the protection of the marine environment from pollution from ships [9]. This was accomplished by the 1973 International Convention on the Prevention of Pollution from Ships, which was completed and adjusted to ensure entry into force by the 1978 Protocol to it – the two instruments together are commonly known as MARPOL 73/78. Since then the international rules and standards set out in MARPOL 73/78 have been extended, improved and strengthened on many occasions with due respect to the international shipping community. Since commitments are a persistent feature of international affairs, the best of legislation will have no impact on the real world unless it is implemented and enforced [10]. Annex I of MARPOL 73/78 Regulations for the Prevention of Pollution by Oil has entered into force in the UK on 2 October 1983. In this context, the UK contains two separate legal systems in the parts facing the North Sea (England and Wales and Scotland), but nevertheless, the legislation on oil pollution, inter alia oil discharges, is common to them both. The only differences are therefore in procedural matters, where the differences between the two systems remain. In practice, these differences are not significant, because practically all prosecutions are brought within the system for England and Wales, since they are handled by the local court for the headquarters of the Maritime and Coastguard Agency at Southampton.

The implementation of MARPOL 73/78 has generally been welcomed by the North Sea States and is known to supersede the earlier OILPOL Convention on the Prevention of Pollution of the Sea by Oil (1954) [11]. However, in an effort to understand the history of UK's engagements in oil pollution enactments for the North Sea, it is significant to highlight a classic English law, i.e. the Prevention of Oil Pollution Act 1971, which was imported from the International Convention Relating to Intervention on the High Seas in Cases of Oil Pollution Casualties, 1969 (Intervention Convention). The Act repealed the Oil in Navigable Waters Act S 1955 to 1971 and was applied into the UK waters including the English Channel [12]. Although the Act, as it relates to shipping, has since been repealed by a consolidating Statute, the Prevention of Oil Pollution Act 1971, and the core of the Convention was embedded in Sections 12–14 of that Act [12]. The Prevention of Oil Pollution Act 1971 (Application of Section 1) Regulations 1984 (S.I. 1984/ 1684) provides that Section 1 of the Prevention of Oil Pollution Act 1971 applies to any oil produced directly or indirectly from crude oil, making certain discharges of such oil an offence under Section 3 of that Act. However, an inherent vice of the Act is the usage of the term "an accident" replacing the original term "maritime casualty" of the Convention. The UK Statute covered discharges from pipelines and in connection with exploration of the seabed as well and is, therefore, even less specific than the Convention, merely contemplating that "an accident includes the loss, stranding, abandonment of or damage to a ship" (s. 12 (9)).

So wide a definition evades any attempt to extract a principle by which "an accident" may be recognised, and at worst, the choice of the term "accident" may be misleading, as it is not clear whether or not a deliberate spillage falls within the sphere of the definition so as to enable the Minister to invoke his powers under the Act [12]. Any such deliberate spillage would certainly establish a criminal offence under Section 1 or Section 2 of the Act, but it may be that the Minister would feel reluctant to use the powers which the Act confers on him for dealing with just such a situation, on the grounds that an accident, in the normal sense of the word, has not occurred [12]. Moreover, it is perhaps pertinent at this point to note that the Act also fails, in the manner of domestic statutes, to enumerate the purposes for which it was enacted. It is remarkable that the Act is silent as regards to parties interested in the vessel as a necessary precondition to the issue of directions of the exercise by the Minister of his powers. Not only is this controversial; it is simultaneously au contraire to the normal tendencies of a property-based system of law, but it also represents a substantial deviation from the Convention, which provides for elaborate measures of consultation with interested parties prior to the taking of any action [12]. The discharge of such oil is now regulated by the Offshore Petroleum Activities (Oil Pollution Prevention and Control) Regulations 2005 (S.I. 2005/ 2055), making a breach of the requirements a criminal offence.

Regulation 18 of the 2005 Regulations provides that Sections 1 and 3 of the 1971 Act do not apply to emissions which are a discharge or release of oil for the purposes of the 2005 Regulations. These provisions have, therefore, been superseded and are considered redundant [13]. A significant criticism of the Act was that it introduced criminal liability for oil pollution in the English legal system. It is unfortunate that there was a feeling that oil spillage originates from a "deliberate act" or "gross carelessness" on the part of shipowners or the crew members and ultimately leads to extensive and irreversible pollution of the seas [14]. However, the Act did not make any significant differentiation between elements of "intention" and "deliberate". But revocation of the Act did not imply that oil pollution would not cease to embrace the notion of criminal responsibility in future legislation for the UK waters of the North Sea.

3.1 Inclusion of Conventions in Current UK National Law

The long-anticipated consolidation of the UK merchant shipping legislation finally arrived with the passing of the Merchant Shipping Act in 1995 (the "Act of 1995") which replaced the thirty or so Acts dating from the Merchant Shipping Act of 1894 [15]. This included provisions previously enacted in the Merchant Shipping Act 1994, which was passed after the stranding of the oil tanker *Braer* in Shetland in January 1993. Section 128 of the 1995 Act empowers the making of an Order in Council to give effect to, inter alia, MARPOL 73/78 [16]. Any violation of MARPOL 73/78 within the jurisdiction of any party to the Convention is punishable either under the law of that party or under the law of the flag state [6]. Article 4 of MARPOL 73/78 requires that signatories initiate proceedings to be taken as soon as possible in accordance with its law against the ship flying its flag where there is sufficient evidence to satisfy itself that a violation has occurred. Penalties for infringement of the various Annexes to MARPOL 73/78 are set out in the Act of 1995 and subordinate legislation made thereunder.

The segment of the Act of 1995 integral to oil pollution in the North Sea is incorporated in Part VI, Chapter II (Articles 131–151), which are the basic texts in British maritime law aimed at oil pollution offences in North Sea UK waters. It simultaneously ensures the integration of international maritime law conventions ratified by the UK and relevant to the protection of the North Sea into British law. A more analytical approach to the Act of 1995 reveals that the UK, compared to other European counterparts, maintain a more rigid position by the wordings of Article 131, which bans the discharge of oil from any vessel in British "national waters". The analogy behind this stringency is coupled with the fact that the UK has not yet decided to declare an exclusive economic zone but wishes to take the advantage of the sovereign jurisdiction over pollution matters conferred by Article 56 (1) (b) (iii) of the United Nations Convention on the Law of the Sea 1982.

A subtle drawback of the Act of 1995 would be that although there is a defence of "reason of leakage" or "accidental leak", the Act does not provide further explanations as to what constitutes an "accident" (Article 132) that could derivate from "negligence" (Article 58 (8)). In line with general criminal law, the prosecution has to prove a case "beyond reasonable doubt", which would mean that the accused would have to be guilty of "criminal negligence" which can be differentiated from "ordinary negligence". The carelessness required for criminal negligence is appreciably more serious than that for ordinary civil negligence. However, under the spectrum of the Act of 1995, any element of negligence would constitute an offence known in English law as "absolute". It is sufficient to show that the event which constitutes the prohibited act actually took place. The person responsible need not even have known that the event happened. The justification for this approach is that the offence is of a kind where it is important to ensure that those responsible take adequate measures to ensure that the prohibited act does not occur. Moreover, the Merchant Shipping Act 1995 implements in the UK the International Convention on Oil Pollution Preparedness, Response and Co-operation (OPRC), the aim of which is to increase the level of effective response to oil pollution incidents and to promote international cooperation to this end. In addition, the implementation of the Merchant Shipping Regulations in 1998 has helped the UK fulfil its legal obligations under international law by introducing oil spill planning requirements and legal oil spill reporting requirements of the OPRC Convention. An analysis of these pertinent regulations reveals that power is given to the government to intervene in the event where there is or there may be a risk of significant oil pollution in any part of the UK waters including the waters connected to the North Sea.

3.2 UK and North Sea International Agreements

Regional conventions dealing with pollution of certain seas or waters by oil could, to a certain extent, be considered more effective than global conventions. This assumption is largely based on the fact that coastal states are more likely to be concerned about sustainable development of marine resources within and approximately beyond their maritime zones since they are involved in the usage and exploitation of those marine and natural resources. To this effect, the coastal states tend to establish cooperation to monitor the international boundaries of the sea that is connected to the national waters. Then again, the hypothesis is that oil pollution of small proportions in the international waters might have a "domino effect" in the national waters and the waters over which a state has declared its rights and sovereignty under international law. In this regard, it is easier to consider the particularities of the regional seas with the help of coastal states cooperation and consideration.

Membership of the 1969 Bonn Agreement comprises of eight North Sea states including the UK. The Bonn Agreement is guided by the principle of protection of the North Sea environment in the event of oil pollution incidents. This protection principle is the first of its kind to be introduced with relevance to the protection of the North Sea. In this context, the Bonn Agreement covers the North Sea, the Skagerrak and the English Channel. The parties under the Bonn Agreement have agreed to notify each other of any marine pollution or threat of marine pollution from an oil spill, which is likely to pose a serious threat to the coast or related interests of another party. They pledge to assist one another to the best of their ability, on request and on a cost-recovery basis.

The Bonn Agreement was revised in 1983 and 2001 to include the European Union and Ireland, respectively, as part of the cluster [17]. The 1983 amendment was coupled with a change of the original title with the addition of the words "…other harmful substances". Although Article 4 (d) of the Bonn Agreement stressed "new ways" and "…effective measures to deal with it", the agreement did not embrace the intervention or contingency aspect of oil pollution in an in-depth manner considering the nature of the English Channel and the surrounding areas. During the *Ekofisk Bravo platform* blowout in April 1977, it was agreed by the contracting parties that the agreement would cover oil spills from platforms, but still failed to provide the much needed contingency plan and pragmatic solutions to limit oil leakage from "near spills" [18]. However, under the auspices of the Bonn Agreement, the UK and France developed the MANCHEPLAN in 1978, which is a comprehensive contingency plan for dealing with major maritime disasters in the English Channel and can be implemented for serious oil spills occurring outside coastal waters [3]. The MANCHEPLAN can be termed as a contingency plan for maritime disasters relating to search and rescue and counter-pollution operations [19]. As regards to the legal side, the objective of the MANCHEPLAN is considered more far-reaching than ordinary international cooperation in the framework of the Bonn Agreement, which concerns just pollution fighting and repression of MARPOL 73/78 offences. Another example of bilateral agreements between North Sea states dealing with oil pollution involving the UK is the Norway-UK "joint contingency plan" for counter-pollution operation [19]. The NORBRIT agreement mainly specifies arrangements for cooperation in the event of a blowout. Although the NORBRIT agreement sets out procedures for pollution incidents likely to affect both parties, it does not cover search and rescue activities.

4 Obscured Oil Pollution Intervention and the UK Legal Regime

"Oil spill intervention" refers to measures taken during an incident to limit damage or avoid a spill altogether, exempli gratia directing a vessel to a place of refuge and directing said place of refuge to accept the vessel or providing and directing a resource onto a vessel to aid in stopping a leak. Spill intervention is a form of preparedness and response and generic actions, which is a process that operates to the conclusion of remediation efforts after the oil spill in the event of maritime casualty [20]. Although related to response, intervention would occur the very moment a national authority is advised of an incident in progress that has the potential for a spill, which can also comprise a vessel in distress with a developing leak.

On 18 March 1967, the 120,000 tonnes tanker *Torrey Canyon* grounded on Pollard Rock, part of the Seven Stones reef in the Scilly Isles to the far southwest of the UK [21]. As the era of the major oil spill began, the *Torrey Canyon* incident exemplified the lack of internationally agreed means of responding to accidents. The International Maritime Organization (IMO) established a Legal Committee to deal with the deficiencies that existed at the international level for assessing liability and compensation for oil spill damage and a new subcommittee of the Maritime Safety >Committee (MSC) to deal with environmental issues [22]. Not only did the *Torrey Canyon* incident expedite the formation of MARPOL 73/78; it also played a significant role in the adoption of the International Convention Relating to Intervention on the High Seas in Cases of Oil Pollution Casualties (intervention convention) by the IMO [22]. This international instrument is the first of its kind that enabled the respective governments of state parties to take action if an accident in international waters threatened its coastline with pollution [22]. Although "intervention" has not been defined in Article II, the necessary conditions leading to "intervention" in the high seas have been highlighted in Article I (1) of the Convention [23]. Conditions include "...grave and imminent danger to the coastline or related interests from pollution and or threat of pollution of the sea by oil" [23]. These risks must be coupled with the "reasonable" expectation that the oil pollution may result in major harmful consequences. Moreover, the intervention might be invoked in "extreme urgency" (Article III), which allows action without prior notification or without continuing consultations that have already begun [23].

From an observation of the wordings of the Convention, it may be gathered that damage control from "near spills" is an important factor, especially for the seas that are pristine in nature and are given the status of Particularly Sensitive Sea Areas (PSSAs) by the IMO. This would apparently be applicable to the North Sea, and an intervention convention was needed to be in place to ideally address generic incidents in the future as a part of state responsibility under international law. Then again during the *Torrey Canyon* disaster, there were no compensation schemes in place for those affected by the spill, leaving the courts as the only recourse for recompense [21]. The British Government was faced with difficulty in finding a way to obtain compensation and requested an emergency meeting with the Inter-Governmental Maritime Consultative Organization to resolve the given situation [21]. This resulted in the International Convention on Civil Liability for Oil Pollution Damage in 1969 (CLC) to provide strict, no blame liability and a compensation regime for the cost of spills to be placed upon the tanker owner and thus avoid the need for costly litigation [24]. But the inevitable question is whether the CLC is adequate enough to cover damages caused by major maritime incidents in the UK waters such as the *Torrey Canyon* itself.

Although the Intervention Convention gives coastal states wide discretion for dealing with oil pollution situations, the Convention has contradicted itself in a certain part whereby a significant drawback is dormant in Article VI. Article VI embodies the notion of compensation for any measures taken in contravention of Article I where such measures have resulted in damage to other parties [23]. The hypothesis gathered from this Article could question the intervention process undertaken by any party in the North Sea and obstruct the intervening state(s) from taking responsive actions in urgent situations. Since the convention does not map out possible intervention options in Article I due to increased flexibility caused by the conjunction of wordings, several scenarios can be predicted from the legal analysis of Article VI. France, in its endeavour to intervene in oil spills in the North Sea to save the English Channel, might retreat if, for any reason and at any stage, the process seems inevitably futile. Similarly, the UK might need an adequate amount of time to rethink about immediate actions as regards to "place of refuge" for the collided vessels located in the North Sea.

The concept of "adequate amount of time" prima facie defeats the very purpose of the intervention convention. Then again, the "place of refuge", if for any reason chosen to be a place in France, might result in compensation payable by the UK if France proves that the intervention undertaken by the UK is in contravention of Article I. In theory, what is considered as "flexibility" might in reality be translated as "compensation". Moreover, the incidence of pollution from "operational" discharges of oil is significant, even within coastal waters, including well-patrolled areas and areas with a high traffic, such as the North Sea. It is perhaps the third most serious form of pollution from shipping on the high seas apart from stranding or collision of vessels. But whether it is "intentional" discharge or "operational" discharge, the intervention convention is ideally in need of specification so that the North Sea waters of the UK can be saved by immediate responses, either from a coastal state or non-coastal state.

4.1 An Analysis of UK Intervention Policy for the North Sea

In the UK, response is developed and linked into an investigation, prevention, response and liability regulatory framework for oil. For both oil and chemical spills, there are no intervention policies or regulatory measures in place. This has, as a result, developed a gap as regards to formal regulated framework for response or liability, since the given focus is only on prevention. The Merchant Shipping (Accident Reporting and Investigation) Regulations 2013 implements the provisions of Directive 2009/18/EC of the European Parliament and of the Council. They set out the procedures for dealing with specified casualties and incidents which are collectively defined as an "accident", including the purpose and scope of an investigation and how an investigation is to be conducted and which accidents and incidents may be investigated [25]. Oil pollution is covered in Article 3 (b) of the regulation, which mentions both "pollution" and "severe pollution". Although the first piece of legislation dealing with widespread oil pollution from ships was introduced in the UK at the end of the First World War, it seems that significant attention was not given to the North Sea area which ultimately gained the status of a Particularly Sensitive Sea Area designated to areas "within and beyond the limits of the territorial sea" [26, 27]. The North-West European water areas are designated as a "special area" in Annex 1 corresponding to MARPOL 73/78. The area includes the North Sea and its immediate vicinities, the Irish Sea and its approaches, the Celtic Sea, the English Channel and its approaches and part of the North Sea Atlantic immediately to the west of Ireland.

For a rapid response to oil pollution occurring in the UK waters in the North Sea, there exists a National Contingency Plan on behalf of the Maritime and Coastguard Agency (MCA), which is an executive agency of the Department of Transport [28]. The legal basis for this plan is Section 293 of the Merchant Shipping Act 1995, as amended by the Maritime Shipping and Maritime Security Act 1997 and the Marine Safety Act 2003 and the Pollution Prevention Control Act 1999 [28]. This plan also meets one of the UK Government's obligations under the OPRC Convention. The Contingency Plan covers the area designated under the Merchant Shipping (Prevention of Pollution) (Limits) Regulations 1996, which specifies those areas that are within the jurisdiction and rights of the UK, including areas of the North Sea. From a legal point of view, the Plan only gives effect to a response, which is "immediate" in nature for reporting oil pollution. In the case of *MSC Napoli* in January 2007, the MANCHEPLAN was invoked for dealing with immediate action to stop oil leakage, including the significant "spill intervention" element, i.e. "place of refuge" [29].

The responsibility for identification and designation of a "place of refuge" was assumed by the Secretary of State's Representatives for Maritime Salvage and Intervention (SOSREP). An important function of SOSREP is acting at the earliest point during a shipping or offshore incident to assess the risk to safety, to prompt the end of any such incident and to ensure that increasing risk is evaluated and appropriate measures taken to prevent or respond to any escalation of risk. As a signatory to the Bonn Agreement, the UK via the MCA and the SOSREP is obliged to take part in "spill interventions". In reality, providing a place of refuge as a part of "spill intervention" has not been addressed elaborately in the National Contingency Plan. The MANCHEPLAN cannot be seen as an adequate instrument to deal with situations which call for an "instant action" to control the given situation which may result in major oil pollution.

It is worth mentioning that the roles of the harbour master and the SOSREP are envisaged in Section 14 of the National Contingency Plan, which is quite innovative and specific. Then again, the vast authority that has been endowed to the SOSREP in representing the Secretaries of State for the Department of Transport is not followed by a detailed account of responsibility in the National Contingency Plan.

Although the random usage of the word "intervention" is observed in the text of the Plan, it cannot be said to address the given situation properly to hinder "oil" from becoming a "pollution". Rather, "intervention" manifests a certain type of power given to the SOSREP to override rules of other government entities during a maritime casualty. Then again, a critical drawback of the UK approach comes as a direct result of the independence of the SOSREP [19]. Since it has already been established that the National Contingency Plan covers waters of the North Sea belonging to the UK, the subject-matter of "place of refuge" may need further interpretation when it comes to seeking a place of refuge for a leaking vessel as a part of “intervention”. The analogy is that any place in the North Sea can literally be a place of refuge. This includes places of significant importance and special status areas designated by the International Maritime Organization. More recently, the government of the UK has designated 27 Marine Conservation Zones (MCAs), some of which fall within the North Sea territory.

In exercising its independence, SOSREP may seek a “place of refuge” in any part of the UK waters in the North Sea designated as an MCA. If for any reason SOSREP fails to intervene to help avoid near spills after entering the so-called place of refuge which is a designated MCA, then the very purpose of “spill intervention” is defeated leaving the MCA contaminated by oil pollution. Moreover, in the case of *MSC Napoli* which suffered a catastrophic hull failure in the English Channel, SOSREP took over and decided that the ship be towed to Portland, i.e. the South of England. En route to Portland the ship encountered more difficulties and was in danger of breaking up and polluting the English Channel [19]. Even though the decision of SOSREP was successful in this case, and it’s dependent decision-making authority is essential for successful performance of its role free of pressure from external parties, some revision may be needed when it comes to “spill intervention” in the North Sea. Failure to take adequate, instant and necessary “spill intervention” measures would mean that the UK may be held responsible to its’ North Sea counterparts, but failure to adequately take conservation aspects into account may lead to irreparable environmental damage. Then again, the concept of intervention under the National Contingency Plan needs further clarification.

4.2 Comparison with Australian Legislation

The UK has not only ratified the intervention convention; it has also extended the applicability of the convention to the Isle of Man which is located in the middle of the Northern Irish Sea. In an effort to comprehend how the UK National Contingency Plan should embody specific measures of intervention to limit or completely prevent oil pollution, examples can be drawn from the Australian national legislation, which has carefully considered various issues and evades legal drawbacks to provide for a more contemporary and pragmatic action of oil spill intervention.

The Commonwealth possesses some residual jurisdiction within 3 nautical miles by virtue of the intervention convention [19]. The intervention convention has been incorporated into Australian law by the Protection of the Sea (Powers of Intervention) Act 1981 (Intervention Act) (Australian Act) [19, 30]. Compared to the UK Plan, the Australian Act is more thorough in so far as it provides a list of measures that may be employed in Section 8 and Section 9 [30]. These include an action to “move the ship or part of the ship to another place” or issue directions so that this can be accomplished. This can also be compared to the intervention convention where no guidance is given as to what measures are permitted, except that under Article V the action must be proportionate to the actual or threatened damage [23].

Then again the Australian Act in Section 10 also includes a power in situations which are not addressed and covered by the intervention convention or the UK Plan. This is aimed at casualties that occur in the internal waters, and the stipulated power is given to the respective authority to move or direct the movement of any ship in internal waters in the Australian coastal sea and any Australian ship on the high seas. This in fact represents the notion of good ocean governance reflected in the Australian Act due to the fact that it is in accordance with the definition of "ocean governance" as provided by the United Nations Convention on the Law of the Sea, 1982 [31]. The definition established gives a reasoned understanding of the term "ocean" which implies the "holistic nature" of the ocean and thus the recognition that problems are closely interrelated and must be considered as a whole because any casualty in internal waters is deemed to have repercussions in the high sea and vice versa. Considering the disasters that have taken place in and around the UK waters, it maybe suggested that the scope of the UK Plan should be extended to consider the interconnectedness of the North Sea waters and the UK internal waters as a part of the "inclusive nature" of decision making and implementation for oil spill intervention.

5 Instruments Against Illegal Oil Discharge

In general, the subject-matter of illegal oil pollution for the North Sea as embodied in the London Convention and OSPAR is similar in terms of provisions. With regard to the dumping of oil, the wordings of the London Convention (as amended in 1980) is less ambiguous and requires all contracting parties to prohibit the dumping of "... crude oil and its wastes, refined petroleum products, petroleum distillate residues, and any mixtures containing any of these, taken on board for the purpose of dumping". The UK ratified the Convention on 17 November 1975 and subsequently ratified the 1996 Protocol. The 1996 Protocol modernised the "London Protocol" and, eventually, replaced it [32]. It introduced (in Article 3) what is known as the "precautionary approach" as a general obligation [32]. Article 3 stipulates that "appropriate preventative measures are taken when there is reason to believe that wastes or other matter introduced into the marine environment are likely to cause harm even when there is no conclusive evidence to prove a causal relation between inputs and their effects" [32]. The article also states that "... the polluter should, in principle, bear the cost of pollution" and highlights that contracting parties should ensure that the protocol should not simply result in pollution being transferred from one part of the environment to another [32]. Moreover, the North Sea states including the UK cooperate in the Paris Memorandum of Understanding on Port State Control (MOU) of 26 January 1982, which took effect on 1 July 1982 [33]. The MOU provides that these Maritime Authorities "will maintain an effective system of Port State Control with a view to ensuring that, without discrimination as to flag", foreign ships visiting the ports under their jurisdiction shall duly comply with the standards laid down in the relevant maritime conventions, inter alia MARPOL 73/78.

Section 6 of Annex 9 of the MOU implies that the Port State shall have the authority to conduct more detailed inspection on the grounds where the master of an oil tanker fails to produce the record of oil discharge monitoring and control system which is pertinent to the prevention of substandard and illegal oil discharges in vulnerable areas of the North Sea. Via this MOU, the UK can administer a thorough inspection and take reasonable measures on foreign vessels to safeguard its parts of the North Sea. It seems that offences against both MARPOL 73/78 and the UNCLOS umbrella convention as regards to illegal oil pollution in the UK waters of the North Sea tend to have an international character involving transboundary, administrative and judicial cooperation between competent authorities [6, 31].

The Paris Memorandum of Understanding on Port State Control and the European Port State Directive ensure an effective, coordinated and uniform system of inspection or Port State Control (PSC) by Maritime Authorities in most European ports. The PSC is the inspection of foreign ships in national ports to verify that the condition of the ship and its equipment comply with the requirements of international regulations and is quite effective in detecting substandard ships that may cause excessive operational discharges in the North Sea or be prone to accidents in the high seas. The European Port State Directive, however, does not provide any legal basis for the institution of proceedings by Port States. The Directive mainly aims at a more uniform execution of the MOU obligations, inter alia by listing ships eligible for a priority inspection, legitimate reasons for a detailed inspection (e.g. a notification report of another Maritime Authority) and criteria for the detention of a ship. This would also enable the North Sea states to have a uniform inspection system for preventing illegal oil pollution. Then again, the new OSPAR Convention requires signatory countries, including the UK and the European Union, to prevent and, where possible, eliminate pollution of the marine environment (previous Conventions merely required a reduction in pollution) [7]. The text of the new Convention places particular emphasis on the use of the “polluter pays principle” and the “precautionary approach”.

From a strict criminal liability aspect, Directive 2005/35/EC of the European Parliament and of the Council of 7 September 2005 on ship-source pollution and on the introduction of penalties, particularly criminal penalties, for infringements (EU Directive) states that ship-source polluting discharges constitute in principle a criminal offence, and according to the Directive, this relates to discharges of oil or other noxious substances from vessels [7]. According to the EU Directive, minor discharges shall not automatically be considered as offences, except where their repetition leads to deterioration in the quality of the water. The sinking of the *Prestige* in November 2002 and of the *Erika* in December 1999 highlighted the need to tighten the net in relation to ship-source pollution. However, accidents are not the main source of pollution, since most of the pollution is the result of deliberate discharges (tank-cleaning operations and waste oil disposal). Although criticised for maintaining a rigid position, this Directive sends a clear message to the polluters of the North Sea waters (high seas) for illegal oil discharges.

The UK has been one of the member states that have challenged the provisions of criminal liability on the grounds that the community lacked competence to prescribe criminal law rules in cases where there is a minor discharge or where there is an oil discharge, which has not caused any damage to the environment. It seems that the UK stands on fair ground when it comes to making criminal convictions in matters of illegal oil discharges even on the high seas. The national policies to a great extent reflect punishment for all types of illegal discharges including oil in any parts of the North Sea including the English Channel. But the UK has held a strong position against the European Commission for criminalising seafarers in the event of oil pollution that may also be the result of an accident. EU Directive 2005/EC/35 was transposed into UK law by the Merchant Shipping (Implementation of Ship-Source Pollution Directive) Regulations 2009, and as a result, criminal sanctions now follow if the discharge was made with intent, recklessly or with serious negligence and unless all reasonable precautions were taken after the damage to prevent or minimise the discharge. The interpretation of the concept of "serious negligence" is not clear, but the amendment could be seen as alleviating the criminal liability, compared to the earlier situation, if only a little.

6 Conclusion

The Convention on Civil Liability for Oil Pollution Damage Resulting from Exploration of Seabed Mineral Resources, 1977 (CLEE 1977), is basically a liability convention for states that have coastlines on the North Sea, the Baltic or that part of the Atlantic Ocean. The convention deals with liability for offshore oil and gas operations and failed to enter into force since there already exists a developed liability regime for the oil industry under the bilateral agreements with the involved coastal states [34]. However, the notion of oil pollution from offshore drilling, exploration and exploitation is also in the subject of a voluntary agreement amongst oil companies operating in North-West Europe, i.e. the Offshore Pollution Liability Agreement 2014 [34]. Under this Agreement, "Designated State" includes the UK and the Northern Ireland whereby the operators of offshore installations accept strict liability for pollution damage and remedial measures [34].

From a legal perspective, it may be deduced that this agreement covers remedial measures for involuntary oil pollution which implies that reasonable measures are to be taken by any party from whose offshore facilities a discharge has occurred, and failure on behalf of the party invokes civil liability where compensation for pollution damage and costs for remedial measures per incident are payable up to a maximum of $250,000,000. Although it has been established that offshore drilling comprises a small segment of the total oil pollution of the North Sea, civil liability incurred under the respective provision of the agreement may hinder future oil pollutions caused by the operators' negligence. It also requires operators of the UK offshore installations to work with reasonable care and be adequately prepared to respond to even minimal discharges of accidental oil spill which is necessary to address special areas of the UK waters belonging to the North Sea. On the other hand, from a more private law approach, the Offshore Installations (Emergency Pollution Control) Regulations 2002 also provide the Secretary of State for Energy and Climate Change with the power to intervene in cases where there may be or is a significant risk or pollution. In these cases, the power is undertaken by SOSREP. In an endeavour to comprehend the legal aspect of the 2002 regulation, it may be deduced that similar to accidental oil pollution, there exists an intervention policy within the framework of the 2002 regulation, which is achieved by SOSREP comprising of wide-ranging remedial measures to be undertaken to prevent oil pollution originating from accidents occurring. The SOSREP, yet again, has been given full discretion to sink or destroy all, or any part of an, offshore installation.

Considering the fact that the main offshore oil- and gas-producing area in the UK is in the North Sea, it can be estimated that relevant measures are embedded in tight-worded relevant agreement and national legislation to prevent unwanted oil spills resulting in oil pollution. Then again, the Offshore Petroleum (Oil Pollution Prevention and Control) (Amendment) Regulations 2011 are unique in its features and extend the provisions of liability for oil pollution to the sea adjacent to the UK from the low water mark up to the seaward limits of territorial waters. The Regulations (Reg. 5) require that the Secretary of State, before granting any licence, consent, authorisation or any approval, where it is considered that any proposed activities are deemed to have a significant effect on a relevant site, whether individually or in combination with any other plan or project, makes a Habitats Regulation Assessment (Appropriate Assessment) of the implications for the Natura 2000 site in view of the site's conservation objectives [35, 36, 37]. This is done with the objective to safeguard special sea areas adjacent to the UK via updating the definition of oil, introduce a permitting system for oil discharges and strengthen the powers to inspect and investigate oil discharges.

Since the grounding of the *Amoco Cadiz* in March 1978, there has been growing criticism of the effectiveness of status quo internationally and regionally, covering oil pollution. Despite the criticism, it seems the UK has held a strong position whereby the risk of acute pollution has been reviewed, and proposals for indicators and environmental targets have been drawn up. The hypothesis behind this speculation is that the North Sea Conference will not be able to provide immediate and long-lasting solutions. Nor would a single convention be able to provide the UK with the necessary tools to fulfil the need to protect its waters in the North Sea. Then again, the EU Directive has a number of considerations which reflect existing international legislation on oil pollution which, in fact, may be contradictory to existing legislation. In addition, MARPOL 73/78 has undertaken the protection objective of numerous areas, and the UK is seen as "one of many".

Considering the aftermath of oil spill disasters in the North Sea waters of the UK, it would not override any international law if those areas were treated slightly differently. This, of course, might explain the unlimited independence given to SOSREP to intervene in oil pollution incidents, whether it be from a vessel or an offshore installation source. Although the liability regime for offshore installations and activities is well established in the UK private sector which is coupled with adequate pollution compensation for most incidents, there is still a need for a widely accepted international regime, covering all aspects of oil [1]. The subject is on the agenda of the International Maritime Organization [1].

There is still opposition to a more comprehensive order from some sectors of the oil industry, especially offshore operators who, at present, are able to conclude simple bilateral agreements with coastal states [1]. But the same opposition always existed, emanating from the shipping industry before and during the incorporation of vessel-source oil pollution legislation. However, this has never acted as a hindrance to the UK for acting unilaterally, and evidence remains with the National Contingency Plan and other regulations, making the UK a pioneer in this field.

The main objective of dealing with oil pollution in the North Sea should not rely on the implementation of viable international law. The objective should be rather on the quick response strategies undertaken by authorised agencies who derive their power from national law to mitigate and limit an oil spill from the very second it has touched the pristine waters. Undoubtedly, the UK has left a mark in the field of private law when it comes to maritime governance by “quick response” to treat oil pollution effectively and remain accountable to all stakeholders of the North Sea at large.

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The German Operational Monitoring System in the North Sea: Sensors, Methods and Example Data

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Abstract Operational oil pollution surveillance has been performed in Germany for almost 30 years. Sophisticated state-of-the-art sensors are being used for frequent airborne surveillance, while satellite data are used as prewarning and additional information input on a routine basis. In parallel, basic research on the imaging of marine oil pollution by synthetic aperture radar (SAR) has been performed, and a basic understanding of the imaging of biogenic and anthropogenic marine surface films by active microwave sensors has been developed. In this paper, we provide an overview of the current operational surveillance system, and we give some historical background summarising some of the results of the research conducted during the past decades. Within this chapter, example images from pollution events are given for several sensors. The German coast's spatial and temporal vulnerability to oil pollution is quantified, and the use of dispersants in a highly vulnerable ecosystem such as the "Wadden Sea" is discussed.

Keywords Aerial surveillance, Dispersant, Drift modelling, Environmental sensitivity, Germany, Infrared, Oil pollution, Satellite services, Synthetic aperture radar, Ultraviolet

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Contents

1 Introduction

The operational surveillance of oil pollution on German coastal waters is an important part of the duties and responsibilities of the German Central Command for Maritime Emergencies. Since parts of the North Sea (namely, its south-eastern part, the German Bight) belong to German territorial waters and the exclusive economic zone, they are frequently overflown by German aircraft carrying a selection of sophisticated sensors, which are especially designed, or optimised, for the use on oil surveillance aircraft. Oil pollution monitoring is an important aspect, because of the high vulnerability of the German North Sea coast (with three national parks, each being a UNESCO World Natural Heritage). Not only big oil accidents, like the ones of the tankers Prestige and Erika, would cause high environmental damage and huge costs, but small oil spills also have an impact on the environment and on the food chain.

Oil spill monitoring by surveillance aircraft and radar satellites is a standard tool to detect and characterise spills. This monitoring also has a deterrence effect and thus – indirectly – reduces the input of these harmful substances.

Scientific research focussing on the signatures oil films cause on SAR imagery has been pushed forward by German researchers. In this chapter, we summarise both the application aspect and the research aspect, with special emphasis on the German waters in the North Sea. Of course, exchange of scientific results and operational aspects is important at an international level, and Germany is part of several methods by which international or regional cooperation is taking place. Aside of the still urgent necessity to increase the security standards of vessels carrying crude oils and its products as well as the necessity to define particular sensitive sea areas (PSSA) with regard to special legislative requirements and control, the risk of oil accidents will continue to exist. Consequently the knowledge of coastal sensitivity is useful not only for the control and management of industrial and urban development, but also during contingency planning for accident response.

Because of general application problems offshore the "Wadden Sea" and due to the high toxicity of particular chemical dispersants, mechanical cleaning is highly favoured in German territorial waters. This determination especially holds for shallow water areas onshore the 10–20 m isobath. On this note, the application of dispersants is only mediated on a case-by-case basis with increasing verification with regard to decreasing water depth [1, 2].

However, more recent generation of these chemicals show a much lower toxicity so that the question of whether or not the application of chemical dispersants should be taken into consideration as an option in contingency planning is reassessed today by the HK ("Havariekommando" – Central Command for Maritime Emergencies) and by the UEG ("Unabhängige Expertengruppe – Folgen von Schadstoffunfällen", Independent group of experts – consequences of pollution accidents).

1.1 The German Part of the North Sea

The German Exclusive Economic Zone, EEZ, reaches from the German North Sea coast into the open North Sea (see Fig. 1). In the east and south-east, it borders to the German part of the highly sensitive "Wadden Sea" (green areas in Fig. 1). Including the German territorial waters (12 nm zone), it covers an area of rounded 41,000 km^2.

Otto et al. [3] give a review of the physical oceanography of the North Sea: "The dominant feature is the tidal motion. This is not only a mechanism for vertical and horizontal mixing. The tidal residuals also contribute to a basic circulation pattern that, together with the long-term net effects of the wind-driven circulation and the baroclinic effects, results in an overall transport that determines the major features of the distribution of the water properties. Superimposed on this there are variations (mainly wind-induced) and regional differences in a wide range of time- and length-scales." The water depth is typically 20–40 m in the German Bight [4].

Surface circulation in the German Bight consists of the tidal pattern superimposed on a net cyclonic current especially in fall, although the dominance was less pronounced in 2013 [5]. Such cyclonic currents would transport a given pollution originated in the southwest towards the German EEZ and the German coast. Currents in the narrow part of the Baltic Sea do not account for equally high transport rates [6]. The North Sea is among the regions of heaviest maritime traffic worldwide (Fig. 2). Some of the major ship traffic routes in the North Sea, e.g. connecting the mouth of the river Elbe, and thereby the southwestern exit of the Kiel Canal and eventually the western Baltic Sea, and the open North Sea, lead partly through the German EEZ. Additionally, commercial activities including, but

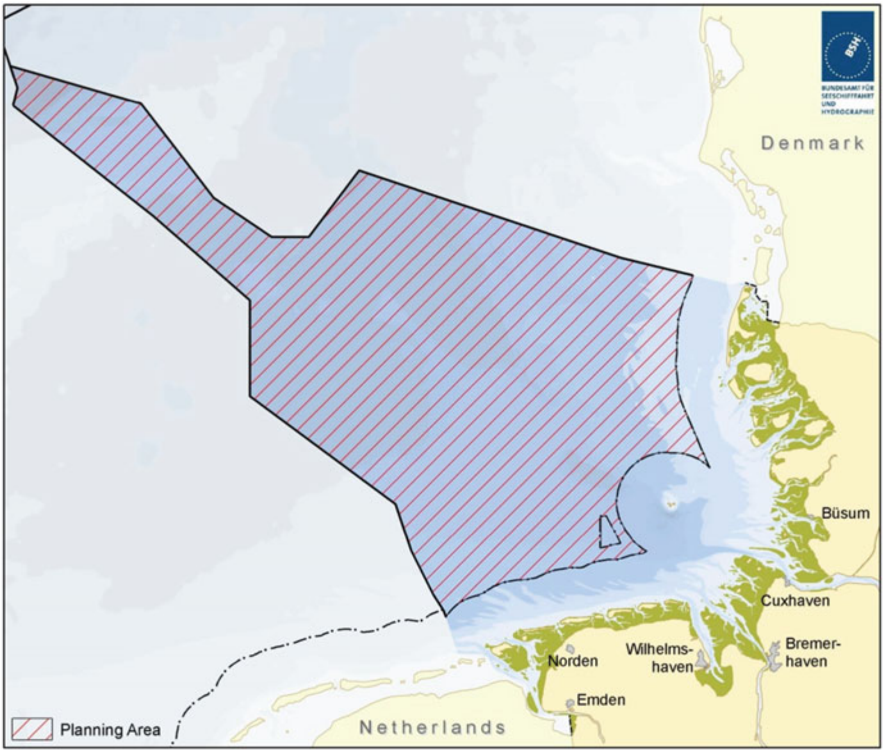

Fig. 1 The German Exclusive Economic Zone, EEZ, in the North Sea. The *dashed-dotted line* marks the border of the 12 nm zone. The *green areas* are intertidal flats that fall dry during low tide. *Source*: BSH

not limited to, oil industry and offshore wind farms constitute potential sources for pollutions.

1.2 Sensitivity of the German North Sea Coast to Oil Pollution

"Sensitivity" in this framework describes a documentation which aims at representing spatial and temporal vulnerabilities of coastal areas with respect to oil spills. Initial work was done in the 1970s, but "nature-related" and socio-economic aspects have been taken into account only for the last two decades. Today, the development of environmental sensitivity indices is pursued worldwide, primarily by national authorities, e.g. NOAA (National Oceanic and Atmospheric Administration), in the USA, but also by the IMO (International Maritime Organization).

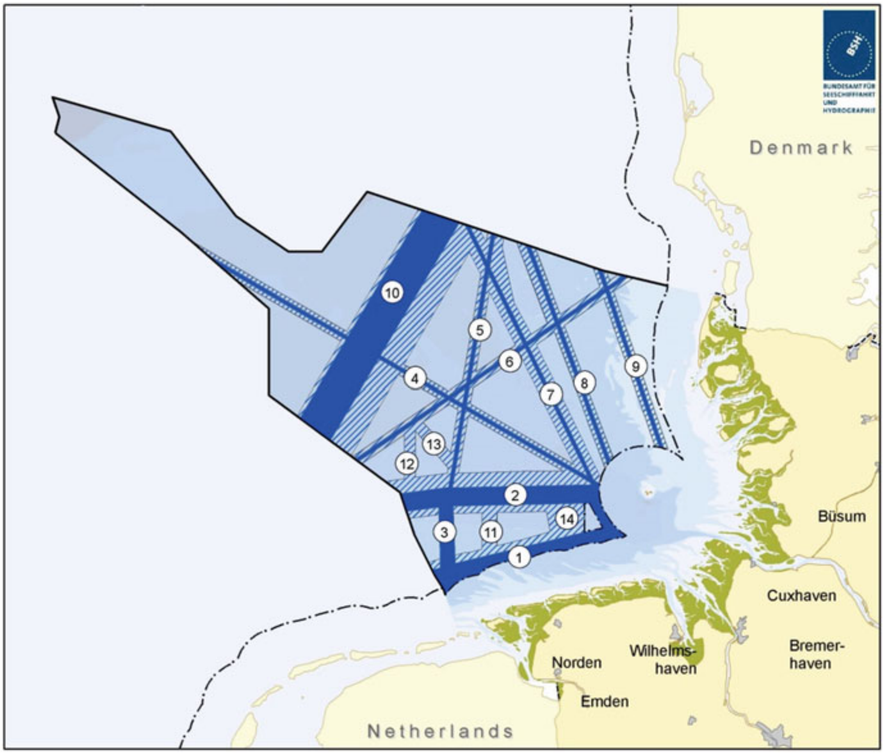

Fig. 2 Main shipping routes in the German EEZ. *Source*: BSH

Today, parameters to define the sensitivity of maritime provinces of the Baltic and North Sea are documented and partly harmonised by the EU-Project BRISK (Baltic Sea, completed in 2012) and BE-AWARE I/II (North Sea, 2012–2015; Bonn Agreement/EU) with participation of the HK ("Havariekommando" – Central Command for Maritime Emergencies).

A complete harmonisation of coastal sensitivity indices cannot be reached and is probably also not very wise, since, aside from cultural aspects, knowledge of the relationships in the systems concerned, such as their condition, is regionally very variable.

Following Dicks and Wright [7], many components of environments are sensitive (some more than others) but not all are equally vulnerable. Sensitivity is highly dependent upon pollutant type, and especially toxicity and persistence, as well as the efforts made by man for clean up after an accident. The range of toxicity and persistence for many crudes and refined products are well known, as are many of the impacts upon marine ecosystems. The sensitivity of a particular area to be damaged by oil depends largely upon the physical characteristics of the habitats, the susceptibilities of individual species (at various life stages) and their role within the community.

Oil causes most damage in systems of low physical energy in which it can be trapped or ponded for long periods of time. The most susceptible types of shore on this scale are mainly associated with "shelter", a physical concept involving protection from wind, wave and current. Sheltered habitats are usually characterised by fine sediments and productive marine communities, and many cases have been reported of considerable oil damage by direct toxicity and smothering at the time of the spill or subsequently by long-term effects by retention of the oil in these areas. Conversely, least damage is likely to occur in systems of high physical energy which turn over rapidly and which may support impoverished communities of highly adapted organisms resistant to physical stress, e.g. exposed rocky headlands. Lesser damage to these systems may result partly from rapid removal of oil by physical means, partly from the fact that communities may be of low productivity and partly because the protective mechanisms of some species provide protection against physical (but not necessarily chemical) impacts of oil [8, 9].

Although such generalisation inevitably has numerous exceptions, several authors have constructed a simple, effective and widely applicable vulnerability scale for a range of shore types based on geomorphological and biological characteristics which are globally applied. They usually aim at a mitigation of intensity, duration and spatial extension of expected effects. Ecology-related criteria are often achieved by including criteria concerning natural resource protection.

1.3 The "Wadden Sea": A Sensitive Environment

A contiguous region of tidal flats, barrier islands, alluvial terrestrial zones and salt marshes, about 500 km long and up to 20 km wide, extends along the North Sea coast of Germany, the Netherlands and Denmark. This "Wadden Sea" is of enormous value as a cleansing site for the coastal water, as a nursery for young fish and as a feeding and nesting ground for nearly all palaearctic species of wading birds and waterfowl. Predation is one of the most important processes. It keeps densities of the large burrowing *in fauna* (organisms living beyond the sediment surface) below carrying capacity, thus positively influencing the amelioration of the sediment.

The proximity of important shipping routes (cf. Fig. 2) and ports is a permanent threat, especially to the German part of the region, which became a national park in 1985/1986. Large quantities of petroleum, for example, which can be spread over wide areas by tides and winds, present not only the danger of temporary damage but rather of permanent harm, since oil, bound to the sediment, is released very slowly and can therefore repeatedly contaminate those parts of the tidal flats that have become free of the oil.

Thus, for oil spill response and precaution measures, a sensitivity study of the entire intertidal area was badly needed in order to assess the potential to minimise ecological and economical damage. Based on comprehensive field surveys [10–12] and in close cooperation with the Central Command for Maritime Emergencies, an automated expert model for the German part of “Wadden Sea” areas was developed at the Institute for Coastal Research (Helmholtz–Zentrum Geesthacht, HZG) [13, 14]). As an operational model, it will serve as an important instrument for decision making processes, precautionary measures and the further design of oil spill response strategies.

Sheltered tidal flats, salt marshes and adjacent estuaries belong to the types of coast which are most sensitive to oil pollution. Since it is not possible to protect the entire German North Sea coast equally at all levels, oil spill contingency planning requires a more detailed classification. For this reason, individual soft bottom habitats, communities and stocks of salt marshes, macrofauna, waterfowl and estuarine biotope types were evaluated and classified according to their vulnerability to oil pollution.

The sensitivity of a particular area to oil contamination depends largely upon the physical characteristics of the habitat, the susceptibilities of individual species and their ecological properties within the communities. Hence, the field work for habitat mapping during 2003–2006 was a central part of the study. For this part, the experiences and results obtained from the previous HZG project “Thematic Mapping and Sensitivity Study of Intertidal Flats” during the years 1987–1992 served as a valuable basis. For example, the documentation of changes during these periods of observation provides information on stability features of the ecosystems involved. During the first project, nearly 5,000 locations were processed and characterised using about 70 parameters for each site. The in situ mapping was a combination of estimated and measured values, collected along a grid net of locations with 1 km interval. The estimated values, including biotic and abiotic parameters, were documented using a standardised protocol (“record sheet”). They comprised, for example, information on the presence of micro- and macroalgae, surface structure (i.e. ripple, colour) and sediment characteristics. The measured values included grain size, shear strength, water content of sediments as well as the macrofauna species present.

The assessment of value of each location was calculated using an automated expert system developed at HZG and based on neural network techniques and advanced classification methods (tree fit). Four classes have been defined to scale the oil sensitivity (Fig. 3) of tidal flat areas from low (1: green) to high (4: magenta). The design of this model enables the “Central Command for Maritime Emergencies” as the main user to calculate the spatio-temporal sensitivity of intertidal areas without extensive further expert assistance.

The spatial distribution of the sensitivity of tidal flat areas (benthic index) was combined with data on saltmarsh distribution and the presence of sea grass and mussel beds. These additional data were integrated using the monitoring results of the national park authorities of Lower Saxony, Schleswig–Holstein and Hamburg. The temporal aspect of this sensitivity was calculated using the monitoring data of

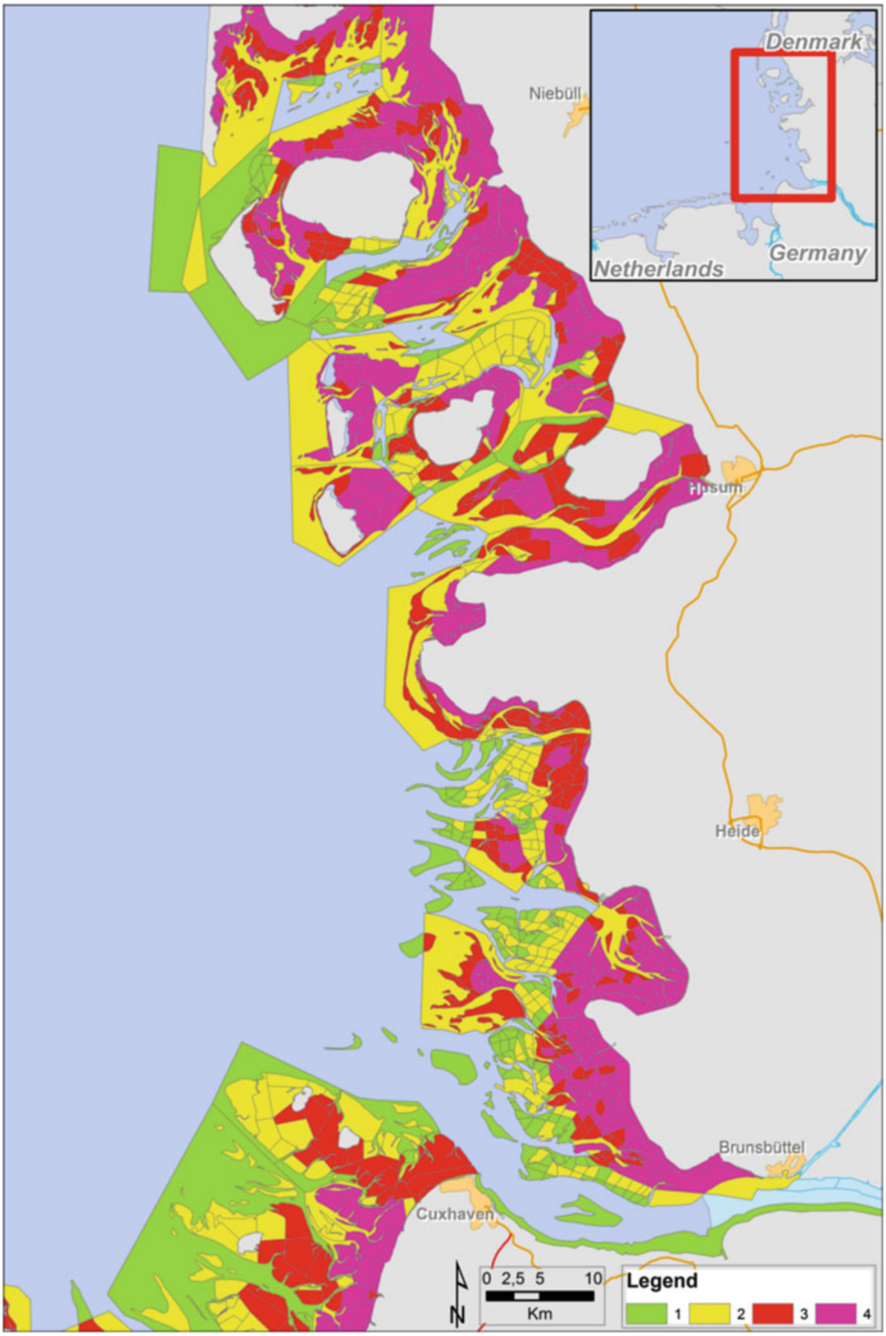

Fig. 3 Part of the oil sensitivity map – summer scenario (© HZG)

breeding and migratory birds which are compiled yearly by these authorities. The complete data sets were used together with a geographic information system (GIS) to generate sensitivity maps of the German North Sea Coast (see Fig. 3). Until 2016 the coastal sensitivity model will be enhanced for the offshore areas of the German Bight.

2 History and Projects

In Germany, remote sensing data for monitoring oil pollution on sea surfaces is used operationally since the mid-1980s. Especially radar techniques, if optimised for oil spill detection, are useful for the surveillance of large areas and for night-time or foul weather work [15]. Side-looking airborne radar (SLAR) and synthetic aperture radar (SAR) systems allow a permanent and inordinate observation, because they are independent of atmospheric and weather conditions [16].

For a long time, only airborne radar sensors were available for operational maritime surveillance. In Germany, the operational aerial surveillance started in 1984 with a rented Cessna 406 aircraft (with radar, infrared and ultraviolet sensors) and proceeded in 1986 by using a Dornier Do 28 aircraft (with equipment from the Swedish Space Corporation). Here, the radar was the far-range sensor for localising possible oil spills. Only 4 years later, the newer Dornier Do 228 was introduced as a platform and the sensor system was extended. In the late 2011, one of the two existing surveillance aircrafts was exchanged by a Do228 New Generation.

The use of satellite data for the detection of marine oil pollution and its discrimination from natural surface films was the topic of a number of research projects at the University of Hamburg, starting in the 1980s: after theoretical and experimental laboratory studies, during the joint US–German project SAXON-FPN (“SAR and X-Band Ocean Nonlinearities – Forschungsplattform Nordsee”), first experiments with an airborne scatterometer on the reduction of the radar backscattering by marine surface films were conducted [17, 18]. In 1994, during the SIR-C/X-SAR (“Spaceborne Imaging Radar–C/X-Band SAR”) campaigns, field experiments with quasi-biogenic and anthropogenic surface films were carried out in the German Bight of the North Sea. The aim of the experiments was to investigate whether active microwave sensors are capable of discriminating between the different kinds of surface films [19]. The main finding of those comprehensive studies was that multifrequency radar techniques have the potential for being used to discriminate between biogenic and anthropogenic surface films, but only at low to moderate wind speeds [21].

In the late 1990s, in the frame of the European project “Clean Seas”, ERS SAR images of three regions within the European marginal seas, including the Baltic Proper, were analysed on a routine basis. For the first time, spatial and temporal statistics were performed to investigate the use of routinely acquired SAR imagery for the monitoring of European waters. Main results of those statistical analyses will be presented hereafter.

In the beginning of satellite-based oil pollution monitoring, the operational use of satellite sensors was hampered due to the long gross processing time of several weeks per image. Later on, in the frame of the European projects OCEANIDES (a follow-on project of "Clean Seas") or MarCoast, SAR data from satellites such as ENVISAT, Radarsat-1 and Radarsat-2 were available at near real time and were introduced to operational pollution monitoring. The Joint Research Centre and among other international cooperation EGEMP, the European Group of Experts on remote sensing monitoring of marine pollution, fostered the exchange of knowledge and the harmonisation, e.g. by compiling satellite surveillance guidelines and evaluating alert mechanisms [22] for an improved interplay of satellite and aircraft surveillance. From 2007 on, CleanSeaNet (CSN) of the European Maritime Safety Agency (EMSA) has been acting as a support service for member states for their marine pollution control.

2.1 Historical Experiments

During two 10-day missions in 1994, a multifrequency SAR system, the "Spaceborne Imaging Radar C/X-Band SAR" (SIR-C/X-SAR) consisting of an L-, C- and X-band SAR was flown on the space shuttle "Endeavour". SIR-C/X-SAR images of biogenic and anthropogenic marine surface films at various places of the world's oceans were acquired during the two missions in April and October 1994. Those images were analysed to investigate whether a multifrequency SAR system such as SIR-C/X-SAR is capable of discriminating between biogenic (Fig. 4) and anthropogenic (Fig. 5) oceanic surface films [19]. Note that the classification between biogenic and anthropogenic surface films was made visually by an expert and was only based on the shape and the size of the observed features. For example, the SAR images shown in Fig. 4 show typical signatures of biogenic surface films: during ongoing algal blooms, surface-active material accumulates on the water surface and the long, narrow, dark streaks follow the surface currents [23]. On the other hand, signatures caused by mineral oil spills (Fig. 5) can often be identified because of their irregular and elongated shape [19].

During both SIR-C/X-SAR missions, scientists of the University of Hamburg performed surface film experiments in the German Bight of the North Sea, which were particularly designed to investigate whether active multifrequency microwave systems (scatterometers or radars) can be used to discriminate between natural surface slicks and mineral oil spills. SIR-C/X-SAR images of those surface film experiments proved that the measured damping ratio (i.e. the ratio of the radar backscattering from a film-free and a film-covered sea surface) strongly depends on wind speed, which is in accordance with results obtained in parallel by the helicopter-borne scatterometer HELISCAT of the University of Hamburg.

The results show evidence that biogenic sea slicks cause a strong damping also at L-band (Fig. 4), whereas anthropogenic oil spills cause damping ratios increasing from L-band to X-band (Fig. 5). Note that the observed damping ratios from

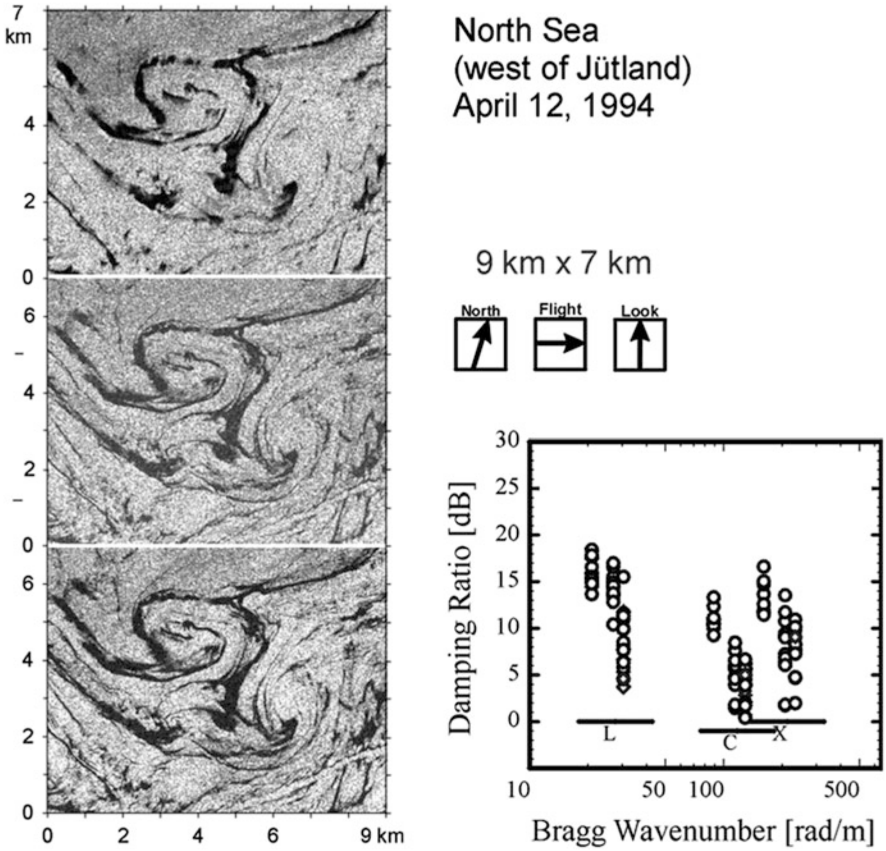

Fig. 4 *Left column*: SIR-C/X-SAR images (9 × 7 km) of the same spot of the North Sea acquired on 12 April 1994 and showing signatures of natural surface films. The images were acquired at L-, C- and X-bands (from *top* to *bottom*), VV polarisation. *Bottom right*: damping ratios obtained from SIR-C/X-SAR images of various natural slicks at low to moderate wind speeds (<7 m s^{-1}). Diamonds and circles denote HH and VV polarisation, respectively. Taken from Gade [20]

biogenic and anthropogenic surface films at C- and X-bands are similar. Particularly at C-band, this is partly due to the insufficient signal-to-noise ratio of the SIR-C/X-SAR system. The results from Gade et al. [19] show that multifrequency SAR imagery yields more information on the damping characteristics of oceanic surface films than single-frequency SAR imagery, which is needed for a better discrimination between different kinds of surface films, particularly under low to moderate wind conditions. Particularly L-band data seems to be crucial for a successful discrimination of different surface films.

The evidence shows that under low to moderate wind conditions, multifrequency radar techniques are capable of discriminating between the different kinds of surface films, whereas at high wind conditions, a discrimination (on a basis of

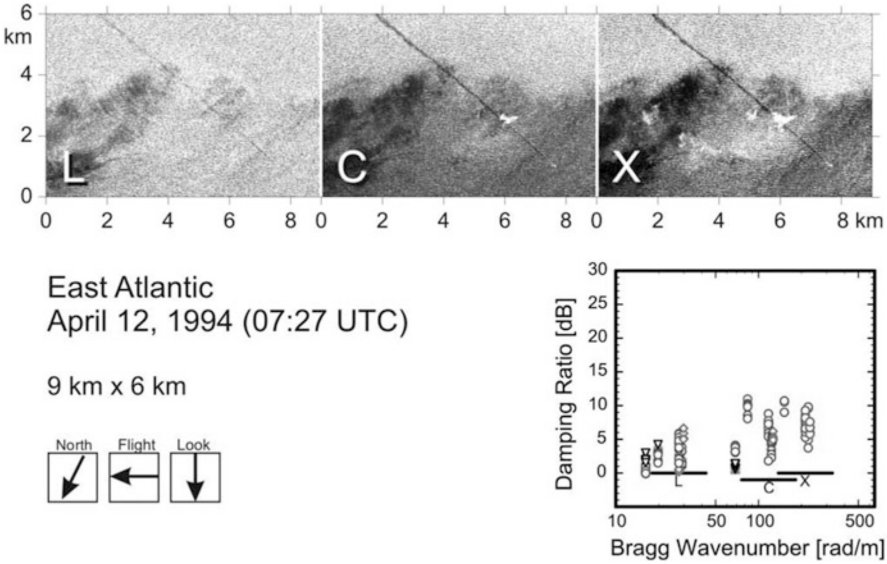

Fig. 5 *Upper row*: SIR-C/X-SAR images of the East Atlantic, north of the Azores, acquired during the first shuttle mission on 12 April 1994 and showing signatures of freshly spilled mineral oil (image dimensions 9 km by 6 km; from left to right: L-, C- and X-bands, VV polarisation). *Bright spots* in the image centre are due to heavy rain. *Bottom right*: damping ratios obtained from SIR-C/X-SAR images of various mineral oil spills at low to moderate wind speeds (<7 m/s) are shown. *Diamonds*, *circles* and *triangles* denote HH, VV and HV/VH polarisation, respectively. Taken from Gade [20]

damping measurements) is impossible (for high wind speed examples, the reader is referred to Gade et al. [21].

3 Monitoring System and Sensors

Today, the combined use of satellite-based SAR images and airborne surveillance is a cost-effective way to monitor deliberate oil spills in large ocean areas [24]. In Germany, the use of satellite services and multisensor aircraft are enhanced by a numerical oil spill drift model to form a combined operational monitoring system. Helmke et al. [6] showed that aerial surveillance becomes indeed more effective if guided by alerts from radar satellite services. The individual parts of the combined system are highlighted in the following.

3.1 Airborne Sensors

The German oil pollution surveillance system is primarily based on two Dornier Do 228 aircrafts, which are operated by the Naval Air Wing 3 “Graf Zeppelin”, on behalf of the Central Command for Maritime Emergencies (CCME) and of the German Federal Ministry of Transport and Digital Infrastructure (BMVI). The sensor systems of the two aircraft with call signs “57+05” and “57+04” are two different versions of the type MEDUSA. This section is based on the “57+05” that replaced a previous surveillance aircraft named “57+01” in 2012/2013. The “57+04” carries as special equipment a laser fluorescence sensor and a microwave radiometer on board (for the “57+04”, the reader is referred to [25], and more details can be found in, e.g. [26–28], and for a general review of airborne remote sensing of oil spills to [15, 29, 30]).

The multisensor mission system comprises, among others, a side-looking airborne radar (SLAR), which acts as a “far-range sensor”, thus allowing for the detection of possible pollutions at distances up to 30 km – depending on the wind conditions – on either side of the aircraft. Thanks to its wide range, this sensor is essential for finding and localising possible pollution. Besides, the extension of a surface slick can be determined. As the sensor emits high-frequency pulses in the X-band (9.4 GHz), the detection of the smoothing of sea surface by oil (or lookalikes) is possible through clouds and at night time but requires intermediate wind conditions.

In addition, an extendable set of “near-range sensors” are used at low altitudes (approx. 1,000 ft), having a viewing range of up to 250 m on either side. With their help, a closer investigation is performed and operationally important additional information (compared to the radar alone) is gained in order to confirm the detected spill as a pollution caused by mineral oil or not.

The main characteristics of the sensors, the applied physical principles and their abilities with respect to oil spill monitoring are summarised in the following: A line scanner in the visible range (VIS) produces images simultaneously to the other channels and delivers helpful information for the judgement of the situation.

The infrared channel (IR) is a passive channel that uses the thermal infrared radiation (8.5 μm to 14 μm wavelength). It visualises the measured radiation temperature that yields from a combination of kinetic temperature and emissivity. As this combined property is usually different between oil slick and surrounding water surface, the two parts can be separated. In addition, it allows for the localisation of thicker patches of oil, if they are warmed up by the sun. This channel has a high spatial resolution of ~3.5 m (at 1,000 ft flight altitude and a velocity of 70 m/s) and works at night time but is impaired by clouds. The ultraviolet (UV) is a second passive channel of the same sensor as the IR channel. It detects the ultraviolet radiation part (0.32–0.38 μm wavelength) of the sunlight reflected from the sea or oil surface, respectively. As oil has a high reflectivity in the ultraviolet, this channel allows for a high-resolution visualisation of even very thin oil layers (<0.1 μm; [29]).

The set of remote sensing sensors is accomplished by photo and video documentation tools. An electro-optical video system that has a channel in the visible light range and an infrared channel allows an enhanced night-time vision.

All sensors of the Do 228 are operated in flight via a central, light-weight computer console with real-time data viewer and near-real-time analysis software. A qualitative and quantitative judgement of observed features of any kind is ensured through a thorough analysis of all available data and through experienced operators. The "57+05" has an electronic sea chart display on board that supports the operators with an improved overview and that delivers additional information about, e.g. water depth, offshore installations and includes ship tracks and data from the automatic ship identification system (AIS). Point targets and polygons marking discovered pollution and the data of all scanning sensors converted to georeferenced images can be displayed. A satellite communication system provides access to the internet for additional information and allows sending out emails and case data from within the flight to the central command for maritime emergencies. Besides, auxiliary information can be received as, e.g. recent satellite images or alerts and drift model output data.

3.2 Spaceborne Sensors

The detectability of marine oil pollution depends, among others, on the local wind speed, and thus, wind velocity vectors from numerical models and/or satellite sensors are used as supporting information for the classification of the detected SAR image features. Together with the features' geometrical parameters such as their shape, orientation or the form of their edges, some information on their vicinity in the SAR image is also used as major classification criteria. In addition, recent efforts focus on the use of polarimetric SAR imagery (i.e. simultaneous SAR imagery acquired at different polarisation combination of the transmitted and received microwaves) [31]. A review of actual classification systems, seen from a European perspective, was recently provided by Ferraro et al. [22].

At present, satellite data from the Canadian Radarsat-2, the German TerraSAR-X, the Italian COSMO-SkyMed and the recently launched European Sentinel-1 are available for operational oil pollution monitoring from space. As an example, Fig. 6 shows a TerraSAR-X image of the German Bight, between the island of Helgoland and the Eastern Frisian Islands on the coast. The image was acquired in StripMap mode on February 9, 2013, at 05:59 UTC (i.e. 1h before sunrise) and shows high ship traffic along the main shipping routes in the German Bight (routes 1, 2, 7 and 14 in Fig. 2). The dark elongated patch (exceeding 10 km) marked by the white arrow is very likely to be caused by mineral oil spilled during night time from a ship travelling west.

The image, however, also demonstrates the difficulties that may arise in the frame of SAR-based oil pollution monitoring, since other dark (and partly

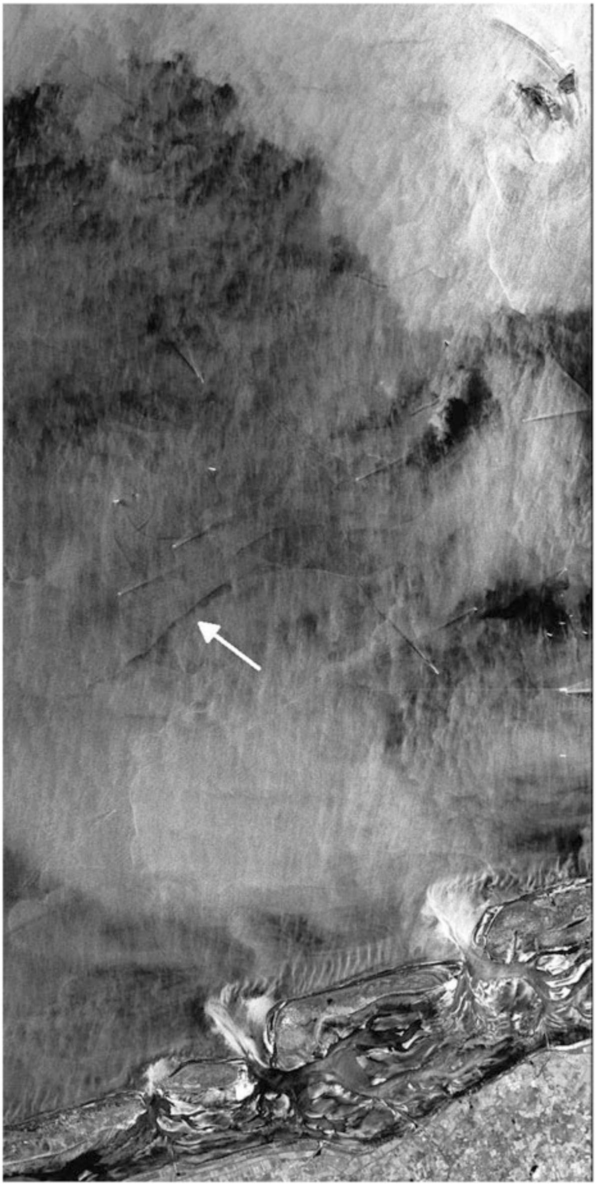

Fig. 6 TerraSAR-X image (StripMap mode, dimensions 35 × 70 km) acquired on 9 February 2013 at 05:59 UTC and showing the German Bight, between the Helgoland island (*upper right*) and the German mainland coast (*bottom*). A number of ships, both travelling and anchoring, can be seen in the image centre. The arrow marks an elongated feature, probably caused by an oil spill © DLR

elongated) features in Fig. 6 are due to ship wakes or low wind areas or are induced by a spatially varying surface current field.

The main limitation of some spaceborne optical sensors is the need for daylight and cloud-free weather conditions, but they have some potential to discriminate between oil and algal blooms [24]. More information on the operational satellite

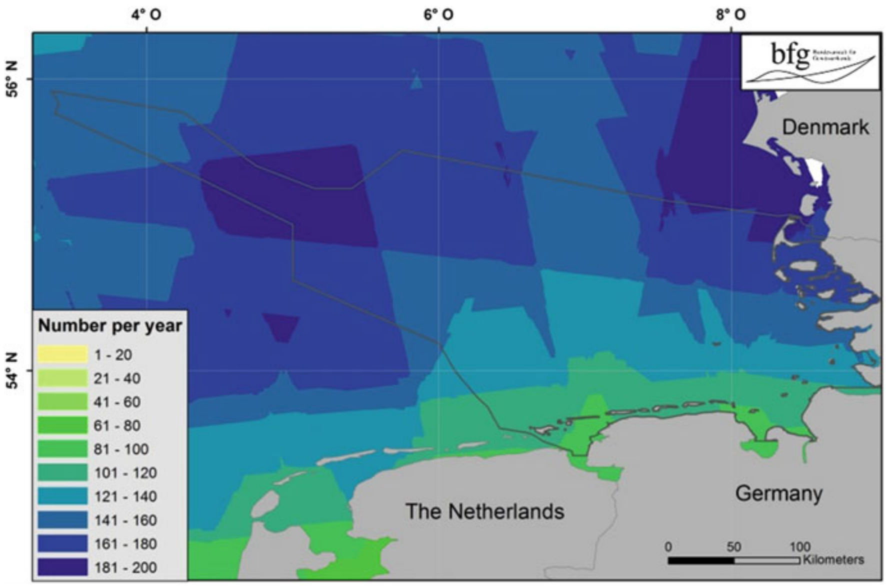

Fig. 7 Satellite coverage of EMSA CleanSeaNet Service for images received by Germany in 2012 (BfG)

surveillance service of EMSA can be found on the EMSA website at http://www.emsa.europa.eu/operations/cleanseanet.html.

3.3 *Combined Monitoring System*

The individual parts of the monitoring system have all their strengths and weaknesses. By combining them, an optimised benefit is received (cf. [6]). This section summarises this aspect of the interplay and synergetic effects of the monitoring tools.

A (low-resolution) radar satellite has the main advantage to deliver a partly automatic first alert and a good overview over a large sea surface of up to 400×400 km^2 that is independent from cloudiness. This output can be achieved in near real time for modern processing chains, i.e. within less than half an hour after satellite overpass. This technique is limited due to repetition times and the need of intermediate wind conditions. Further, it does not provide a direct indicator for oil, but only for the lack of capillary waves on the sea surface. Therefore, it is prone to lookalikes and can only deliver indications for possible pollution.

Thus, radar satellites deliver a good overview and first alerts, which then need to be checked by aerial surveillance. Besides, they can help with monitoring in case of known hotspots, as, e.g. spills that happened after an accident. Figure 7 shows the satellite coverage of the German EEZ of the North Sea at the example of the year

2012. The German EEZ has been covered between weekly and four times per week by the EMSA CleanSeaNet service.

As described in the respective section, an aircraft equipped with a modern sensor system delivers a variety of add-on information about surface slicks. Combined with the experienced operators on board, in many cases, the discrimination between oil and lookalike can be made. Further, it allows for a high-resolution routine surveillance or for monitoring in case of an accident.

As a pollution response, assistance and assessment tool aircrafts are more flexible and deliver much more information than radar satellite services. In addition, they can – especially if combined with in situ samples – be used for the preservation of evidence in case of deliberate pollution.

Though the information content of aerial surveillance, data is much higher, the endurance and coverage of the aircraft are limited. Therefore, the effectiveness is increased, if the aircraft routes can be redirected following the satellite information: either to specifically check possible pollutions detected by satellite for verification or to reduce the attention on areas reported as clean. In practice, satellite services are used as an alert tool to better direct the flights of aerial surveillance. In addition independent aircraft flights are performed.

The question how the satellite service information should be prepared for optimal operational use and for the planning of follow-up actions is subject to ongoing discussions and research [22]. Next to the operational use, the combination of satellite and aircraft is a valuable tool for validation – either of the satellite service or also for drift models – and thus for improvement of the existing tools.

In Germany, the operational oil spill drift model is operated by the German Federal Maritime and Hydrographic Agency (Bundesamt für Seeschifffahrt und Hydrographie, BSH) [32]. Until 2014, the BSHdmod.L, a Langrangian oil drift and dispersion model, was used. In 2015, it was replaced by an adapted version of the HELCOM Seatrack Web model [33–35]. The model provides forecasts up to 72 h at spatial and temporal resolutions of 1–3 nm and 1/4 h, respectively, and is capable of backtracking pollutants. Thus, it can be used to derive the likely origin of the observed pollution.

If a possible marine pollution is detected by remote sensing, drift model runs are started at BSH. Results of prognostic drift model runs are important as support for pollution response on sea or land. It helps to decide if response units are required and where to place them. Additionally, in hindcast mode, the backtracking results can – possibly combined with AIS (automatic ship identification system) information – help to find the origin of pollution.

As a part of the DeMarine project, a prototype for a processing chain was developed to semiautomatically implement remote sensing information by satellite or aircraft as input into the operational BSH drift model. In this way, position, area and distribution of remotely sensed oil spills can – after manual selection – be automatically processed, and a provisional model output is generated to be reviewed by the model operators. This includes as well a gain of information content and quality as well as saving of time [36].

4 Example Data

In this section, we present some examples of remote sensing data showing marine oil pollution in the North Sea. Historically, only mono-frequent (C-band) SAR data were used for spaceborne oil pollution surveillance, and only during two short (10-day) space-shuttle missions in 1994, multifrequent SAR sensors were in orbit. However, recently, SAR sensors working at L- and X-bands have been placed in orbit, thus giving the opportunity to benefit from previous research on the use of multifrequency SAR sensors for oil pollution monitoring [37].

The capability of SAR sensors for detecting marine oil pollution has been known for decades [16]. SAR images acquired from the first and second European Remote Sensing Satellites, ERS-1 and ERS-2, have been used to demonstrate this capability and to compare SAR signatures of marine oil pollution with those from other features ("lookalikes") that also cause a reduced radar backscattering from the sea surface and, thus, dark patches on the SAR images [38].

As an example, Fig. 8 shows an ERS-2 SAR image acquired on 27 July 1997 at 10:49 UTC over the southern North Sea, the English Channel off the mouth of the river Thames. Dark areas in the left and right parts of the image are due to low wind and to natural surface films, which manifest in large black areas and in thin dark patches following the local currents, respectively. In the right image centre, an elongated horizontal dark patch can be delineated, which is wider on its right (eastern) end. This feature is likely to be caused by mineral oil freshly spilled from a ship travelling westbound, i.e. into the river Thames. This example

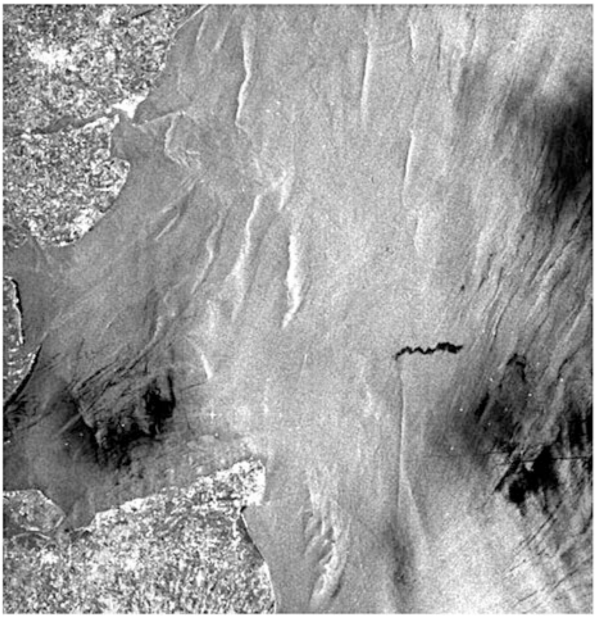

Fig. 8 ERS-2 SAR image of the southern North Sea, the English Channel off the mouth of the river Thames, acquired on 27 July 1997 at 10:49 UTC. Most bright features are caused by underwater bottom topography; most dark patches on the left and right are due to low wind and biogenic slicks. The dark patch in the right image centre is freshly spilled mineral oil © ESA

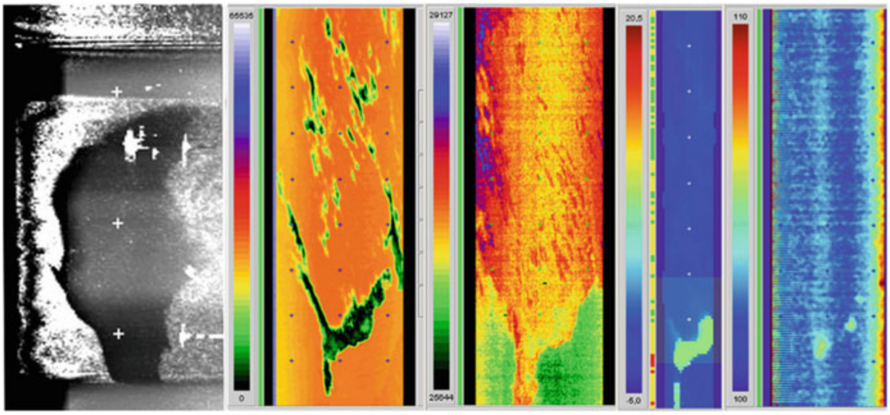

Fig. 9 Example data of a confirmed oil pollution event observed by the sensor system of the Do228 57+04. From *left* to *right*: SLAR, IR, UV, LFS, MWR (© BfG, CCME 2011; cf. [25] and in similar form in [39])

demonstrates the strength of spaceborne SAR sensors for oil pollution detection, but also the danger of misinterpretation of dark features seen on the SAR imagery.

In Fig. 9, data from the surveillance aircraft "57+04" of a pollution event is shown that has been confirmed as mineral oil. The so-called waterfall display composes the subsequent data lines of the line scanner without georeferencing, i.e. without correcting for variations in speed or aircraft orientation. In this case, the oil originates from a platform. The SLAR image (to the left, different scale) gives an overview: The black area in the middle of the stripe originates from the reduced backscattering due to the lack of capillary waves that is caused by the oil spill. The IR highlights the thicker parts of the oil (here: green and black), whereas the UV shows the maximum extend of the slick. The MWR images points out the thickest parts (in this case sparse; in green at the lower end of the stripe) of the slick and allows for an estimation of thickness. The laser fluorescence sensor sees the rather thin and thicker oil parts (here in green) in a much smaller scanning stripe and gives a classification of the oil (here: crude oil).

The more modern surveillance aircraft "57+05" (Fig. 10) enables the operator not only to create a waterfall display of the line scanner data but also georeferenced images of the sensor data superimposed on a map. Figure 11 shows such georeferenced data of the "57+05" (though here displayed with the help of an independent geoinformation software). The radar image (a) provides the overview. It is constantly monitored by the operator during surveillance flights.

After a clear indication for a major pollution was encountered, the aircraft route was changed and the pollution (marked in (a) by a white polygon) was directly overflown. In (b), in addition to the polygon, the flight track is shown together with the area observed by the near-range sensors (grey area). The georeferenced images of the VIS line scanner (c), the UV (d) and the IR (e) substantiate the identification of the spill. The film is likely to be very thin in most parts of the area, as in the

Fig. 10 German pollution control aircraft Do228 57+05 flown on behalf of CCME (www.havariekommando.de; © MFG3, A. Golz, 2014)

infrared (e), only small patches give a stronger signal. Also in the photograph (g) taken from the position marked with a star in (b), it can be seen that most area is covered by an oil spill of the thinner classes (sheen and rainbow) of the Bonn Agreement Oil Appearance Code, but also that there are some thicker areas. In (f) the same area is shown by a RadarSAT-2 image acquired about 5 h later. Note that the oil had spread significantly in the meantime so that a larger area was covered.

4.1 Statistics

Statistical analyses of detected oil pollution incidences have always been a key element of both the scientific evaluation of the processed SAR data and the assessment of the state of the marine environment with respect to frequent oil pollution. This section contains some main findings of those analyses that were performed at the University of Hamburg in the late 1990 and that can be seen as a basis for those routine analyses performed later.

4.1.1 "Clean Seas" Statistics

Gade and Redondo [40] analysed more than 700 ERS SAR images of European marginal waters (acquired between December 1996 and November 1998 over the Baltic Sea, the North Sea and the northwestern Mediterranean Sea) with respect to the detectability of marine oil pollution. Example results are shown in Fig. 12. They were the first to derive areas of mean oil pollution taking into account dark patches in the SAR images that show a significant reduction in the radar backscatter. In all

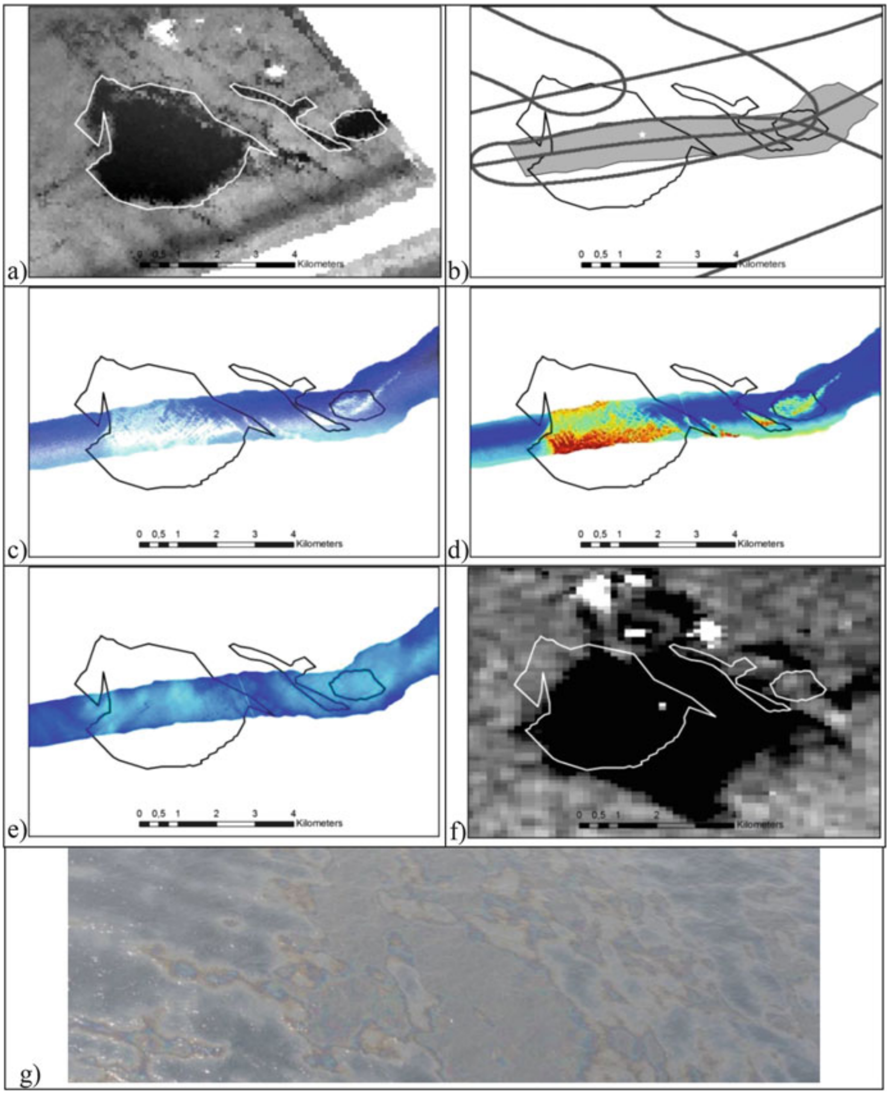

Fig. 11 Example data of a confirmed pollution event observed by the sensor system of the Do228 57+05. (**a**) SLAR image, (**b**) overview with polygon of polluted area, area covered by near-range sensors; flight track and position of photo taken, (**c**) georeferenced image of VIS line scanner, (**d**) georeferenced image of UV line scanner, (**e**) georeferenced image of IR line scanner, (**f**) (© CCME (www.havariekommando.de); BfG; for f: © RADARSAT-2 Data and Products © MacDONALD, DETTWILER AND ASSOCIATES LTD. (2012) – All Rights Reserved. RADARSAT is an official mark of the Canadian Space Agency. Courtesy of EMSA

regions of interest, they found a larger amount of oil pollution during summer (April–September) than during winter (October–March), which they explained by the overall higher wind speed during winter time.

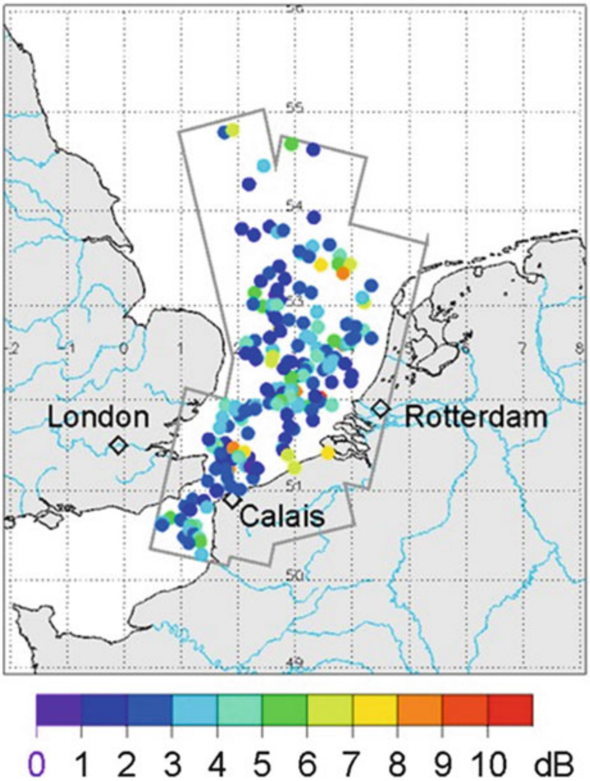

Fig. 12 Results of the analyses of 207 ERS-2 SAR images of the southern North Sea. Each dot denotes the location of a detected possible oil spill, the colour coding denotes the measured reduction in the radar backscatter (damping ratio)

Gade et al. [41] used model wind speeds of the German Weather Service (Deutscher Wetterdienst, DWD) to estimate the influence of the local mean wind speed on the overall detectability of marine oil pollution. The model results for the southern North Sea for the entire period of interest (December 1996 until November 1998) are shown in Fig. 13, where the left panel contains the values calculated for summer (April–September) and the right panel contains those for winter (October–March). Note that the maximum mean wind speed in the area of interest during summer is just above 8 m/s, whereas it is well above 10 m/s during winter.

Using the wind speed information from the DWD model, Gade et al. [41] showed that in general, i.e. in all three European test sites, most oil spills were detected at mean (modelled) local wind speeds between 3 and 4 m/s (Fig. 14, left panel). However, this also coincides with the maximum of the general wind speed distribution (middle panel of Fig. 14), which lies between 5 and 6 m/s. As an objective measure of the detectability of marine oil pollution, Fig. 14 shows the "normalised oil spill visibility" (NOSV) calculated as the (normalised) ratio of the two former.

For the first time, the NOSV gave a clear quantitative estimate of the detectability of marine oil pollution. The results of Gade et al. [41] prove that higher wind speeds cause lower detectability of oil pollution, and vice versa. A simple (spline)

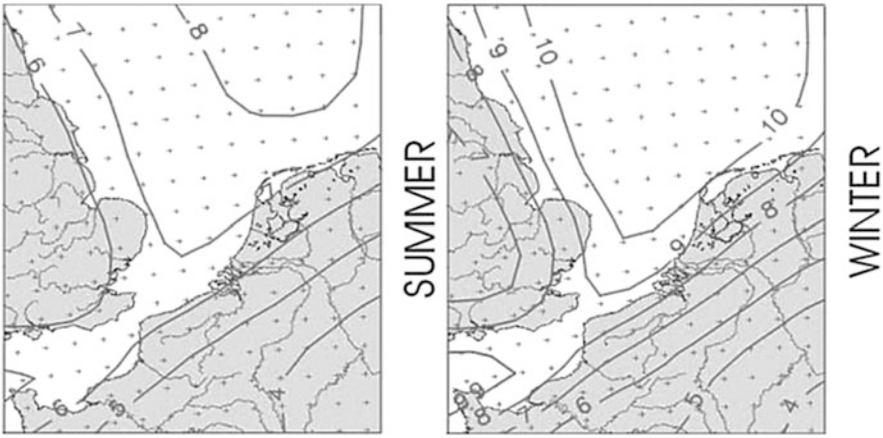

Fig. 13 Mean wind speeds for the southern North Sea for December 1996 through November 1998, as derived from a numerical model driven by the DWD. *Left*: mean wind speeds for summer periods (April–September). *Right*: mean wind speeds for winter periods (October–March). After Gade et al. [41]

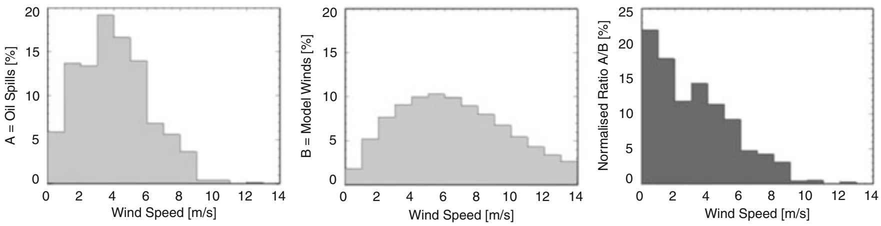

Fig. 14 *Left*: distribution of detected oil pollution with wind speed. *Middle*: frequency of the DWD model winds. *Right*: “normalised oil spill visibility” calculated as the ratio of the oil spill distribution and model wind speed distribution. After [41]

fit to the NOSV distribution indicates that oil spill detection in European coastal waters is possible only at wind speeds below 10 m/s and that the definite detection of marine oil pollution at higher wind speeds is unlikely. Gade et al. [41] used these results to explain why less oil pollution was detected in the northern test areas during winter time, and they were the first to produce density maps of oil pollution for European marginal seas (Fig. 15).

Figure 15 clearly shows that continuous high pollution density in the southern North Sea throughout the year, i.e. during both summer and winter. Less pollution was found during winter time (right panel) and that throughout the year. Local minima (and maxima) indicate that a too small amount of SAR images was used for this investigation. Nonetheless, Gade et al. [41] concluded that it is unlikely that less pollution occurs during winter months, but that the overall higher wind speed results in a lower detectability of that pollution. This also means that any seasonality in ship traffic does not manifest in higher oil pollution of the southern North

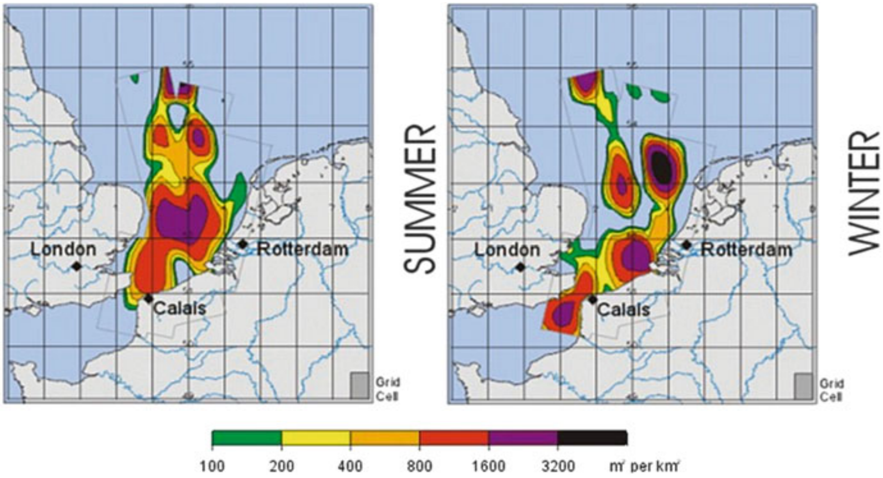

Fig. 15 Density maps of (detected) oil pollution in the southern North Sea, as derived from 207 ERS-2 SAR images between December 1996 and November 1998. *Left*: summer months (April–September). *Right*: winter months (October–March). The maximum pollution density was found along the main ship traffic route through the English Channel. After [41]

Sea (again, we note that only a limited number of SAR images were used for those statistics and that the inflexible acquisition times may also have caused a bias in the results presented herein).

4.1.2 Combined Statistics

Figure 16a shows a map of the possible pollutions in the North Sea part of the German Exclusive Economic Zone (EEZ) originally reported by the satellite service in the years 2008–2013 that have been checked by aerial surveillance. The results of the checks are displayed in the map, divided into the classes: confirmed as mineral oil, natural phenomena, other substance, unknown feature and nothing observed. This shows that the detections based on satellites alone have to be taken with care – though there can be a time lag of some hours between satellite overpass and check.

Figure 16b shows additional pollution that has been discovered during aerial surveillance flights following a satellite image. This figure includes not the data from the many flights that have been performed independently from the satellite images. The aerial surveillance is performed on a regular basis but with changing schedules at any day of the year and at day and night time, partly combined with satellite overpasses and partly independently.

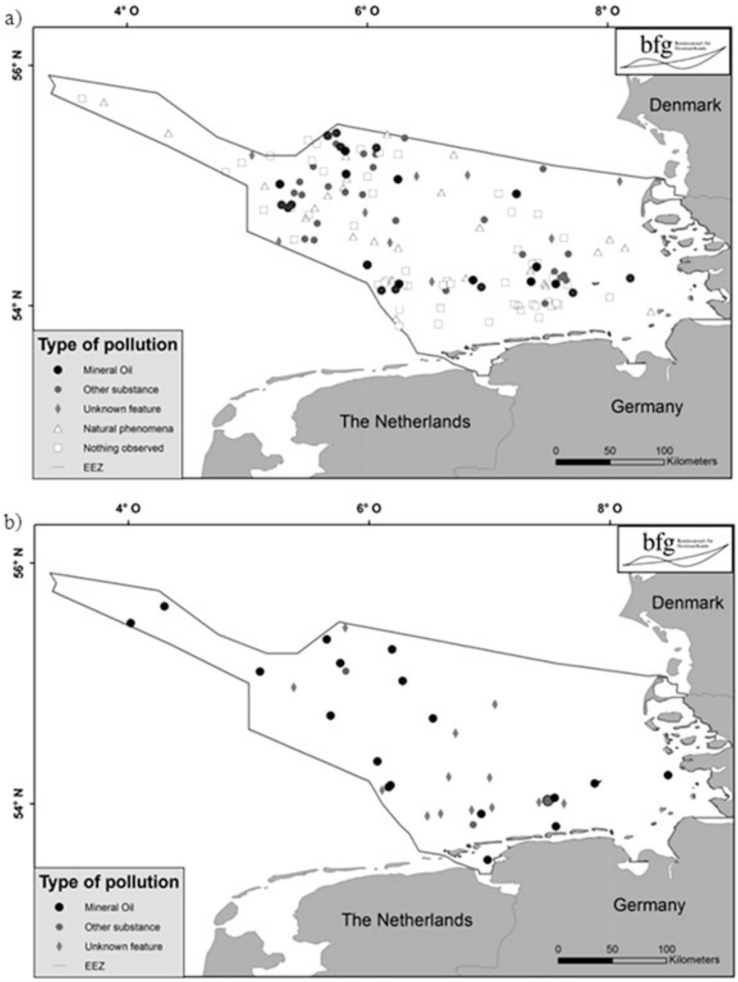

Fig. 16 Results of aerial surveillance of possible oil spills reported by the satellite service in 2008–2013: (**a**) validation results of the alerts; (**b**) additional pollution found by the aerial surveillance during the dedicated satellite check flights (© BfG, CCME)

5 Application of Chemical Dispersants in Intertidal Waters

A spreading slick itself forms a large region of "sheen", about 0.1 μm thick containing less than 5% of the total oil volume. The majority of oil is bound to a much smaller area with a thickness of several millimetres in case of a stable emulsion. Within the first few hours or days, most crude oils will lose up to 40% of their volume by evaporation [42]. This process, driven by temperature and wind speed, reduces the portion of lighter components of the oil and a smaller volume with a higher viscosity and minor toxicity is left [43]. This loss of oil components to the atmosphere is supplemented by a much smaller rate of dissolution. The amount of water-soluble hydrocarbons around an oil slick is generally in the ppb range but remains toxic and bioavailable for marine organisms. On the other hand, the incorporation of water into the oil residue left by evaporation and dissolution leads to a large increase of pollutant volume raising the viscosity once again. Very stable emulsions, formed by some oils, are resistant to any chemical treatments or heating.

Under rough sea conditions, low viscous oils to a large extent disperse into the water column, forming droplets of a wide size spectrum. While larger oil droplets resurface, only the smaller ones (<70 μ) remain in permanent dispersion. Clay and particles of similar size (1–100 μ diameter), and organisms, interact with dispersed oil droplets by adsorption and ingestion. In waters of high turbidity, as, for example, in estuaries, the resulting oil-mineral complexes can reach high levels and obey the characteristic environmental processes of sedimentation and accumulation in areas of low hydraulic energy like nearshore tidal flats and watersheds [42].

The final weathering process of spilled oil is biodegradation. All but the most refractory components of a crude oil can be degraded by biological actions in the water column as well as in sediments. The rates depend on temperature and the availability of oxygen.

5.1 Advantages and Disadvantages of the Application of Chemical Dispersants

The advantages of using chemical dispersants are twofold: In the first place, they reduce the pollutant volume on the water surface. Secondly, they increase the rate of biodegradation processes by increasing the reactive surface of the oil. Their effectiveness depends mainly on the kind of the oil, its state of weathering (viscosity and degree of water-in-oil emulsions) and on the hydraulic energy in the area of concern. Other factors of gradual influence are salinity, turbidity and temperature [44].

Coastal waters of the German Bight show a wide range of salinity, turbidity and energy characteristics: With increasing distance from the coast, depending on the tide especially in estuarine areas, the salinity changes from less than 5‰ to more than 30‰ [3]. The pattern of turbidity is reverse but it is interrupted by sharp gradients. The heterogeneity of wave energy on a small scale (some 100 m), caused by changing wind conditions, water depth and current speed in estuaries, tidal channels and creeks also decreases with distance from the coastline, while the heterogeneity and number of sensitive tidal and subtidal habitats increases. Briefly, the effectiveness of dispersants will be greater the further offshore they will be applied (more wave energy and higher salinity) – the danger to fundamental systems functions is greater if they are used nearshore where high adsorption rates of oil droplets by particles lead to increased microbial degradation with detrimental consequences for oxygen contents.

On the other hand, several nearshore habitats and communities are highly sensitive to oil slicks; examples are mussel beds, shell mounds, sea grass meadows, salt marshes and stocks of resting and moulting birds [45]. For most of them, an assessment of the "good or bad" effects of the application of chemical dispersants also depends on the specific conditions at the time an accident happens. An important example are moulting and resting birds. Moulting bird stocks are clearly much more vulnerable to untreated oil slicks than to chemically dispersed oil. During between one and two months in summer, these birds are unable to fly. In distinct areas, stocks of such birds can reach far more than 100,000 individuals; just swimming or drifting on the water, they are helpless in the face of contaminating oil slick residues. Their stock sizes and population dynamics are very well known and steadily monitored so that the degree of uncertainty in estimating damages to the population level is comparably low. Although the survival of their population and their role in systems functions may not be at risk, nevertheless, a sharp decline of their local stock size must be avoided for natural resource protection reasons.

5.2 Modelling in Case of an Accident

Which specific ecosystems are actually endangered will depend on winds and currents that prevail at the time an accident happens. Forecasting the future evolution of oil spills is an important part for planning countermeasures. Nowadays, numerical drift calculations are readily available. In Germany, these services are provided by the Federal Maritime and Hydrographic Agency (BSH, cf. also Chapter Combined Monitoring System), based on operational hydrodynamic simulations. In such simulations, algorithms for particle movement are combined with a mathematical description of spreading, evaporation, dissolution, formation of emulsions, dispersion in the water column and sedimentation. In the model, particle movements depend on marine currents and the wind speed in 10m height multiplied by an empirically tuned wind drift factor.

5.3 Modelling for Risk Analyses

Modelling in case of a specific accident must be distinguished from precautionary risk assessments or the development of strategies to improve emergency preparedness and response. At the Helmholtz–Zentrum Geesthacht (HZG), corresponding studies have been conducted that make use of existing model-based reconstructions of atmospheric and marine conditions for the last decades. These simulations with high resolution in both space and time (hourly data) available from the data base coastDat (www.coastDat.de; [46]) were originally produced mainly for climate research purposes. In the present context, however, the data provide a mathematical laboratory for risk assessments of different kinds. A toolbox PELETS-2D was developed that allows for the generation and evaluation of extensive ensemble particle transport simulations. Particle trajectories can be calculated either forward or backward in time [47]. A typical setup would consist of a specific release scenario (i.e. release at a specific location) which is then initialised repeatedly every 24 h within a long period of several years or even decades. The resulting large ensemble of simulations realistically represents the spectrum of an accident's possible consequences under realistically represented variable meteorological conditions. The inclusion of weathering processes based on the corresponding BSH routines is optional and restricted to calculations forward in time.

Questions like "Will dispersants work effectively with a particular oil in the environment of interest?" or "What are the ecological consequences of dispersant use?" involve a large amount of uncertainty with regard to potentially relevant parameters. Even if these parameters were perfectly known (a very unrealistic assumption), their values would hold only for a selected specific oil type, dispersant and given environmental conditions (temperature, salinity) and degrees of freedom that make it hard to derive a general description of risk. Chrastansky and Callies [48] provide an example, however, of how already simplified considerations allowed for an explanation of interannual and spatial variations in beached bird survey data caused by chronic oil pollution. In a similar way, pure transport analyses without considering weathering processes can help delineate spatial regions that would possibly be affected with or without the application of chemical dispersants. This approach leaves more advanced questions about the toxicity of pollutants (possibly mixed with dispersants) for later more in-depth analysis.

Figure 17 refers to an assumed oil spill 12 km north of the island of Wangerooge. The hypothetical oil release was initialised every 28 h within the year 2001, and for each of these simulations, time evolution under realistic weather conditions was simulated for the next 14 days. Assuming passive tracers, the figure compares the percentage of tracer particles stranded in the German "Wadden Sea" with (top panel) and without (bottom panel) taking into account an extra wind drift. The extra wind drift is obviously the main driver for "Wadden Sea" pollution, concentrations predicted in the bottom panel referring to a dispersant being applied are much lower (note that axes are scaled differently!). A second observation is that with wind drift included, the risk of the "Wadden Sea" being affected varies smoothly with changing weather conditions.

By contrast, without an effective wind drift (i.e. with the dispersant being applied), tidal transports are relevant for the fraction of the polluting mass that enters the "Wadden Sea". An indicator for this is that events neighbouring in time may nevertheless have different consequences due to different tidal phases at the assumed time of hypothetical oil release.

There are, however, a couple of model scenarios for which application of chemical dispersants cannot keep the "Wadden Sea" unaffected. In some cases, these events seem to coincide with those when without application of the dispersant (i.e. with wind drift included), coastal pollution would be low (as winds blow

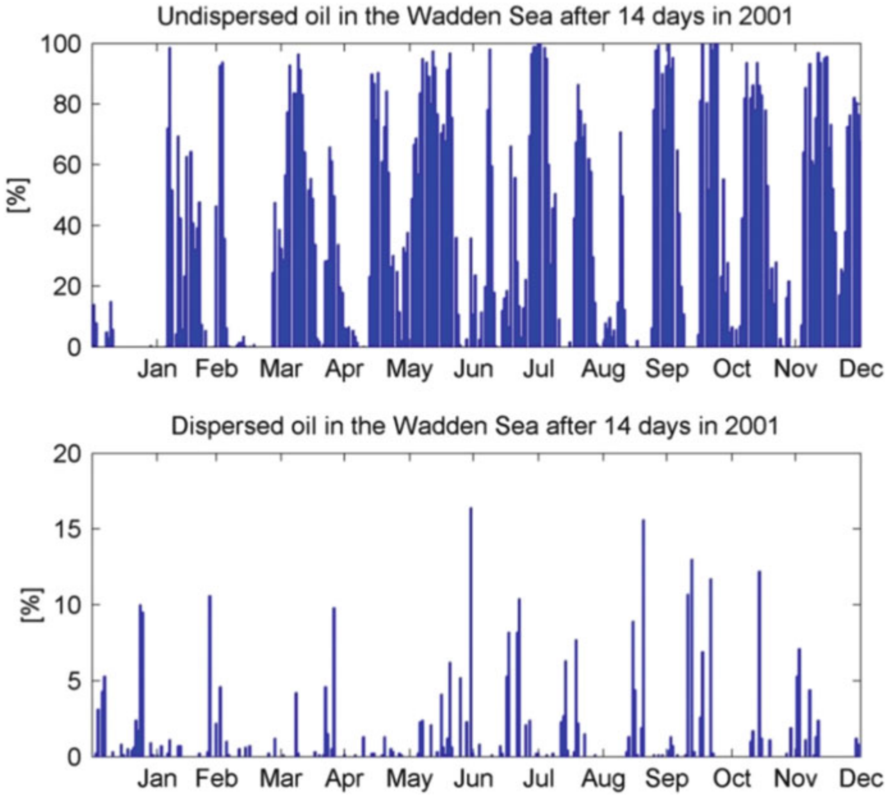

Fig. 17 Percentages of passive tracer particles released at 53.90°N 7.83°E that enter the German Wadden Sea within a 14-day period. Results are shown with (*upper panel*) and without (*lower panel*) taking into account an extra wind drift factor

offshore). This relationship is somewhat blurred by the fact that within the long period of 14 days, simulated wind conditions of course do not remain constant. Nevertheless, it is obvious that the advantages of favourable wind conditions should not be destroyed by an unnecessary use of chemical dispersants.

6 Summary

The German part of the North Sea is being frequently monitored with respect to possible oil pollution both from aircraft and from space, as well as from patrol vessels and intertidal field surveys. We have introduced the combined German oil monitoring system using satellite services, aerial surveillance and drift modelling. The sensor system on board of the oil surveillance aircraft of type Dornier228 is presented as well as some images. Further, SAR imagery examples show marine oil films in various parts of the North Sea.

Basic research on the visibility of marine oil pollution and of natural surface films has been performed in Germany, and some fundamentals on the discrimination of anthropogenic oil films and biogenic sea slicks were given. Decision making on the use of dispersants must be made in the presence of large uncertainties regarding different aspects of potential environmental damages. These aspects can hardly be precisely simulated. Nevertheless, existing long-term simulations of atmospheric-marine conditions provide valuable input, focusing on the pure transport phenomena.

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Beached Bird Surveys in the North Sea as an Instrument to Measure Levels of Chronic Oil Pollution

Kees Camphuysen and Martin Heubeck

Abstract Seabirds are particularly sensitive to marine oil pollution. Systematic surveys of beach-cast corpses of birds ('beached bird surveys') not only document the adverse effects of oil pollution on wild birds but are particularly useful for monitoring spatial and temporal patterns and trends in chronic oil pollution. In this chapter, we briefly review the history and current schemes of beached bird surveys around the North Sea and the development and sensitivity of the monitoring instrument, followed by an overview of the most recent developments and trends. Oil pollution at sea has been known since the late nineteenth century, and the first beached bird surveys were conducted in the 1920s. Oil rates (the proportion of seabirds found on the tideline that were oiled) remained very high until the late 1980s, but have since declined markedly. Protocols were modified in the late 1990s in order to obtain an internationally accepted monitoring instrument. The subsequent continuation of the declining trends in oil rates around the North Sea is discussed. The species composition of the seabirds most commonly found oiled suggests that coastal areas are currently more or less free from chronic oil pollution, while higher pollution levels occur around shipping lanes in areas with the highest shipping densities.

Keywords Beached bird surveys, Chronic oil pollution, Historical overview, Monitoring techniques, North Sea, Oil pollution, Recent trends

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Contents

1 Introduction

Systematic surveys of beach-cast corpses of birds (‘beached bird surveys’) have been used for many decades to highlight and document the adverse effects of oil pollution on wild birds (notably seabirds and coastal waterbirds). In this chapter we explore the potential of these censuses to monitor spatial and temporal patterns and trends in chronic oil pollution. The earliest counts of dead seabirds were made simply to draw attention to an issue that was previously unknown (early in the twentieth century), but more systematic surveys in the 1950–1980s were to show that chronic oil pollution was a really serious issue, killing hundreds of thousands of seabirds annually around the world [1]. Critics argued that seabird populations in the 1970s and 1980s were actually flourishing, such that the impacts of elevated winter mortalities were difficult to detect in the expanding populations [2]. Seeing high numbers of oiled seabirds perish every winter made headlines in national newspapers and in television news bulletins, such that the urge to minimise oil pollution became strongly advocated by the general public and environmental NGOs.

This chapter provides a historical overview of beached bird surveys around the North Sea, describes developments to test the technique as a monitoring instrument and provides an overview of the most important spatial patterns and long-term trends in oil rates (i.e. the fraction of all seabirds found on a beach that are oiled). There is a large body of literature on the results of beached bird surveys, and rather than repeating what has been published extensively, we focused on the key messages provided by this technique and the possibilities of using this tool to monitor future trends in oil pollution.

2 Beached Bird Surveys Around the North Sea: Historical Overview

The first reports of oiled seabirds washing ashore within Europe were published in the early twentieth century [3, 4], but it was not until the First World War that oiled seabirds became a common phenomenon [5]. War activities at sea were thought to explain the strandings: torpedoed merchant and military vessels were assumed to have leaked oil, which killed birds at sea, and birds and oil then washed ashore [6]. However, well after the war further incidents and mass strandings of oiled seabirds occurred, in fact around the world, and this prompted people to report their findings [7–16]. It was not until the 1950s and 1960s that systematic attempts were made to establish and maintain programmes for monitoring beached (oiled) birds, firstly in Belgium [17] and the Netherlands [15, 18] but subsequently also in the UK and in other countries around the North Sea [19–21].

In the early 1970s, largely in response to the media coverage of the major oil spill from the Torrey Canyon in Britain and the public outcry that followed [22, 23], the number of European countries in which beached bird surveys were organised increased markedly. In the late 1970s, concern over the possible impact on seabirds of oil exploration, production and its transportation in the northwestern North Sea led to monthly beached bird surveys being established in the Northern Isles of Scotland [24, 25], an area of low shipping density where oiling incidents had been recorded [26] but with little anecdotal evidence of a major, chronic problem. Further south in the North Sea, chronic oil pollution levels were arguably higher than ever before at the time [1], and the Royal Society for the Protection of Birds (RSPB) in Britain began to co-ordinate results internationally [27]. When the national scheme in Britain was suspended in 1986, this role was temporarily assumed by the Danish Ornithological Society [28], but the international liaison fell apart in the mid-1990s. Currently, beached bird survey schemes operate more or less independently in around ten European countries. Over the past four decades, beached bird surveys have been particularly intense in Belgium [29], Britain [30–33], Denmark [34, 35], Germany [35–37] and the Netherlands [38].

3 The Development of a Monitoring Instrument

Operational discharges by ships and frequent leakages of oil by ships and offshore installations (i.e. chronic oil pollution) were identified as the main sources of oil washing ashore and on beached seabirds in many studies [39–42]. Initial beached bird surveys simply reported numbers of oiled birds found, usually corrected for observed effort (number per km of coastline searched for casualties) [18]. These numbers were often very large and the results were therefore quite impressive [1]. Critics realised that the numbers of birds washing ashore varied in fact considerably, for example, as a result of changing wind directions [43–45], so the results were possibly more influenced by environmental conditions rather than reflecting the amounts of oil at sea. Also, in early monitoring programmes, observer effort was often minimised, for example, by focusing all effort on a single midwinter weekend (usually late February) [27, 28, 46, 47]. Comparing survey results between years became rather difficult, given that some winters were mild (with predominantly westerly winds over much of Europe), while others were severe (with offshore winds prevailing over most of continental Europe and cold-induced mortality among waterbirds increasing the number of corpses found). Nevertheless, the international beached bird survey revealed large-scale spatial patterns in oil rates that mirrored

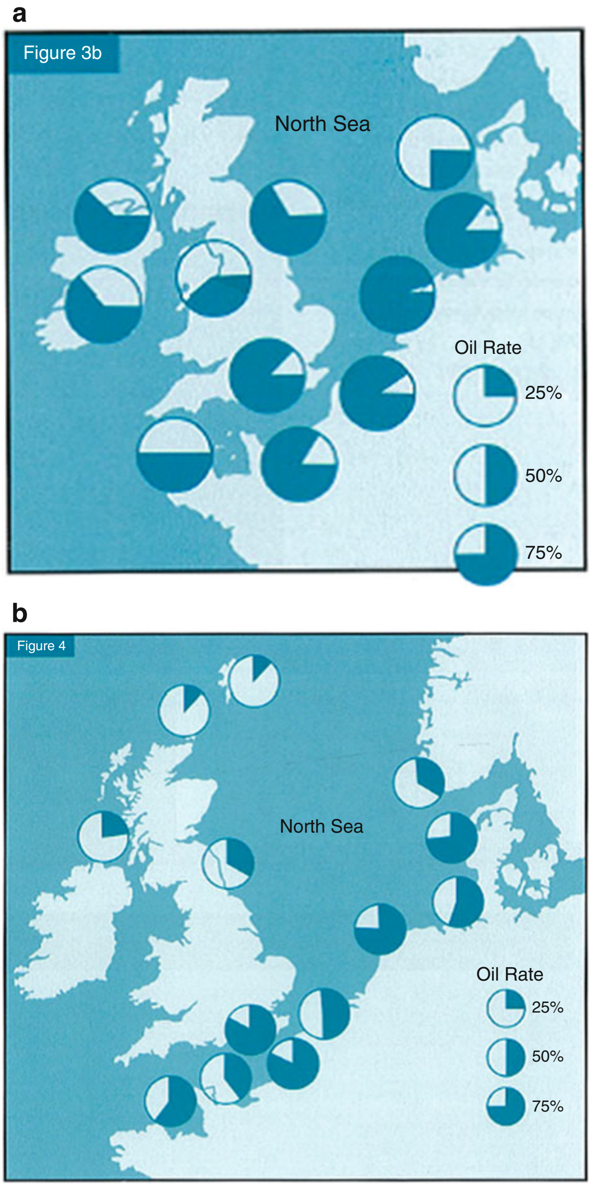

Fig. 1 (**a**) Spatial pattern in oil rates (% oiled) in auks (mostly guillemots and razorbills) found around the North Sea in the 1970s and early 1980s; (**b**) oil rates in common guillemots in the late 1980s and 1990s. Sources: (**a**) Stowe (1982) [27], (**b**) Furness and Camphuysen (1997) [48]. *Notes*: Oil rates tended to be high in the English Channel and in the southern and eastern North Sea, where shipping intensities are high, and much lower in the northwest

differences in levels of chronic marine oil pollution around the North Sea that might be expected from variable densities of shipping and industrial activity offshore (Fig. 1) [27, 48]. This was after the protocol of beached bird surveys had changed: all birds had to be reported, and a fraction of oiled casualties (the *oil rate*) was calculated from the number of carcasses that were indeed contaminated with oil.

At the third North Sea Ministers Conference in 1990, it was decided that the possible use of beached bird surveys had to be investigated, as an indicator of the effectiveness of actions taken to reduce oil pollution of the seas. Following a report on 'The value of beached bird surveys in monitoring oil pollution' [47], it was concluded at the interim Ministers Conference in Copenhagen in December 1993 that 'In 1995 it should be possible to assess the effectiveness of the measures already agreed, and an assessment should be made available to the Fourth International Conference on the Protection of the North Sea. The Monitoring of oiled seabirds should continue as a useful indicator of the effectiveness of these measures'.

A comprehensive analysis of Dutch beached bird survey data, a study commissioned by the Dutch government to evaluate the monitoring properties of this technique, showed that oil rates remained fairly constant between species and between areas, with rather small fluctuations between years [49]. The assumption is that the fraction of all beached birds that is oil contaminated (the *oil rate*) is in some way related to the levels of chronic oil pollution at sea. The fraction of oiled birds (y), or the *oil rate*, has presumably some s-shaped relation with some index of oil pollution (x). A widely used mathematical representation of such s-shaped curve is the logit function:

$$y = \frac{e^x}{1 + e^x} \tag{1}$$

The analysis focused on this index of oil pollution, which equals (as follows from (1)):

$$x = \log\left(\frac{y}{1 - y}\right) \tag{2}$$

Statistical trends in observed oil rates were calculated by linear regression after logit transformation of the data [49, 50].

The oil rate is in fact to be interpreted as the probability that a bird or a bird corpse encounters oil while in contact with seawater within a particular part of the North Sea. Oiled beached birds may have been contaminated by oil while still alive (genuine casualties, *pre-mortal* contamination with oil). Alternatively, however, carcasses may have floated into an oil slick (*post-mortal* contamination). Post-mortal contamination is not always easy to separate from oiling as a cause of death. If we group the first category (birds oiled while still alive) under a and call all other birds found on some beach d, then $d = (b + c)$ in which b are carcasses that were contaminated and c are carcasses that remained clean. The oil rate found on the beach (s) is then $(a + b)/(a + b + c)$, while we would have preferred a genuine oil rate (r) of $b/(b + c)$ which is the same as b/d, because this ratio would only depend on floating time, the distance and the surface area contaminated with oil slicks. So, while

$$r = b/d \text{ and } s = (a + b)/(a + d) \tag{3}$$

when we assume

$$a = qd, \tag{4}$$

the relationship between the desired oil rate $r(b/d)$ and s, the actual oil rate found on the beach, or $(a + b)/(a + d)$, would be

$$s = (qd + b)/(qd + d) = q/(1 + q) + 1/(1 + q)r, \quad (5)$$

a relationship that could be illustrated as in Fig. 2.

Hence, monitoring oiled beached birds does not necessarily reflect varying levels of oil-induced seabird mortality, but rather the chance that a bird, or a corpse of a bird, encounters an oil slick while in contact with surface waters in a given area. Even landbirds produce an index larger than zero. Given that the oil rates of landbirds, waders and freshwater waterfowl are typically very low, *b* must be small.

Oil rates tend to be positively correlated with anticipated species-specific oil vulnerability indices (OVIs) that are based on numerous factors including exposure and behaviour (see Table 1) [1, 51–55]. This suggests that the oil rate does indeed reflect the dangers imposed by chronic oil pollution on seabirds [1, 38, 48, 56].

The 1995 study was also concerned with the statistical power of appropriate trend tests [49]. The power (1-β) is the probability that a trend, if present, will be detected as statistically significant. The detection probability depends on the size of the trend, the error variance, the number of years (n) and the reliability of the test (α). The power analysis performed on the basis of 10 years of Dutch data (1986–1995) showed that significant trends were to be expected with a certainty of 75% in data sets of 13–17 years [49]. When using a slightly longer subset of data, available for the mainland coast of the Netherlands, it was confirmed that this was indeed the case: all declines found were significant trends. The conclusion from the analysis was that BBS results are sensitive and useful to detect even minor trends in the frequency of occurrence of oil on the corpses. Different levels in oil rates between species would reflect species-specific differences in exposure and vulnerability; spatial and temporal trends could effectively be used to illustrate changes therein in time and space.

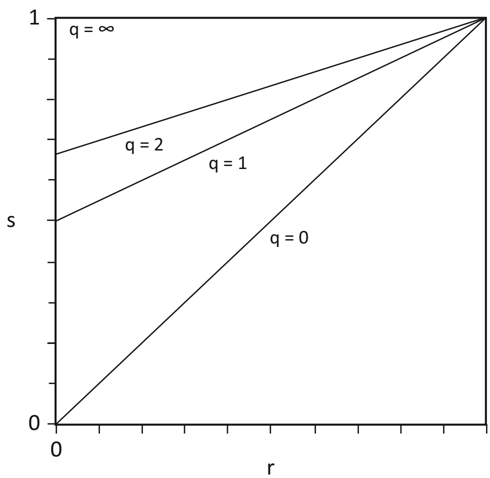

Fig. 2 Relationship between the oil rate *r* (*b*/*d*) and the oil rate *s*, as found on the beach (see text)

Table 1 Oil vulnerability indices[a] (OVIs, mean and range for species groups, from Camphuysen 1989) for North Sea seabirds and oil rates (%) reported since the 1970s in birds stranded in the Netherlands (NZG/NSO database, Dutch Seabird Group unpublished data). The table is ordered by OVI ranging from high to low, missing values where $n < 25$ corpses

Species (group)	OVI	Range	Mean oil rates (%)				
			1970s	1980s	1990s	2000s	2010s
Razorbill	86		97	89	69	62	4
Guillemot	82		95	88	68	67	19
Auks[b]	77.2	(65–86)	96	89	68	65	11
Eider	75		65	47	10	4	0
Divers (loons)	66.3	(65–68)	94	88	76	79	
Scoters	65.5	(65–66)	89	87	67	55	4
Kittiwake	66		80	83	53	46	5
Cormorant/shag	66.0	(59–73)		32	9	2	1
Gannet	65		91	82	77	48	5
Fulmar	65		75	61	31	16	3
Other sea ducks	64.2	(45–75)	44	27	5	10	
Grebes	53.3	(46–58)	58	63	30	37	5
Terns	47.9	(46–51)		17		0	
Larus, gulls	45.1	(36–66)	61	38	13	3	1
Skuas	42.6	(36–58)		44	31	16	
Other wildfowl	35.0	(26–53)	43	23	7	3	0
Waders	31.0	(20–43)	9	8	1	2	0
Herons and rails	26.0	(23–29)	22	10	2	2	2
Landbirds			19	16	4	1	0

[a]OVIs are indices based on 20 factors of indication vulnerability to oil pollution (each weighed on a 5-point scale ranging from 1 (insignificant) to 5 (highly significant)). A maximum score would be 100 points, but the highest species-specific score actually established was 86 (razorbill). See Camphuysen 1989 and 2007 for details [1, 51]

[b]A combination of razorbill, guillemot, puffin and little auk

These findings were confirmed during a later analysis, commissioned by the Ad Hoc Working Group on Monitoring of the Environmental Assessment and Monitoring Committee (ASM, Oslo and Paris Convention for the Prevention of Marine Pollution), in which data from the international beached bird survey were used [50]. Comprehensive guidelines for future beached bird surveys were formulated on the basis of the analysis, and these formed the basis for the implementation of a new monitoring programme in which strandings of common guillemots, *Uria aalge*, an oil-sensitive, very abundant seabird around the North Sea, were used to evaluate patterns and trends in chronic oil pollution around the North Sea [50]. The oil rate was now generally accepted to illustrate the ‘risk’ of birds to become oiled, and differences in oil rates would thus highlight area-specific differences and temporal trends in these risks. The oil rate, now strictly based on a sufficiently large sample of ‘complete’ (intact) corpses of birds, could describe trends in oil contamination among seabirds, coastal birds and more land-oriented birds, believed to mirror trends in the amount of oil pollution of the seas washing our shores.

4 OSPAR EcoQOs and Oil Pollution

Following years of preliminary investigations, beached bird surveys were finally seen as a valuable, independent and cost-effective instrument (given a massive volunteer input to search beaches for dead birds) to monitor levels of chronic oil pollution around the North Sea [57]. In a set of Ecological Quality Objectives for the North Sea, the proportion of oiled common guillemots among those found dead or dying on beaches is listed under Issue 4 (seabirds), EcoQO element (f) [58]. The EcoQO, as agreed by the Fifth North Sea Conference, was defined as: *The proportion of such birds should be 10% or less of the total found dead or dying*, *in all areas of the North Sea* [59]. The ICES Working Group on Seabird Ecology (ICES WGSE) and ACE reviewed the proposal and recommended in 2003 [60, 61] that trends might best be reported as 5-year running means of percentages oiled. In line with this, it was advised that a period of at least 5 years in which an average of 10% or less oiled common guillemots has been recorded should occur before the conclusion that the objective has been reached could be justified statistically. ICES WGSE therefore suggested that the EcoQO be reformulated as: *The average proportion of oiled Common Guillemots should be 10% or less of the total found dead or dying in each of 15 areas of the North Sea over a period of at least 5 years and that sampling should occur in all winter months* (*November to April*) *of each year* [60]. This reformulation was adopted in 2005 [62]. OSPAR was now ready to implement one of its first Ecological Quality Objectives (EcoQOs). Ten years later (2015), although annual updates have been provided by numerous contracting countries, the EcoQO was still not formally implemented.

5 Oil Pollution and Stranded Seabirds in the 1950s–1970s

The 1950s to the 1970s were three decades during which chronic oil pollution was an immense problem within the North Sea and beyond, most notably around the major shipping lanes. Major oil incidents occurred (such as with *Torrey Canyon*, *Pacific Colocotronis*, *Ekofisk Bravo* and *Amoco Cadiz*), but it was clear that chronic oil pollution was the ongoing, continuous threat for marine wildlife, arguably killing vastly greater numbers of seabirds on an annual basis [1, 30, 63–69]. Oiled seabirds were gradually seen as a major imperative for preventing and reducing the continued illegal oiling of the seas by ships [70], but it took time for measures to be taken en even much more time for the implementation of new regulations following OILPOL 1954[1] and MARPOL 1973/78.[2]

[1] In 1954, the United Kingdom organised a conference on oil pollution which resulted in the adoption of the International Convention for the Prevention of Pollution of the Sea by Oil (OILPOL), 1954. Following entry into force of the IMO Convention in 1958, the depository and secretariat functions in relation to the Convention were transferred from the United Kingdom government to IMO.

[2] IMO 1973/78. International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto (MARPOL 73/78). International Maritime Organization, London, http://www.imo.org/home.asp.

Fig. 3 A selection of oiled common guillemots collected on the shoreline in the Netherlands within one week in 1978. *Note*: Virtually all birds are contaminated with oil, most birds only partly. There was no particular oil spill known to have occurred at the time (Photo Royal Netherlands Institute for Sea Research)

In the southern North Sea, as exemplified by beached bird surveys organised along the Dutch shoreline, over 90% of all auks, divers (loons) and northern gannets washing ashore were oil contaminated, year after year [1] (see Table 1). Given that many thousands of corpses were recorded every single winter, just in this area more seabirds died from oiling than in most of the major oil spills recorded anywhere in the world. Midwinter oil rates of auks and divers found in the UK between 1971 and 1979 amounted to 60–70%, with the highest values reported from the east and south coasts of England (English Channel and Southern Bight [27]). About half the common guillemots found in winter in Orkney were contaminated with oil in the late 1970s (Erik Meek, RPSB in [47]), and these waters were normally considered 'relatively clean'. From an analysis based on international midwinter beached bird surveys, using common guillemots as an example species, it was found that winter oil rates were highest in the Netherlands (Fig. 3 [27]). The reported oil rates in this area were probably higher than anywhere else in the world at that time.

6 Oil Pollution and Stranded Seabirds in the 1980s and 1990s

The 1980s and 1990s saw a period of gradual decline in oil rates around the North Sea, which coincided (not surprisingly) with a decline in the amount of oil washing ashore; oil that couldn't be accounted for as a result of particular spills or discharges. In the southern North Sea, exemplified by surveys in the Netherlands, the oil rate in auks fell from 90% to approximately two-thirds of all birds found in winter along the shoreline. For northern gannets and divers, the levels dropped from 90% to three quarters. Remarkably, however, in coastal seabirds, the oil rates declined much faster. For the gregarious wintering common eider, a characteristic species for the Wadden Sea and Dutch coastal waters, oil rates fell from 65% in the 1970s to 47% in the 1980s and only 10% in the 1990s. Similarly, in coastal gulls (genera *Larus* and *Chroicocephalus* combined), oil rates fell from 61% in the 1970s to 38% in the 1980s and 13% in the 1990s. A later analysis confirmed that coastal seabirds were better off than pelagic species, and these trends were consistent with tendencies to police nearshore waters more effectively than offshore waters [38].

Declining trends were reported in all North Sea countries [29, 35, 71], and while the initial declines were gradual, the drops were steeper in later years and particularly near the end of the twentieth century. Declines in oil spills were reported around the world, emphasising once again that beached bird surveys are indicative for ongoing trends in levels of pollution [72–81]. The added value of beached bird surveys over others, possibly more direct techniques of monitoring oil pollution (such as aerial surveys, remote sensing or advanced detection techniques from space), is twofold: a direct idea of the effects of oil pollution on marine wildlife (actual wildlife damage) and a high spatial and temporal resolution of the data. The finding that coastal waters were now much better protected than the offshore zone was novel and not quite obvious from other data sets.

7 Recent Patterns and Trends

Recent patterns and trends in European beached bird survey results are basically continuations of further declines in oil rates. Oddly, in the southern North Sea (notably in Belgium and in the Netherlands), overall densities (i.e. numbers of birds found dead, whether or not oiled) of stranded birds have markedly declined overall, and many of these declines are inconsistent with the abundance of these seabirds and waterbirds as wintering birds within this region of the North Sea. A most striking example is the recent abundance of wintering divers (or loons, Gaviidae), oil-sensitive species that were markedly less common in the 1960s and 1970s than they are today, which have virtually disappeared as (oiled) stranded birds in recent decades. An explanation for these declines is hard to give, except if the oil may have played a more significant role in overall seabird mortality than ever anticipated. Further research is required to study these declining trends within the context of overall seabird (wintering) abundance.

Given the OSPAR Ecological Quality Objective (the *average proportion of oiled common guillemots should be <10% of the total found dead over a period of at least 5 years*), it is interesting to evaluate recent levels and trends in oil rates in arguably the more heavily polluted parts in the North Sea: the southern North Sea with its major shipping lanes and high wintering densities of seabirds. Within the Netherlands, with its sandy beaches bordering this area, an oil rate of 10% (i.e. logit

−0.95) in common guillemots has been approached once, in winter 2012/2013 (10 % oiled, logit −0.91), but the significant long-term declining trend is promising (Fig. 4). Whether or not a level of 10% is feasible at all could be demonstrated by using another, highly oil-sensitive, gregarious and common wintering species, the common eider *Somateria mollissima* (a coastal species). It is clear that the oil rates in this species are now consistently well below logit −0.95 for more than a decade (Fig. 5), whereas oil rates in this species averaged 42.5% (range 10–77%; mean logit −0.13, range −0.95–0.51) in the 1970s and 1980s, the especially protected World Heritage Site Wadden Sea included.

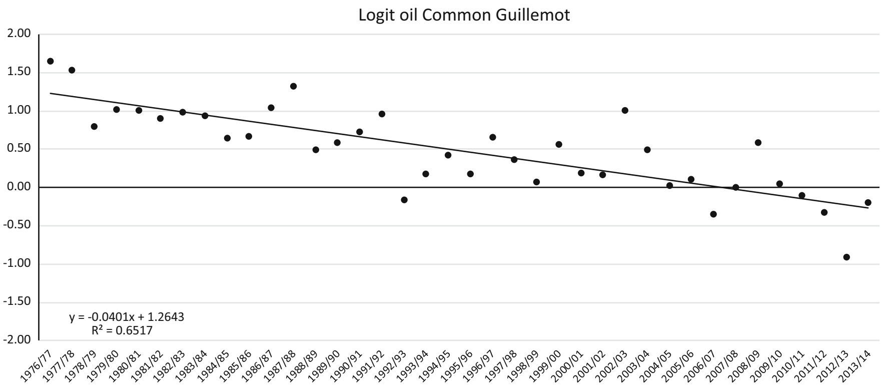

Fig. 4 Significant decline in logit-transformed oil rates in common guillemots found dead in the Netherlands since the mid-1970s. *Note*: Plotted values include seasons in which at least 25 intact carcasses could be inspected for traces of oil along the North Sea coast

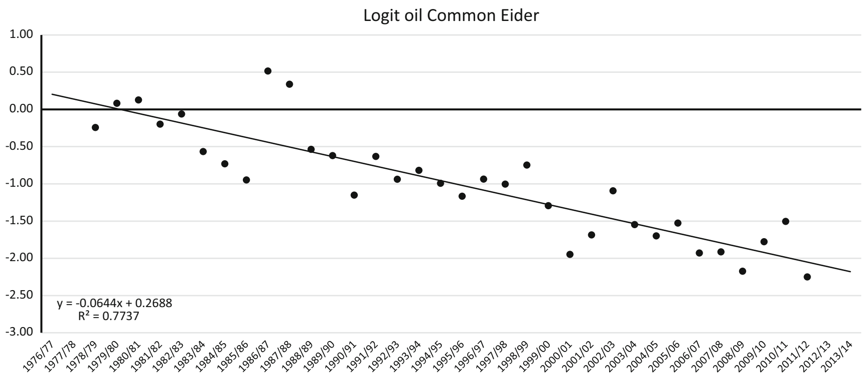

Fig. 5 Significant decline in logit-transformed oil rates in common eiders found dead in the Netherlands since the mid-1970s. *Note*: Plotted values include seasons in which at least 25 intact carcasses could be inspected for traces of oil along the North Sea coast and within the Wadden Sea area

8 Discussion

Apart from simply signalling the effect of marine oil pollution on wildlife, notably on marine birds, an objective of beached bird surveys has been to monitor patterns and trends in the amount of (chronic) oil pollution of the sea by assessing the fraction of oiled objects on a beach. BBS data reflect a direct census of the occurrence of oil, with some very strong points because of its scale (all Europe), cost (with partly volunteer schemes rather low budgets are possible) and the length of its time series. In most countries, data are available over at least the last two or three decades, with unchanged methods, forming unique data sets which can readily be explored and which may form an additional source of information to other, perhaps more direct measurements.

The declining trends in oil rates found in all beached bird surveys around Europe are encouraging, and they show that countermeasures, or better education of maritime crew, or both have been effective. The results are consistent with declines found in oil pollution through other measurements [82–84], but the beached bird surveys tell us more. Beached bird surveys are informative about the adverse effects of oil pollution on marine wildlife, the scale of impact on the ecosystem, and provide remarkably informative data on spatial patterns in chronic pollution that may be used to fine-tune aerial surveys and to focus on areas that still require further attention to minimise oiling. Various data sets, outlined elsewhere within this volume, do indicate that deliberate, illegal spills still occur frequently and further attention is required to bring levels of chronic pollution further down.

The OSPAR EcoQO Oiled Guillemot, although carefully designed, has never been formally implemented, because individual member states have objected to this against the independent measurement. It is a great pity that several established beached bird survey schemes became unstable due to a lack of funding, so a pan-European overview of recent levels and patterns in oil rates is difficult or perhaps even impossible to provide. Beached bird surveys, thanks to the volunteer input involved, are a highly cost-effective way of measuring trends (as was actually agreed upon by the North Sea Ministers conferences and OSPAR itself). The outcomes (consistent declines in oil rates) have also been encouraging and detailed enough to deserve more attention from the legislative bodies and national authorities. It has been a long time since beached bird surveys were simply used to flag up the incompetence of authorities to reduce chronic oil pollution, and now that joint efforts are seemingly successful, this positive news could have been shared more widely.

In line with an earlier publication on spatial patterns of chronic oil pollution (Camphuysen 2010) [30], there is still a need to further reduce pollution levels away from the coast, in offshore waters. The OSPAR EcoQO for common guillemots (<10% oiled consistently) is within reach, but is frustrated by illegal spills at greater distances from the coast. In nearshore waters, probably round the North Sea but certainly in the Southern Bight where traditionally the highest levels of pollution were found, our goals have been achieved: oil pollution is now a scarce phenomenon. Incidental spill may still occur and probably will always occur for as long as oil-based engines are used in marine traffic, but the grim aspect of chronic oil pollution that was so familiar to people living along the coast for many decades seems now consigned to history.

Acknowledgement Beached bird surveys are impossible without volunteer input, and literally thousands of volunteers have been involved around the North Sea since the early 1950s. Their motivation was to help highlight the adverse effects of marine pollution on marine wildlife, and it has been the responsibility of hundreds of regional, national and international co-ordinators of these schemes to analyse and report the collected data. Given the long history of oil pollution, many volunteers did not live long enough to even witness the change in the attitude of man, as a result of which chronic pollution is now finally substantially minimised. A final step towards genuinely oil-free marine surface waters has still to be made; illegal discharges and leakages following ignorance during shipping and offshore activities still occur frequently. With respect to the material presented here, we would like to thank Jaap van der Meer (statistical advice), Eric Stienen and Sabine Schmitt for their help with recent literature and census reports.

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Monitoring Oil Pollution from Oil and Gas Installations in the North Sea

Angela Carpenter

Abstract Oil and gas installations are a source of oil inputs to the North Sea. Those inputs can include oil discharge as a result of production processes or from accidental spills. Two bodies play a major role in monitoring oil inputs from those installations. The OSPAR Commission is responsible for monitoring oil and gas installations against various performance standards, collects samples from those installations to determine whether those standards have been met or exceeded, and also monitors accidental spills. The Bonn Agreement Secretariat also plays a role through its aerial surveillance and, more recently, satellite monitoring activities in the North Sea region. Once a spill has been identified and confirmed as being mineral oil rather than other types of oils or even algae or a natural event, the Bonn Agreement seeks to identify the source of that oil. Through a programme of surveillance activities, it also specifically monitors the areas around oil and gas fields. This chapter provides an overview of the activities of the OSPAR Commission and Bonn Secretariat as they relate to oil and gas installations and examines data on inputs of oil to the marine environment to identify trends in oil pollution from those installations.

Keywords Aerial surveillance, Bonn Agreement, Cuttings, North Sea, Oil platforms, Oil pollution, OSPAR Commission, OSPAR Convention, Produced waters, Satellite surveillance

Contents

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1 Introduction

Two bodies play a significant role in monitoring oil pollution from oil installations in the North Sea. The first is the OSPAR Commission, the body responsible for carrying out activities under the aegis of the Convention for the Protection of the Marine Environment of the North-East Atlantic, 1992 (OSPAR Convention) [1].

The OSPAR Commission is the competent regional organisation guiding international cooperation in the region, and a major role of the Commission is to develop harmonised policies and strategies, including drawing up programmes and measures under a number of thematic strategies [2]. Those thematic strategies are biological diversity and ecosystems, eutrophication, hazardous substances, offshore oil and gas industry (the focus of this chapter) and radioactive substances.

One of the roles of the OSPAR Commission is to monitor oil discharges from the offshore oil and gas industry in the North Sea and more widely in the OSPAR Maritime Area (see Fig. 1). Further information on the content of the OSPAR Convention and on the responsibilities of the OSPAR Commission is provided in chapter of this volume [3].

Region I of the OSPAR Maritime Area covers Arctic waters, an area including the Barents Sea where oil and gas production is expected to increase. Region II is the Greater North Sea, the area where the offshore oil and gas industry has been a major economic activity since the 1960s (see Fig. 2). The remaining OSPAR regions are Region III, the Celtic Seas; Region IV, Bay of Biscay and the Iberian Coast; and Region V, the Wider Atlantic.

The second body which monitors oil pollution in the North Sea region is the Bonn Agreement Secretariat, responsible for administering the requirements of the Agreement for cooperation in dealing with pollution of the North Sea by oil and

Fig. 1 OSPAR Maritime Area. *Source*: OSPAR Commission

other harmful substances, 1983 together with its amendments of 2001 (Bonn Agreement) [5].

Figure 3 identifies the zones of responsibility under the Bonn Agreement, where the eight countries bordering the North Sea have undertaken aerial surveillance, since the late 1980s, using specially equipped aircraft to detect oil and other harmful substances [6]. The UK has, since 2012, mainly used satellite imagery for first alerts, and these are followed up by further investigations including aerial surveillance [7].

While Ireland joined the Bonn Agreement in April 2010 as a Contracting Party, it does not undertake aerial surveillance activities. Geographically, therefore, the Bonn Agreement now covers an extended area to the west of Scotland and south-west England and the waters off Ireland extending into the north-east Atlantic. Only the North Sea area set out in Fig. 3 is considered in this chapter and generally only the area to the north of the zone operated jointly by the UK, France and Belgium.

Further information on the Bonn Agreement, its history and its actions to eliminate accidental and illegal pollution from ships in the North Sea is provided in chapter of this volume [8].

This chapter presents an overview of the activities of the OSPAR Commission and of the Bonn Agreement Secretariat related to monitoring oil inputs to the North Sea. It then presents a broad overview of the levels of inputs, both from oil and gas industry sources and from shipping, based on Bonn Agreement aerial surveillance

Fig. 2 Oil and gas production pipelines in the North Sea, 1991. Source: North Sea Quality Status Report 1993 [4, Figures 1–10, p 17]. *Note*: This figure shows oil and gas production platforms and pipelines in 1991, together with the position of oil wells and exploration drillings

data. A more detailed examination of trends in oil pollution specifically from oil and gas platforms as a result of routine operations and accidental spills is then presented, based on OSPAR Commission data. Finally, some conclusions are drawn as to trends in levels of oil pollution in the region over the nearly three decades for which data is available.

Fig. 3 Bonn Agreement zones of responsibility for aerial surveillance. *Source*: Carpenter (2007) [6, Fig. 1, p 151]

2 The Role of the OSPAR Commission in Monitoring Oil Inputs from Oil and Gas Industry

The OSPAR Commission's strategic objective with regard to its Offshore Oil and Gas Industry Strategy (Offshore Strategy), part of the wider North-East Atlantic Strategy, is to "prevent and eliminate pollution and take necessary measures to protect the OSPAR maritime area against the adverse effects of offshore activities", which includes exploration, appraisal or exploitation of liquid and gaseous hydrocarbons [2].

The Offshore Strategy requires the OSPAR Commission to implement the Strategy progressively and, where applicable, to follow on from and be consistent with commitments made under other OSPAR Strategies. In order to address programmes and measures related to the need to prevent, control and eliminate pollution under Annex III of the OSPAR Convention and to be adopted under Annex V of the Convention following identification of relevant human activities, the Offshore Strategy requires the Commission to collect information about threats to the marine environment from pollution or from adverse effects from offshore activities, to establish priorities for taking action and to establish and periodically review environmental goals to achieve the Offshore Strategy's objectives.

Annex III of the Convention relates to pollution from offshore sources. Annex V of the Convention relates to protection and conservation of ecosystems and biological diversity [1].

As part of the process of achieving the objective of the Offshore Strategy, the Commission collects information on threats to the marine environment from pollution or adverse effects from offshore activities including exploration, appraisal or exploitation of liquid and gaseous hydrocarbons in the OSPAR Maritime Area [2]. A number of measures have been developed to monitor and control emissions, discharges and losses of substances from offshore installations. Information on discharges and waste handling from offshore oil and gas installations has been collected and reported since 1978, originally under the former Paris Convention of 1974 [9] and subsequently under the OSPAR Convention.

2.1 OSPAR Offshore Industry Committee Role and Responsibilities

The OSPAR Offshore Industry Committee (OIC) is responsible for facilitating the implementation of the North-East Atlantic Environment Strategy, and in particular the Offshore Strategy, by: developing and applying a risk-based approach for the management of produced water from offshore activities, keeping under review the need to actions to prevent potential adverse effects from offshore activities and also considering the implications of decommissioning redundant oil and gas installations [10].

Specific monitoring and assessment activities of the OIC, in line with the OSPAR Strategy for the Joint Assessment and Monitoring Programme (JAMP) [11] for the period 2014 to 2021, include annual data collection and periodic evaluation of the impact of discharges, emissions and losses of substances from offshore sources, which cause or are likely to cause pollution; improvement of tools to collect, process and interpret such data, together with appropriate initiation and review of technical studies including best available techniques (BAT) and best environmental practice (BEP); and preparing assessments, including assessments on specific issues, such as assessments of the impacts of decommissioned pipelines and cutting piles, and arranging for their publication [10].

2.2 Measures Relating to Discharges Contaminated with Oil

In 1986 PARCOM (the Paris Commission, the main executive body of the Paris Convention) put in place a recommendation (PARCOM 86/1) for a 40 mg/L emission standard for platforms, under which a standard of 40 mg/1 for the average concentration of hydrocarbons in effluents discharged from platforms should be applied to all platforms constructed after 1 January 1988. It also indicated that emission standards should be set at or below this standard for all individual platforms, unless a Contracting Party could justify why it was unable to do so [12].

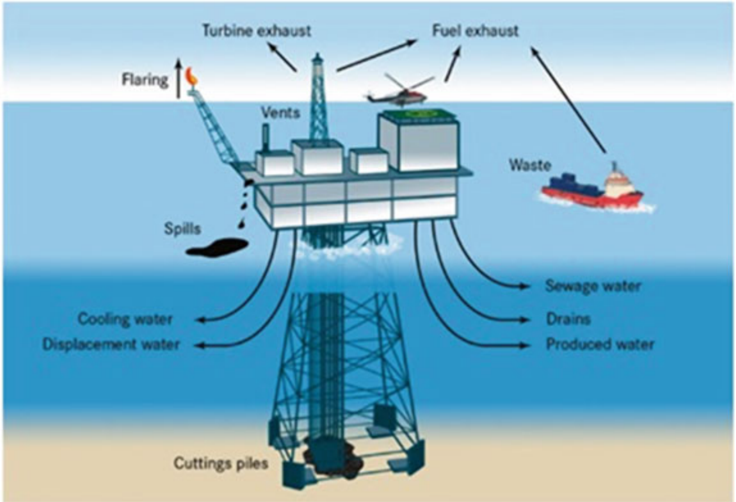


Fig. 4 Sources of oil inputs from oil and gas installations. *Source*: OSPAR Quality Status Report 2010 [14, Fig. 7.1, p 65]

PARCOM 86/1 was subsequently revoked, for produced water only, by OSPAR Recommendation 2001/1 for the Management of Produced Water from Offshore Installations [13]. Produced water (PW) is water that comes from the reservoir as a by-product of oil and gas extraction. PARCOM 86/1 remains applicable, however, to ballast water, drainage water and displacement water from offshore installations. DW is seawater used for ballasting the storage tanks of offshore installations which is discharged into the sea when oil is loaded into those tanks. Figure 4 illustrates the different sources of oil inputs that can be produced by oil and gas installations.

An additional requirement under Recommendation 2001/1, as amended by Recommendation 2006/4, was that, for each installation failing to meet the 30 mg/L standard, Contracting Party reports to the OIC should include an evaluation of BAT and BEP so that information was available on why installations cannot meet the performance standard [15].

Analysis of samples from oil and gas installations is conducted under an agreed reference method of analysis for the determination of dispersed oil content in PW [16]. The results of those analyses, which determine the number of installations failing Recommendation 2001/1 standards, are discussed at Sect. 5.3 in this chapter.

2.3 Measures Relating to the Use and Discharge of Drilling Fluids and Cuttings

Two measures are in place relating to the use and discharge of drilling fluids and cuttings. The first of these is OSPAR Decision 2000/3 on the use of organic-phase drilling fluids (OPFs) and the discharge of OPF-contaminated cuttings [17]. OPFs are fluids which are an emulsion of water and other additives in which the continuous phase is a water-immiscible organic fluid of animal, vegetable or mineral origin. Cuttings are solid material removed from drilled rock together with any solids and liquids derived from any adherent drilling fluids.

While only small amounts of oil are discharged to the marine environment via OPFs in cuttings (see Sect. 5.2.1), some discharges were made from UK installations in 2010–2012. This is permissible, under Decision 2000/3, with prior authorisation of the national competent authority, and this may, for example, be for geological or safety reasons, or in exceptional circumstances. BAT and BEP must be applied in reaching the decision to authorise such discharges [17].

The second measure relating to discharges of drilling fluids are the guidelines for considering the best environmental option for the management of OPF-contaminated cutting residues [18]. While the use of BAT and BEP are described in Decision 2000/3, the guidelines set out how residue disposal should be managed, on a case-by-case basis by the national competent authority (NCA), to achieve the best environmental option in dealing with such residues.

Factors which could influence the decision by an NCA as to what is the best environmental option are outlines in the guidelines. These may include the location of oil and gas reservoirs and whether they are in remote or environmentally vulnerable areas. Technical factors such as the amount of drilled cuttings generated; availability of deck space, energy, etc., on the installation; and the meteorological conditions during operation should also be considered [18].

Environmental factors such as risk to human health; total energy needed to treat, transport, etc.; the OPF-contaminated cutting residues; and levels of emissions to air, water and sea sediment should be examined to compare different options for disposal of cuttings. Finally, a holistic evaluation of, for example, the economic feasibility of transporting to shore OPF cuttings for processing, reinjection of cuttings or offshore treatment of OPF cuttings for discharge to the sea is also required [18].

3 The Role of the Bonn Agreement in Monitoring Oil Pollution in the North Sea

As noted in Sect. 1, the Bonn Agreement has, since the late 1980s, used aerial surveillance to monitor the North Sea for oil pollution and pollution from other hazardous substances. More recently, it has also made use of satellite surveillance imagery, provided by the European Maritime Safety Agency (EMSA) under its CleanSeaNet programme [19].

The Bonn Agreement programme includes a number of different surveillance activities, and these are outlined at Sects. 4.1–4.3.

3.1 National Flights

In order to prevent illegal or accidental pollution of the North Sea, most Bonn Agreement countries, with the exception of the UK, undertake aerial surveillance to enforce maritime pollution rules and standards such as those set out under the MARPOL 73/78 Convention [20]. That Convention has designated the North Sea as a special area where mandatory methods are in place to prevent marine pollution by oil. Specially equipped aircraft are used to patrol the zones of responsibility set out in Fig. 3, although some flights also cross the boundaries of those zones.

Flights take place during both daylight and the hours of darkness and provide first reports on possible pollution incidents. A first report is where raw data on a slick has been obtained using specialised instruments such as synthetic aperture radar (SAR), side-looking airborne radar (SLAR) and infrared or ultraviolet (IR/UV) line scanners or cameras [21]. A slick may subsequently be verified as mineral oil or some other substance by experienced observers who are able to identify a slick from its appearance on the sea surface, for example.

In the event of there being doubt about the nature of a slick, sampling of polluted water may occur, and techniques such as combined gas chromatography and mass spectrometry techniques (GC/MS) can be used to analyse the substance and confirm whether it is oil or not. It can also be used to confirm the source of the oil discharge, e.g. from a specific ship, by comparing the sample of polluted water with samples taken from a ship suspected of being the source of the oil [21].

3.2 Coordinated Extended Pollution Control Operations

CEPCO activities are additional aerial surveillance activities where neighbouring countries, not necessarily Bonn Agreement countries, agree to cooperate to conduct intensive surveys in areas of high traffic density during a relatively short period (e.g. 24 h) or over a longer period (one week for a SuperCEPCO).

In 2000 six countries conducted CEPCO activities (Belgium, France, Germany, the Netherlands, Sweden and the UK). A total of 18 flights took place (7 by France) lasting a total of 45.5 h. Only nine slicks were observed (seven in daylight, two at night), one of which came from a rig in the German zone and one each from ships in German and Swedish zones [21, 22]. Generally, low numbers of flights, flight hours, observed and confirmed slicks and the source of slicks were apparent in all but one year between 2001 and 2013. 2007 had the highest number of CEPCO flights (73) and flight hours (208) with 35 slicks observed (1 at night). However, only five polluters were identified (all ships) from that year's activities. There were no CEPCO flights at all in 2003 or 2011.

An example of a SuperCEPCO was one organised between France and the UK, which took place from 12–18 October 2010 [23]. After nearly 107 flight hours, split 55.4 h during daylight and 51.2 h during darkness, only two slicks were observed (one each in daylight and darkness). One slick was confirmed as a mineral oil spill of unknown origin, with an estimated volume of 2.13 m^3. A similar exercise from 10 to 14 September 2012 between France and Spain (a non-Bonn Agreement country) saw six aircraft from five countries undertaking 42.7 flight hours (19.4 h during night-time). One slick was observed during daylight and confirmed as oil. The source of that slick, estimated at only 0.9 m^3, was unknown [7].

3.3 Tour d'Horizon (TdH) Flights

Tour d'Horizon flights are conducted specifically to monitor offshore oil and gas installations located within the zone of responsibility of each Contracting Party. Patrol flights are arranged by the individual countries and cover predetermined routes.

Since 2003 additional data has been provided as a separate Annex (Annex II) in the annual aerial surveillance reports on the results of TdH flights [24]. That includes information on when flights took place and on flight routes, for example. It also includes summary results by country and presents: a breakdown by month, date and time, the position (latitude and longitude) and the quantity of oil (approximate amount) for observed spills; and, where it is know, the identity of the polluter is also included. This can be a rig, a ship or unknown (see Sect. 4.3). The additional data may also include some remarks about the nature of the sighting. Finally, a Detection Investigation Summary is also provided in the reports and includes a Government Inspector Assessment of the pollution incident and remarks about what action, if any, was taken; including legal action.

3.4 Satellite Surveillance Programmes

Remote sensing of oil and other harmful substances entering the North Sea had, until 2002, only been reported on from aerial surveillance activities. Since 2003, however, remote sensing from satellite surveillance activities has also been reported in the Bonn Agreement annual reports. As noted in Sect. 1, the UK has relied solely on satellite imagery provided through EMSA CleanSeaNet [19] as a source of first alerts of oil slicks in its zone of responsibility.

There are a number of early examples of the use of satellite programmes. In 2003, for example, the Admiral Danish Fleet HQ received approximately 100 satellite pictures while the Norwegian Coastal Administration (NCA) supported a national satellite programme called SATHAV. In the latter case, the Norwegian Space Agency had a long-term agreement to use Canadian RADARSAT images for the Norwegian Exclusive Economic Zone (EEZ). The NCA used satellite images between September and end of December 2013 for oil spill monitoring purposes and also for military ship detection [24]. Between 2003 and 2006, Germany was a partner in an EU programme called OCEANIDES which, for example, developed tools for monitoring illicit marine oil discharges by advances in satellite image processing techniques [25].

In 2004, Sweden established a satellite programme and received over 150 satellite images covering both its North Sea and Baltic Sea areas [26] for a number of years thereafter. From 2004, the UK was involved in a tripartite satellite surveillance programme with Germany and the Netherlands using ENVISAT earth observation data provided by the European Space Agency (ESA)[1] and also RADARSAT images.

The EMSA CleanSeaNet [19] service was launched in April 2007. This service provided near real-time radar satellite imagery from RADARSAT and ENVISAT SAR satellites. CSN was available free of charge to all Coastal States in the EU and covered all European Sea Areas. 275 satellite scenes were provided for the North Sea region for marine pollution monitoring purposes [27]. North Sea CSN Service statistics have formed Annex IV of the Bonn Agreement surveillance reports since the report for 2009 when it delivered 326 images [28].

The Annex IV data includes the number of images delivered each month, together with information on CSN detections, and those detections checked and confirmed as being oil spills by member states. In 2013 there were 601 images delivered, 814 possible spills detected, 168 possible spills checked (21%), and 20 spills were confirmed as mineral oil [7].

4 Bonn Agreement Data on Oil Inputs from Shipping and Oil Platforms

This section examines the findings of the Bonn Agreement aerial surveillance programme between 1986 and 2013. The figures and tables in this section have been compiled using data from the Bonn Agreement aerial surveillance reports for those years and included all types of aerial surveillance activities, i.e. national flights, CEPCO flights and Tour d'Horizon (TdH) flights. It also examines the use of data obtained from satellite surveillance activities since 2003.

4.1 Observed Slicks in the North Sea from All Sources, 1986–2013

Figure 5 illustrates the level of aerial surveillance activity and number of observed spills for the period 1986–2013. That data has, since 1992, included identification

[1] See https://earth.esa.int/web/guest/missions/esa-operational-eo-missions/envisat for further information on the ENVISAT programme.

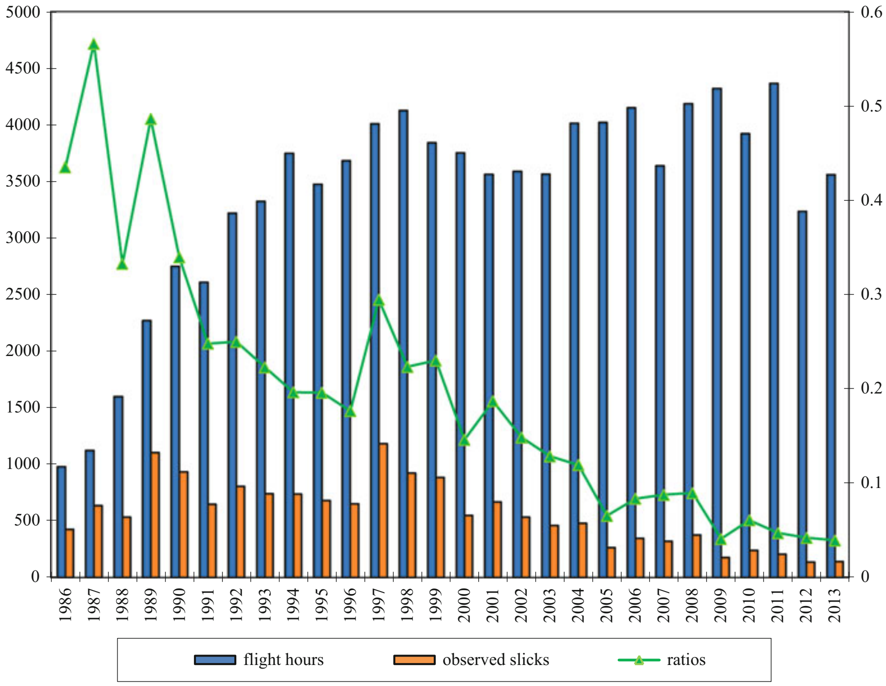


Fig. 5 Bonn Agreement aerial surveillance data for all North Sea countries, 1986–2013. *Notes*: Fig. 5 only includes observed slicks that are confirmed as mineral oil – since 2012 the Bonn Agreement has also reported slicks confirmed as being other substances. The number of flight hours and observed slicks is shown on the *left*, the ratio of slicks to flight hours on the *right*

of slicks during the hours of darkness, the result of improvements in technology on board surveillance aircraft, for example.

Figure 5 also illustrates the marked decline in the actual number of observed slicks over the 27 years for which data is available. From a high of 1,104 slicks in 1990 (and a further high of 1,181 in 1997), the number of slicks fell to 140 in 2013. During the same period, the number of flight hours rose from 977 in 1986 to a peak of 4,366 in 2011. As noted in the introduction, since 2012, the UK has mainly used satellite imagery, and this is reflected in the fall in total flight hours across the eight North Sea countries (3,235 h in 2012 and 3,558.6 in 2013).

In respect of the ratio of slicks to flight hours, i.e. how many slicks were observed for every hour of flying time, this has fallen from a high of 0.57 (just over one slick every half an hour) in 1991 to 0.04 (approximately one slick for every 25 h of flying time).

Until 2003 the number of spills reported both by country and as a total for all eight countries was the number of spills observed, without any confirmation of the type of spill. A spill may therefore have been an oily sheen on the water surface from an algal bloom, some type of weather phenomenon, or from another type of oil such as cooking oil. Since 2003 the figures provided in Bonn Agreement annual reports are confirmed mineral oil slicks, and, from that year on, only confirmed mineral oil slicks appear in Fig. 5.

As an example of the difference made by confirming the nature of a slick, in 2003 there were 458 confirmed slicks across the North Sea compared to 592 slicks prior to confirmation. Also in 2003, there were 290 detections from flights out of the Netherlands, but only 191 of those were confirmed as mineral oil [24].

4.2 *Results from Satellite Imagery Post-2004*

As noted at Sect. 3.4, since 2004 satellite imagery has also been used to identify slicks (mineral oil and other substances), and, since 2009, EMSA CSN data has been reported at Annex IV of the Bonn Agreement annual reports. The data provided at Annex IV includes the number of images delivered each month, together with information on CSN detections, and those detections checked and confirmed as being oil spills by member states. In 2013 there were 601 images delivered, 814 possible spills detected, 168 possible spills checked (21%), and 20 spills were confirmed as mineral oil [7].

Table 1 compares the number of spills detected using satellite imagery between 2004 and 2013 against those detected using aerial surveillance. It shows the proportion of oil slicks confirmed as being mineral oil in those years from both types of data.

In Table 1 it is apparent that a higher proportion of slicks observed using aerial surveillance are confirmed as being mineral oil: less than 20% for satellite

Table 1 Confirmed spills from satellite imagery and aerial surveillance, 2004–2013

	Satellite imagery data			Aerial surveillance data		
Year	Spills detected	Confirmed mineral oil	% Confirmed	Spills detected	Confirmed mineral oil	% Confirmed
2004	378	46	12.17	540	429	79.44
2005	399	28	7.02	386	257	66.58
2006	407	86	21.13	478	347	72.59
2007	280	43	15.36	459	319	69.50
2008	700	90	12.86	559	375	67.08
2009	247	42	17.00	414	177	42.75
2010	411	29	7.06	414	238	57.49
2011	422	25	5.92	389	206	52.96
2012	509	31	6.09	227	136	59.91
2013	631	24	3.80	333	140	42.04

Source: Bonn Agreement annual reports for 2004–2013 (2008 to 2013 annual reports were, at the time of writing, available from the Bonn Agreement Secretariat at http://www.bonnagreement.org/publications; reports for earlier years are available by writing to the Bonn Agreement Secretariat) detections in all but 2006 and more than 50% and as high as 80% for aerial detections in all years except 2009 and 2013.

With improvements in technology and the introduction of satellite imagery, it can be assumed that a higher number of slicks are being captured by all the surveillance activities. It can also be assumed that intentional oil spills are now less likely to occur than they were prior improved night-time surveillance and satellite observations. Where ship operators may previously have chosen to intentionally discharge oil into the North Sea during the hours of darkness, the risk of an oil slick being identified and tracked back to a ship has also been improved as a result of technological improvements and the introduction of satellite surveillance activities.

4.3 Sources of Oil Spills

The Bonn Agreement Secretariat has, since 1997, provided specific information on the source of oil spills, i.e. identifying whether they come from ships, from oil platforms or from unknown sources. Figure 6 illustrates that the number of slicks confirmed as coming from either rigs or ships during the period 1997 to 2013 is

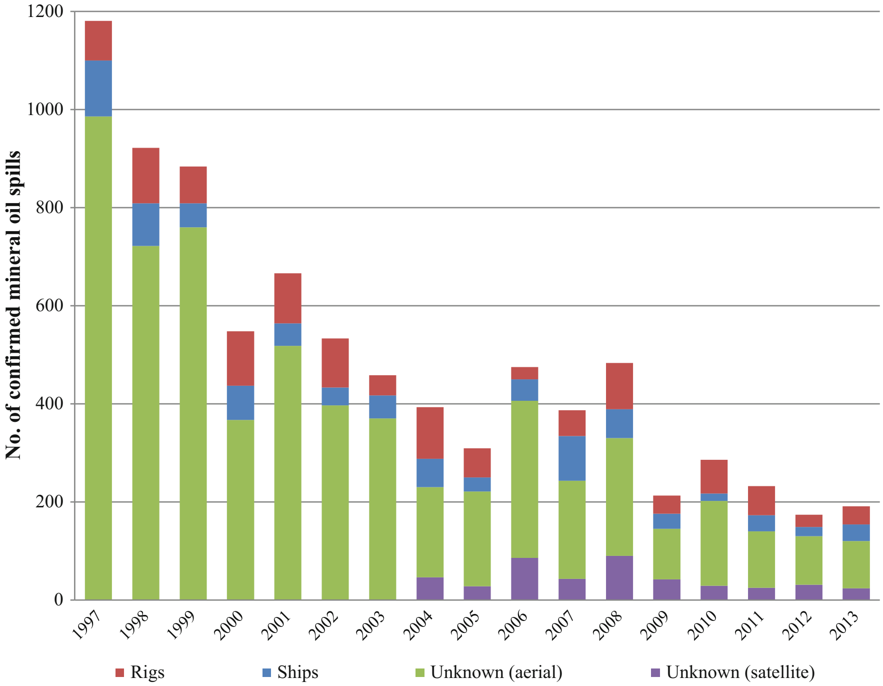


Fig. 6 Source of confirmed oil slicks from all sources, 1997–2013

quite low as a proportion of all confirmed mineral oil slicks. In 1987 there were 81 confirmed spills from rigs, 114 from ships and 986 of unknown source. By 2013, those numbers had fallen to 37 confirmed spills from rigs, 34 from ships, 96 from unknown sources using aerial surveillance data and a further 24 from unknown sources using satellite data.

The source of the majority of slicks remains unknown, even with the addition of satellite imagery from 2004 onwards. Figure 6 does, however, reinforce the fact that the total number of confirmed mineral oil slicks has continued to fall in the North Sea over many years.

Considering specifically those slicks that were confirmed as coming from oil and gas installations, Bonn Agreement TdH flights are one of the main sources of that information. Figure 7 presents data on the number of confirmed spills from rigs for seven countries between 1992 and 2013. France is excluded from Fig. 7 as it has no oil installations in its zone of responsibility. While France did undertake some TdH flights during some of the years, it reported only a single confirmed spill from an unknown source in 2005.

1992 saw the highest number of observed slicks from TdH flights with 121 slicks across the North Sea and 116 in UK waters. In subsequent years, the total number of observed slicks was 59 or less and, between 2003 and 2013, was less than 10 in 6 of those years. Apart from in 1992 there have been 9 or less spills in UK waters in the years where TdH flights took place, and no pollution was reported in many of those years. From 1993 onwards, the highest number of observed and confirmed slicks from rigs was generally located in Netherlands waters, the only exception being in 2001 when Belgium reported 22 slicks and the Netherlands 19 slicks.

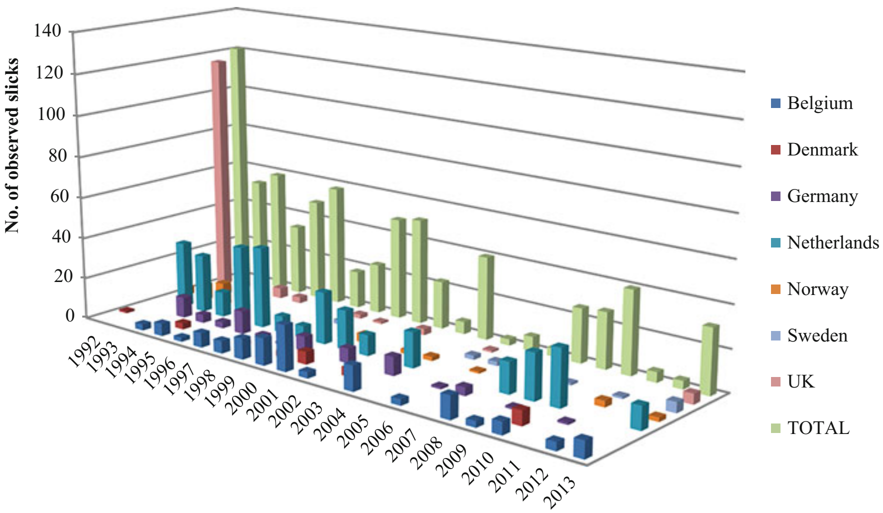


Fig. 7 Bonn Agreement Tour d'Horizon data on rigs as the source of observed slicks

Over time the reported data has provided more information on slicks from other sources observed during TdH flights. For example, since 1998 the reports have included ship-source slicks. Between 1998 and 2013, there were 8 years where additional slicks were observed and identified as coming from ships (e.g. 5 in 2000, 1 in 2003 and 4 in 2012) and 8 years where there were no observed slicks from ships. Since 2004, the TdH data has also included confirmed slicks from unknown sources. There were 9 such slicks in 2004 (8 in German waters, 1 in Belgian waters) and 15 in 2005 (e.g. spread across 6 countries with 5 in Netherlands waters and 4 in Danish waters).

5 OSPAR Monitoring Data on Oil Inputs from the Offshore Oil and Gas Industry

The majority of oil and gas installations in the OSPAR Maritime Area (see Fig. 1) are located in OSPAR Region II – the Greater North Sea, as illustrated in Fig. 2. For example, between 1990–1992 and 1996–1998 the number of platforms in the region increased from 300 to 475 and oil production doubled in the region for that same period. Geographically, major oil deposits were being exploited in the northern part of the North Sea in the Norwegian and UK sectors, while gas deposits were exploited mainly in the shallower southern regions in the UK, in the Danish and Dutch sectors and in shallower Norwegian waters [29].

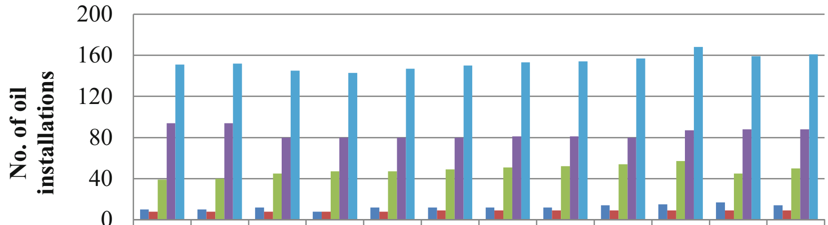
Figure 8a, b shows the number of oil and gas production installations in the North Sea between 2001 and 2012. Figure 8a, b includes only oil and gas platforms in production (including those where drilling is still ongoing). They exclude subsea installations, exploration and development drilling rigs with no simultaneous production and other facilities such as offshore underground storage and loading buoys. Denmark has no gas installations and therefore does not appear in Fig. 8b.

5.1 Oil Production in the North Sea

While oil production in the North Sea region doubled in the period 1990–1992 and 1996–1998, figures for total production of hydrocarbons (both oil and gas in total oil equivalents – toeqs) since 2001 show that there was a fall in production of almost 44% for the period 2001–2012. Figure 9 illustrates that total combined production figures for Denmark, the Netherlands, Norway and the UK fell from just over 513 million toeqs in 2001 to just over 290 million toeqs in 2012, and there are also fluctuations for each individual country.

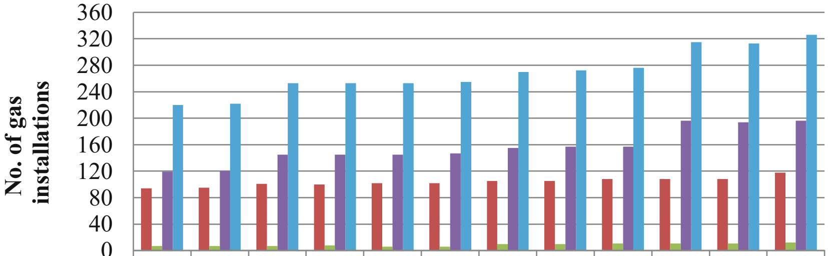
Looking at each country in Fig. 9 individually, annual production in the Danish sector was less than 30 million toeqs during the period 2001–2012, falling to 16.29 million toeqs in 2012. Dutch production figures were less than 25 million toeqs in

a)



	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
DK	10	10	12	8	12	12	12	12	14	15	17	14
NL	8	8	8	8	8	9	9	9	9	9	9	9
NO	39	40	45	47	47	49	51	52	54	57	45	50
UK	94	94	80	80	80	80	81	81	80	87	88	88
Total	151	152	145	143	147	150	153	154	157	168	159	161

(b)



	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
NL	94	95	101	100	102	102	105	105	108	108	108	118
NO	7	7	7	8	6	6	10	10	11	11	11	12
UK	119	120	145	145	145	147	155	157	157	196	194	196
Total	220	222	253	253	253	255	270	272	276	315	313	326

Fig. 8 Number of oil and gas production installations in the North Sea with emissions and discharges covered by OSPAR measures, 2001–2012. (**a**) Oil installations; (**b**) gas installations

all years and were 17.15 million in 2012. Both Norway and the UK have seen a large drop in production, Norway from a high of 264.6 million toeqs in 2004 to 170.5 in 2012 and the UK from a high of 211 million toeqs in 2001 to less than 86.5 million toeqs in 2012.

Overall, combining the production figures for the four North Sea states, there has been a fall from over half a billion toeq produced in 2001 to just over 290 million toeqs in 2012 (a fall of almost 42% in just over a decade).

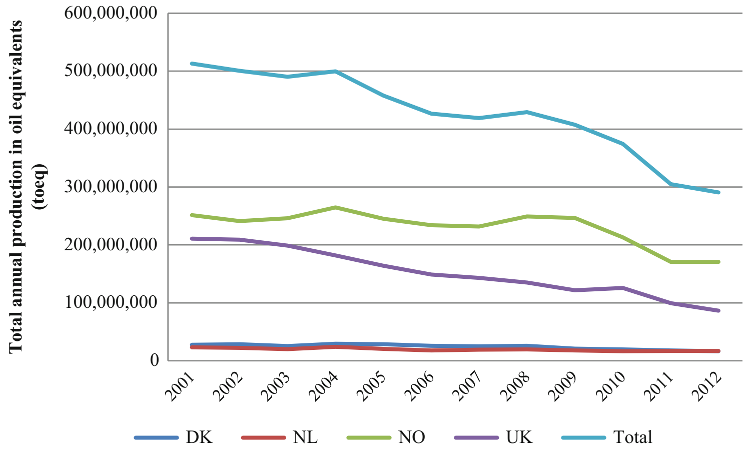


Fig. 9 Total annual production in total oil equivalents (toeqs) for the North Sea, 2001–2012

5.2 Discharges, Spills and Emissions from Offshore Oil and Gas Installations

A broad range of information is provided via OSPAR Commission reports on discharges, spills and emissions from offshore oil and gas installations to the North Sea.[2] That information includes: the name of the installation, quantities of water discharged during the year, annual average oil content and total amount of oil discharges (tonnes per year). Other information set out in the reports includes: discharges of oil-based fluids in cuttings either discharged to the sea or injected into disposal wells, volumes of produced water (PW) and displacement water (DW) discharged to the sea and the number of accidental spills together with the quantity of oil spilled.

5.2.1 Discharges via Cuttings

OSPAR data for the period 1984 to 1999 [30] identified the main source of oil discharges in the region as being via cuttings. In 1984 over 88% of total discharges in the Danish, Dutch, Norwegian and UK sectors came from cuttings. The UK had the highest proportion at 92.7%. Less than 8% of total discharges came from production water in those same sectors in 1984. By 1997, only the UK had

[2] OSPAR Commission reports on discharges, spills and emissions from offshore oil and gas installations are available at http://www.ospar.org/v_publications/browse.asp?menu=00080800000000_000000_000000 (select "search series" and "Offshore Oil and Gas Industry"). Reports are available for the years 1988–1989, 2000–2001 and then annually from 2002.

discharges of cuttings accounting for more than half of the total discharges in its sector (52%), while the figure for Denmark was 18%, and for the Netherlands and Norway was 0% [30].

No oil-based mud-contaminated cuttings (fluids containing low aromatic and paraffinic oils together with mineral oil-based fluids that are neither synthetic or of a class that is prohibited) have been discharged since 1996. Furthermore, almost no organic-phase drilling fluids (OPFs – see Sect. 2.3) and cuttings have been discharged since 2004 [31]. In that year 425 tonnes of oil and other OPFs were discharged via cuttings from Norwegian installations, down from a figure of 3,951 tonnes discharged by Norwegian and UK installations in 2000. From 2005 to 2008, there were zero discharges of cuttings to the sea after treatment.

More recently, in 2009, the UK released 0.3 tonnes of OPF to the sea in treated cuttings. That amount is tiny when compared to the amount of OPF cuttings injected. For example, Denmark injected 1,344 tonnes into disposal wells that year, Norway 26,937 tonnes and the UK 11,560 tonnes. By far the greatest amount of OPF cuttings were transported to shore for treatment and/or disposal. In 2009, Denmark transported 7,880 tonnes to shore, the Netherlands 15,381 tonnes, Norway 39,072 tonnes and the UK 35,101 tonnes. Therefore, in 2009, only 0.3 tonnes of OPF cuttings were discharged to the North Sea, 57,745 tonnes were injected into disposal wells, and 97,434 tonnes were transported to the shore [31].

Between 2010 and 2012, discharges to the sea from UK installations amounted to 1 tonne in 2010, 4 tonnes in 2011 and 5 tonnes in 2012 [32–34]. As noted at Sect. 2.3, authorisation would have been required from the competent UK national authority, under Decision 2000/3 [17], to allow those discharges to take place.

5.2.2 Discharges via Produced Water and Displacement Water

Since the early 2000s, the main sources of oil inputs to the sea have been inputs via PW and DW (see Figs. 10 and 11), together with accidental discharges (see Fig. 12a, b and Sect. 5.2.3). As noted in Sect. 2, PW is a by-product of oil and gas production operations and includes formation water, condensation water and reproduced injection water. DW is seawater used for ballasting the storage tanks of offshore installations so that, when oil is loaded into those tanks, the water is displaced and discharged to the sea.

Figure 10 illustrates the quantity of water discharged annually to the marine environment via PW and DW, together with volumes of PW injected back into the reservoir to increase pressure and stimulate increased yields and/or continued production from ageing oil fields. It also includes a combined figure for PW discharged and PW injected.

The volumes of PW and DW being discharged to the sea both declined during the period 2001–2012. The volume of PW fell from almost 400 million m^3 of PW in 2001 (high of 423 million m^3 in 2004) to 318.48 million m^3 in 2012 (a fall of almost 25% between 2004 and 2012). The volume of DW also fell from 67.75 million m^3 in 2001 to 34.4 million m^3 in 2012 (a fall of nearly 50%). During the same period,

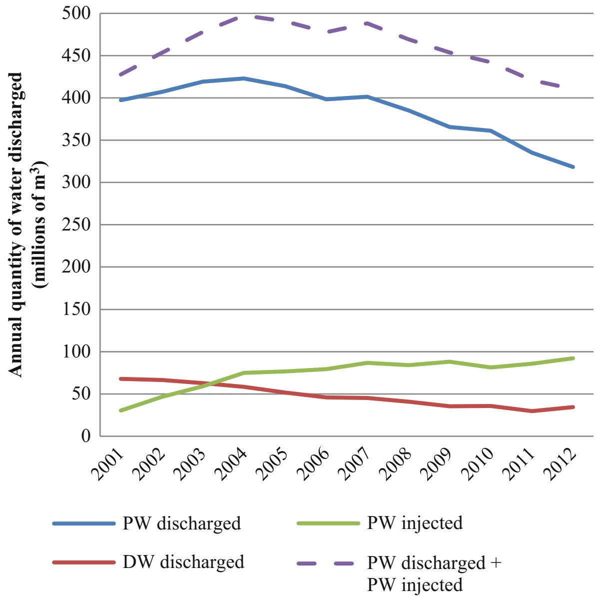


Fig. 10 Annual quantities of produced water and displacement water discharged to the North Sea and produced water injected, 2001–2012

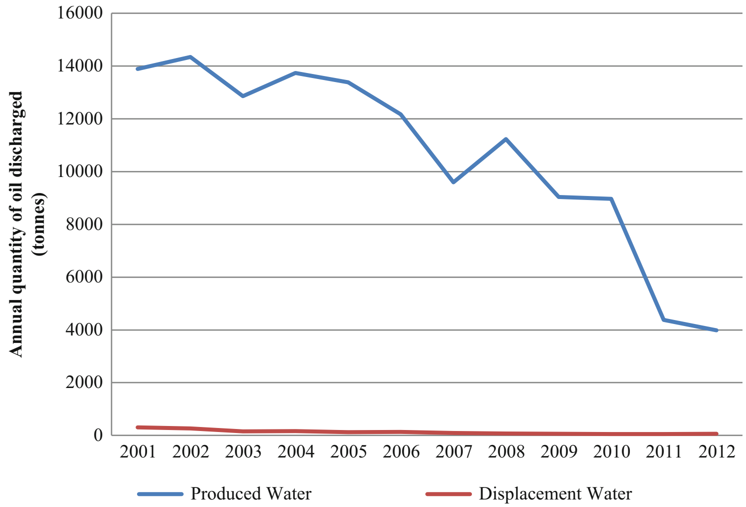
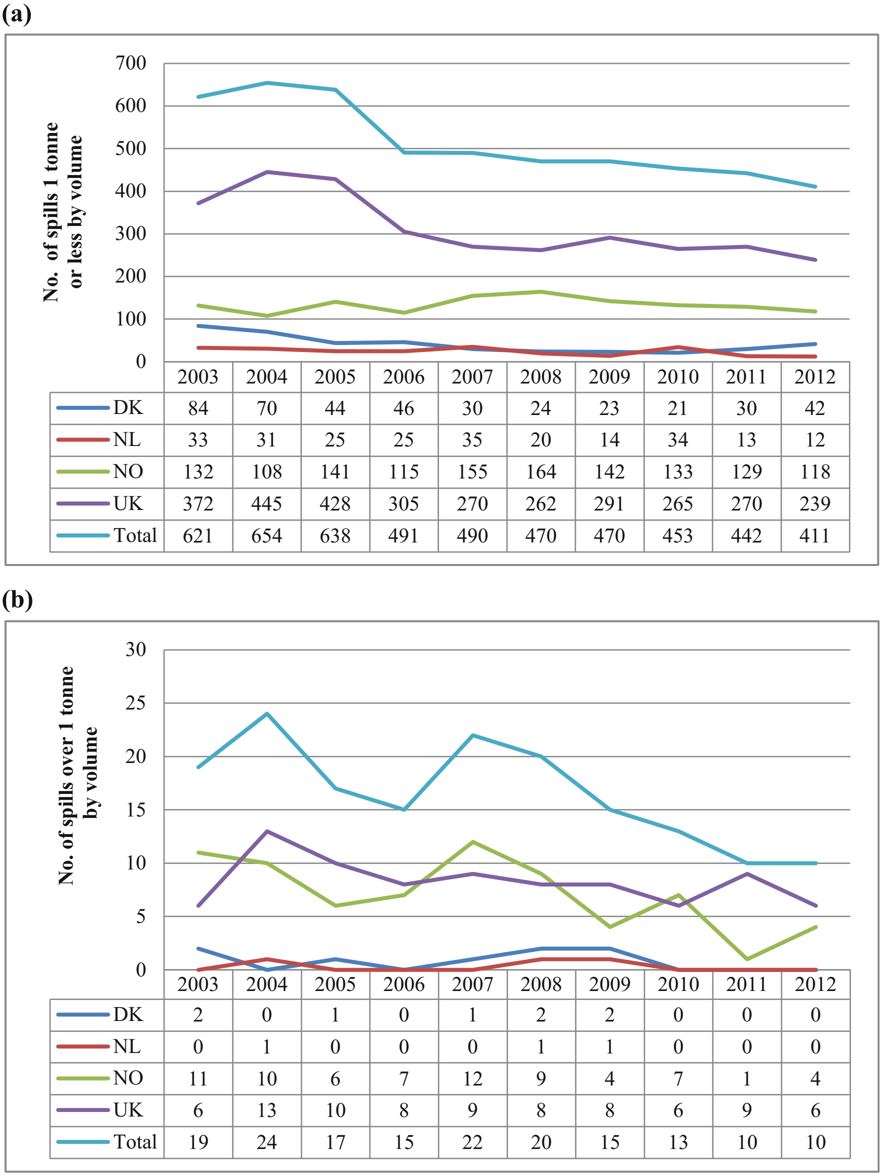


Fig. 11 Annual quantity of oil (in tonnes) discharged via produced water and displacement water, 2001–2012



(a)

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
DK	84	70	44	46	30	24	23	21	30	42
NL	33	31	25	25	35	20	14	34	13	12
NO	132	108	141	115	155	164	142	133	129	118
UK	372	445	428	305	270	262	291	265	270	239
Total	621	654	638	491	490	470	470	453	442	411

(b)

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
DK	2	0	1	0	1	2	2	0	0	0
NL	0	1	0	0	0	1	1	0	0	0
NO	11	10	6	7	12	9	4	7	1	4
UK	6	13	10	8	9	8	8	6	9	6
Total	19	24	17	15	22	20	15	13	10	10

Fig. 12 Accidental spillages of oil in the North Sea from oil and gas installations, 2003–2012. (**a**) Number of oil spills 1 tonne or less by volume; (**b**) number of oil spills greater than 1 tonne by volume

the amount of PW which has been injected grew from 30.27 million m^3 in 2001 to 92.13 million m^3 in 2012 (an increase of over 300%).

The dashed line in Fig. 10 shows the combined totals for PW discharged to the sea and injected back into the reservoir. In 2001 the combined amount was 427.6 million m^3, while in 2012 it was 410.61 million m^3. The figure for combined discharged and injected PW in 2012 is 96% of that for 2001, indicating that there has been a move away from discharging PW into the sea to injecting PW back into the reservoir.

Between 2001 and 2012, the quantity of oil (in tonnes) being discharged from installations via PW and DW to the sea also fell (see Fig. 11). The quantity of oil discharged in PW fell from 13,892 tonnes in 2001 (14,345.5 in 2002) to 3,990 tonnes in 2012. The amount of oil discharged in PW in 2012 was therefore less than 30% of the figure for 2001. In the case of DW, the fall in the quantity of oil was from 262.6 tonnes in 2001 to 61.4 tonnes in 2012, with the volume in 2012 being slightly less than 20% of that for 2001.

5.2.3 Accidental Oil Spillages from Oil and Gas Installations

Figure 12a, b illustrates that the majority of accidental oil spills are one tonne or less by volume. In 2003 there were 621 spills of that size across the four North Sea countries and only 19 spills greater than 1 tonne by volume. In all years from 2003 to 2012, the vast majority of spills occur in the Norwegian and UK sectors, with around 60% of all spills in UK waters during that period (closer to 70% in 2004 and 2005). Accidental spillages are, by their very nature, unpredictable. Less than 5% of total oil discharges entering the North Sea came from accidental spills between 1999 and 2012, with the exception of 2007 when a single large oil spill from a Norwegian installation accounted for around 40% of total oil discharged in that year [31].

As noted at Sect. 4.3, the number of mineral oil spills identified by Bonn Agreement aerial surveillance activities has declined in the North Sea over many years. Those surveillance activities include monitoring the areas around oil and gas installations under Bonn Tour d'Horizon flights (see Sect. 3.3). That reduction over time is also apparent in the OSPAR data, with accidental oil spills having from oil and gas installations having fallen by around one third between 2004 and 2012.

5.3 Installations Exceeding OSPAR Performance Standards

OSPAR annual reports on discharges, spills and emissions from offshore installations exceeding the OSPAR 40 mg/L performance standard for dispersed oil between 2000 and 2006, subsequently 30 mg/L from 2007 [35] (see Fig. 13a). OSPAR also provides cumulative data on the total amount of oil discharged from those installations exceeding that performance standard (see Fig. 13b).

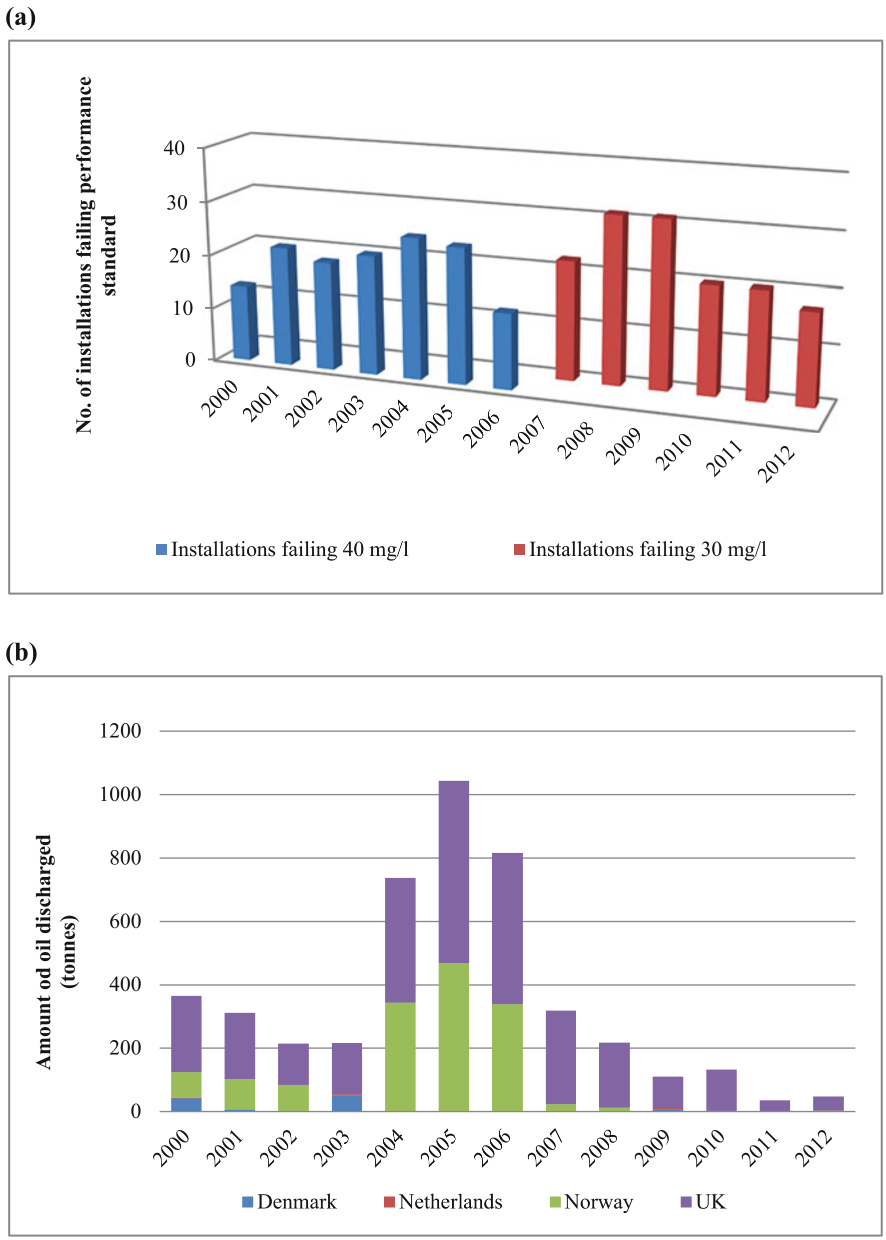


Fig. 13 Installations exceeding OSPAR Recommendation 2001/1 targets and amount of oil discharged (tonnes), 2000–2012. (**a**) Number of installations exceeding the 40 mg/L discharge target, 2001–2006; number of installations exceeding the 30 mg/L discharge target, 2007–2012. (**b**) Amount of oil discharged over 40 mg/L standard (tonnes), 2000–2006; amount of oil discharged over 30 mg/L standard (tonnes), 2007–2012

Samples of discharges of dispersed oil in PW are collected from both manned and unmanned installations. In the case of manned installations, a minimum of 16 samples are taken each month, from a point "immediately after the last item of treatment equipment in, or downstream of, a turbulent region, and . . . before any subsequent dilution" [2001/1 consolidated text]. Samples have, since 2007, been analysed using chromatography (GC) to measure oil concentration in samples [16]; prior to that, the analysis method used infrared detection (IR).

Data on the number of installations exceeding the OSPAR performance standard shows that, in 2001, there were 22 installations which failed to achieve the 40 mg/L standard (out of 151 oil installations and 220 gas installations), resulting in a discharge of approximately 312 tonnes of dispersed oil in PW to the sea in that year [36]. Eighteen of those failing installations were gas installations (15 UK, 3 Dutch), and four were oil installations (1 Danish, 1 UK and 2 Norwegian).

By 2012, under the stricter 30 mg/L standard, only 17 installations failed to achieve that standard, releasing 47.44 tonnes of dispersed oil in PW in that year [34]. Six out of the 17 were oil installations (1 Danish, 2 Dutch and 3 UK), while the remaining 11 were gas installations (1 Norwegian, 1 Dutch and 9 UK).

Overall, it is apparent that far fewer installations are failing the performance standard for discharges in PW, despite those standards having been made stricter. It also appears that gas installations are more likely to exceed the performance standard upon closer examination of OSPAR annual reports. What is clear is that far less oil is entering the marine environment of the North Sea from oil installations in discharges of PW.

6 Conclusions

This chapter has examined trends in the level of oil being discharged to the North Sea in general and in particular inputs from oil and gas installations. The majority of those installations are located in the waters of four countries – Denmark, the Netherlands, Norway and the UK. In the case of oil and gas production, the majority of such activities in the region have been located in the waters of Norway and the UK. Two bodies are responsible for monitoring the North Sea region, the OSPAR Commission (which also monitors the wider North-East Atlantic) and the Bonn Agreement Secretariat.

An overview of all inputs to the North Sea, using Bonn Agreement aerial surveillance data, shows that the number of observed and confirmed oil slicks in the region – from both ships and oil and gas installations – has fallen over a period of nearly three decades. Increased surveillance activities through aerial surveillance, and more latterly satellite imagery, shows that the number of oil slicks fell from around one slick for every hour of surveillance flights in 1991 to around one slick for every 25 h of flying time in 2013.

The introduction of surveillance activities during the hours of darkness, and the use of satellite imagery, has resulted in improvements in identifying the source of slicks and may act as a deterrent for ships that might previously have discharged oil to the sea at night or in more remote areas of the North Sea. Bonn Agreement surveillance activities have also been specifically targeted to monitor discharges from oil and gas installations (see Sect. 3.3) and support the work programme of the OSPAR Commission specifically related to the oil and gas industry.

The OSPAR Commission has in place a number of performance measures and targets against which oil and gas installations have to perform. For example, there are measures in place setting maximum permissible levels of oil in discharges from produced water [13] and from organic-phase drilling fluids (OPFs) and contaminated cuttings [17], together with agreed levels of sampling and methods of analysis [16].

Based on data reported annually by the OSPAR Commission, it is apparent that while the number of oil and gas installations in the North Sea has increased over the last decade, total annual production fell by almost 44% between 2001 and 2012. Many of the oil fields located in the North Sea are ageing, making it harder to extract oil and gas. One result of this has been increased reinjection of produced water back into the reservoir to increase pressure and improve yields from those fields. A further result has been that less produced water is discharged to the sea, while stricter standards on permissible levels of oil in that discharged water have resulted in less oil being discharged – down from 13,892 tonnes in 2001 to 3,990 tonnes in 2012, a fall of 70% [34].

Cuttings were the major source of oil entering the marine environment of the North Sea between 1984 and 1999 [30]. However, stricter standards, changes in drilling fluids, increased levels of injection of OPF cuttings into disposal wells and most significantly the vast majority of cuttings being transported to shore for treatment and/or disposal mean that virtually no oil enters the North Sea from that source. In 2012 only 5 tonnes were discharged to the North Sea [34] compared to 3,951 tonnes in 2000 [31], and special permission has to be sought from the competent national authority before any such discharges can be made.

Accidental spillages from oil and gas installations continue to occur. However, the number of total spills has fallen by around one third between 2003 and 2012 [34]. Less than 5% of accidental oil discharges to the North Sea come from oil and gas installations [31].

Overall, based on both Bonn Agreement Secretariat and OSPAR Commission data, it is clear that the levels of oil entering the North Sea from oil and gas installations has fallen in recent years. Continued monitoring, sampling against agreed standards and the use of best available techniques and best environmental practice and consideration of the environmental and economic impacts of the activities of installations should lead to further reductions in discharges from installations in the future.

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Oil Spill Sampling and the Bonn-Oil Spill Identification Network: A Common Method for Oil Spill Identification

Gerhard Dahlmann and Paul Kienhuis

Abstract This contribution describes the development and some highlights of the internationally agreed standard procedure CEN/TR 15522–2:2012: "Oil spill identification – Waterborne petroleum and petroleum products – Part 2: Analytical methodology and interpretation of results based on GC-FID and GC-MS low resolution analyses" [1]. In particular, handling of changes caused by weathering of spilled oil is described here: PW plots (partial weathering plots) allow a proper and unequivocal identification of oil, despite those changes. CEN/TR 15522–2:2012 has been produced by Bonn-OSINet (Oil Spill Identification Network of experts within the Bonn Agreement). Researchers from all over the world have cooperated and contributed to its development. This method has been continuously improved and tested over the last decade. Cooperation of laboratories culminated in COSIweb (Computerized Oil Spill Identification), an online program which includes a huge database of more than 2,200 oil samples at the time of writing and an automatic evaluation system. This web-based resource provides the possibility to handle raw data produced anywhere in the world and to evaluate these data as if they were produced in a user's own laboratory.

Keywords Oil Spill Identification Network, Environmental forensics, Oil Spill Weathering, OSINET, Bonn Agreement, COSIweb, Computerized Oil Spill Identification, Web-based

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Contents

1 Introduction

Bonn-OSINet was established in Ostend, Belgium, during one of the Bonn Agreement's annual meetings in 2005. Spilled oil from the "Tricolor", a Norwegian vehicle carrier that sank in the English Channel in 2002, had reached the coasts of Belgium, France, and the Netherlands, and whereas oil strandings were actually expected, laboratories from these countries were not able to prove any connection with the ship's oil, at that stage. High cleaning costs were claimed, and not being able to provide proof that the stranded oil originated from the "Tricolor" resulted in problems with reclaiming the costs of that cleaning.

"No match" was found between source and spill samples. Reasons for this might be wrong combinations of spill and source samples being available for comparison and/or unsufficient experience in oil spill identification. Results could have been much more useful as evidence if labs testing samples had known each other and had cooperated and samples had been exchanged. Thus, the Bonn Agreement decided in 2005 that laboratories involved in oil spill identification in the Bonn Agreement area should cooperate in the future.

It proposed that a forum of Bonn experts on oil spill identification should be created, with Dr. Gerhard Dahlmann (Germany) as convenor. Recommended by the workshop, the aim of the forum was to provide mutual assistance in difficult cases, to promote quality assurance in oil spill identification (especially through ring tests, development of common reference materials (CRMs), and sample exchanges) and consider the possibility of a common database of oil sources [2].

From the very beginning, Bonn-OSINet proved to be very useful because in a new attempt to identify stranded oil in the Tricolor case in 2006, combined sets of spill and comparison samples could be analyzed. While some differences between spill and comparison samples were found, these could without doubt be attributed to the weathering of the spill samples.

Based on the evidence that oil was leaked from the Tricolor, combined now with analytical results of stranded oil, the Netherlands, Belgium, and France received, respectively, 1.8, 2.0, and 0.54 million € from assurance companies in 2007.

Cooperation and mutual assistance might require that all participating laboratories analyze and compare oil samples in the same way. A common method makes such cooperation much easier. The final conclusion about the relation between samples should be as objective as possible. Every participant should be able to trace back every conclusion produced by other laboratories step by step.

1.1 Difficulties in the Development of a New Method

Producing a common method for oil spill identification posed a big challenge, particularly regarding the great variability of oil spill cases, and the many different circumstances, where chemical comparisons of oil samples are required. Publications about chemical investigations in oil spill cases are rare. These are always focused on bigger cases [3–5]. Bigger cases consume more resources, require more time, and allow deeper investigations into the composition and the compositional changes of oil in the environment. Thus, in those cases, analytical errors can be determined more precisely, and even experiments can be made, in order to verify the findings observed on field samples [5].

Modern, so-called "unconventional" statistics, such as pattern recognition or PCA, can only be used for result evaluation in bigger cases, where a large number of samples is taken, and more than one source is suspected [6, 7].

Large oil spill cases occur only rarely. Smaller ones do not generally receive the same level of attention and are also not described in literature. However, hundreds of oil spills are still found every year in European waters, although their numbers have decreased over the last years [8–11].

Participating laboratories had different experiences and preferences: they had worked with different kinds of oil, e.g., crude oils in the oil platform area of the middle and northern North Sea, heavy fuel oils (HFOs) on the highly frequented shipping lanes in the southern North Sea, or light fuel oils in inland waters. In addition, the preconditions in the laboratories varied, as most laboratories had only very few cases per year, where oil samples had to be compared with suspected source samples. In these cases, analytical instruments were mainly used for other purposes, e.g., marine environmental monitoring. These instruments could thus only be used a very limited time, and the analytical parameters had to be changed, when oil samples had to be analyzed.

1.2 Intercalibrations and Participation

Since OSINet was established in 2005, annual ring tests – Round Robins – have been conducted for increasing knowledge and experience of laboratories and for

Table 1 Intercalibrations (Round Robins), number of participants, and main topics

Year	Samples	No. of participants	Topics
2006	Crude oils	13	Recognition of oil type, comparability of data
2007	HFOs	19	Introduction of PW plots, variability of data
2008	Crude oils	23	PW plots for estimation of weathering, variability
2009	Bilge samples	24	Inhomogeneous distributions, mixing of products
2010	Crude oils	25	Evaporation, biological degradation
2011	HFOs	25	Heavy weathering, 10-year-old HFO samples
2012	Crude oils	26	Complexity of Nigerian oils, photooxidation
2013	HFOs	27	"Weathering" within the suspected ship

improving the quality of analytical data. Each Round Robin dealt with different kinds of problems, which appear when spilled oil has to be compared with oil from suspected sources (Table 1). If these problems could not undoubtedly be solved during those tests, further experiments were conducted by different participants for clarification. This often resulted in scientific publications [12–16].

The method has been continuously tested and improved over the last years. Since 2005, the number of OSINet participants has grown from six members of the Bonn Agreement area to about 50 scientists from 27 laboratories from 20 countries all over the world.

Summary reports of the Round Robins can be found on the Bonn Agreement website, section Bonn-OSINet [17].

2 Methodology

2.1 General Principle and GC–FID

The principle of oil spill identification is based on the fact that petroleum consists of many thousands of different organic compounds. It is simply neither practical nor possible to analyze and compare all of them. Therefore OSINet decided to analyze the samples by means of gas chromatography with flame ionization detection (GC–FID) and low-resolution gas chromatography–mass spectrometry coupling (GC–MS), in order to compare the general compound patterns and to measure a range of specified compounds. Both analytical techniques are adequately available in laboratories and are precise enough for a large range of compounds and compound groups.

It is always easier to ascertain what it is not than what it is. Thus, the general concept for comparing oil samples consists of looking for differences. A fuel oil cannot be identical with a lubricating oil, for example. Such a difference can easily be identified by simple GC–FID. Preliminary investigations by GC–FID are thus of great value, where comparison samples are taken from several different compartments of a suspected ship, which contain different types of oil.

Further characteristics of the samples can be identified by GC–FID, such as roughly the concentration of oil in the spill samples, the shape of the "unresolved complex mixture" (UCM), the shape of the envelope of the *n*-alkanes, or the relation of the branched chain alkanes pristane and phytane. If "obvious" differences of samples are detected, even between samples of the same type, investigations may be terminated here.

However, the decision to declare samples as nonmatching should not be made, if there is even the slightest doubt that the samples are not identical. In such cases, samples must be further analyzed using the more complex GC–MS.

One has to keep in mind here that the composition of spill samples may have changed because the reduction of compounds due to weathering begins as soon as oil is released into the environment.

2.2 GC–MS

By means of GC–MS, a great multitude of compounds may be found in oils. Huge collections of oil compounds, proved to be especially useful in bigger oil spill cases, are available in literature [18]. Generally, knowledge about the classification of oils and their differentiation is derived from geochemistry, because information about the source and maturity of detected oil is required in oil exploration [19–21]. Detailed classifications are achieved by means of compound concentrations and relations of compound groups.

Time and resources might always be too limited to determine all compounds, which can be measured. But what are the most important?

Empirically, i.e., gained from field and laboratory experiments, intercalibrations, and oil incidents, where the source oils were known, a minimum set of compounds is chosen, which must be used in every investigation (normative compounds). Since not all compounds are present in every oil type, this set is adapted to the special type of oil involved in a given oil spill incident. Examples of additional compounds which may also be useful are then provided (informative compounds).

Thus, distinct sets of (semi)quantitative concentrations of oil compounds have to be determined and have to be compared between spill samples and samples from suspected sources.

Concentrations are identical, i.e., not discernible, if their differences do not exceed the repeatability limit of the analytical method. If they are all identical, the proof is given that the findings of the visual inspections are actually true, i.e., the samples are identical without any scientific doubt.

In every oil spill case, double measurements are used for verifying the procedure. These repeated measurements are used to find out, whether the precision of the analytical method is adequate, and whether all compounds of the oil involved can actually be determined precisely enough. If not, it is justified to exclude those compounds from the given sets.

2.3 Weathering

When a spill sample is compared with a suspected source sample in this way, however, differences in concentrations of compounds may not only be present due to analytical error.

Differences in compositions may also appear because of weathering processes, contamination, and inhomogeneous distributions of oil. All these problems can even appear at once.

In order to avoid "false-negative" conclusions, the responsible analyst has to be acquainted with these difficulties, and he has to be able to show indisputably that they have not falsified the results. This means that the proof has to be given that every single observed difference is not derived from the fact that spill and suspected source sample consist of different oils. In other words, the proof has to be given that it is possible that a spill originates from a suspected source, despite those differences.

Spilled oil samples and suspected source oil samples can never be identical because the composition of oil changes, as soon as it is released into the environment. Volatile compounds evaporate immediately, for example, and their concentrations decrease rapidly. Correspondingly, the concentrations of less volatile compounds increase. Thus "identity" can no longer be determined. The composition of the oil has changed.

2.4 A Nice Analogy

Sometimes jurists do not follow the argument that differences between spilled oil and suspected source oil are caused by weathering processes. The reason might be that it's not easy to refute an expertise, where "identity" is concluded, and a conclusion like this often does not leave much space for the consideration of evidence. "How can you be sure that the oils were not different from the beginning?" is thus a common question in court trials.

Others even make use of the definition of the word "identity," which means that every measured characteristic of two samples must be the same. A modification of this definition, e.g., "no differences, except those, which are caused by weathering of the spill sample," for example, is simply not accepted.

A good response in this case might be the following analogy: if the sun is shining, and I spend the whole day outside in the sun, my face will have turned red in the evening and might be tanned the next day. Thus, a special characteristic of my person has changed, but I am still the same person.

Weathering processes follow distinct rules, such as a longer stay in the sun will consequently lead to a deeper red color of my face, and effects of evaporation will be more severe, the longer an oil spill stays in the environment. A further parallel can be found with regard to the strength of the irrigation from sunlight.

2.5 *Partial Weathering Plots (PW Plots) and Mere Evaporation*

Generally, lower boiling oil compounds are more affected by evaporation than higher boiling ones, which means that their concentration is more reduced. However "more or less" is a very vague term to use, while actually the proof is needed that a reduction by evaporation has taken place.

The very first steps for presenting this proof are undertaken in the NORDTEST method NTChem001 [22]: PW plots are mentioned here, which may generally show how compounds and compound classes decrease by different weathering processes of the spill sample. Here, their concentrations in the spill sample are plotted against their concentrations in the suspected source sample. Corresponding ratios are given in percentages, and if not affected by weathering processes, all values must fall on a straight 100% line. However, in NTChem001 [22], only a very general description of the PW plots is given, and the compounds, which have to be measured, are not given in detail, nor is there any information given with regard to the analytical uncertainty of the method.

Objectivity is highly increased, when the kind and number of compounds to be used for the PW plots are prescribed. Thus a set of "normative" compounds is given in CEN/TR 15522–2:2012 [1], and all of them have to be determined always and in any case. If a compound of this set is excluded from the PW plot, it has to be explained why, e.g., because it is too low in concentration and/or cannot be measured precisely in repeated measurements. The latter is proved by those PW plots, where double measurements are used. The double analysis of a sample will theoretically result in data points at 100%. In practice, however, inherent variance of the instrument and data handling causes variations around the 100% value (see Fig. 1).

There is not any difference, if semiquantitative values are used here. Practically, and instead of absolute concentrations, it is even more convenient to normalize the concentrations of the compounds on the concentration of a stable, higher boiling

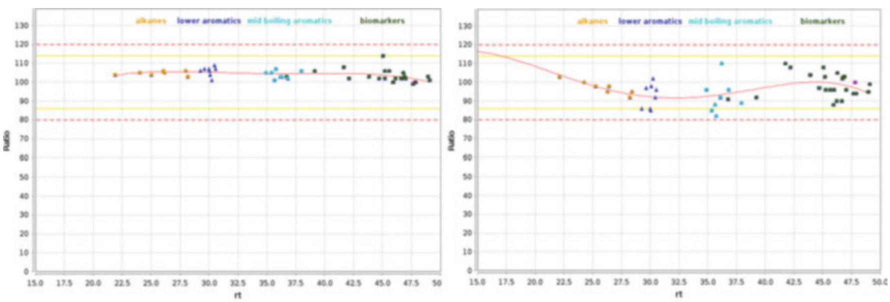

Fig. 1 PW plots of double measurements of the spill sample of RR2013. The standard deviation of the data points in the left graph is 2.8 and in the right graph 7.4

compound, which is not easily affected by weathering processes, e.g., hopane (Eq. 1).

$$\text{Ratio of compounds} = 100^*(\text{s1}/\text{hop1})/(\text{s2}/\text{hop2}), \quad (1)$$

where 1 and 2 correspond to the spill and the suspected source sample, respectively.

Error limits (yellow, ±2 st. dev.; red, ±20% of the ratio) are included, representing the maximal accepted analytical error based on a st. dev. of 7.5% which is allowed in repeated measurements and between the non-weathered part of matching samples. Several Round Robin tests have shown that these limits can normally be reached. The comparison of double measurements is done in the same way as the comparison of a spill with a suspected source sample and forms an integral part of the method.

Concentrations of compounds affected by weathering processes are lower in the spill sample than in the original oil, and the amount of reduction can directly be measured in the PW plots. If the error limits of a compound are exceeded, this has to be explained.

If evaporation is assumed to have caused this reduction, it has to be shown that the amount of reduction of every higher boiling compound corresponds with the amount of reduction of every lower boiling compound.

Compounds evaporate, when their boiling points are exceeded, and when a nonpolar column is used in GC, compounds are mainly separated according to their boiling points.

Based on these principles, simulated distillation by GC is widely used for characterizing oil products in petroleum industry. Consequently, if a spill sample is affected by evaporation, a similar S-shaped evaporation curve must appear, when the concentrations of the oil compounds of the spilled oil, divided by the concentrations of these compounds in the suspected source oil, are plotted against their retention times (see Fig. 2).

One has to keep in mind here that, compared to the ratios produced from compounds detected by the same mass fragment [1], an additional error is introduced. This error is connected with the sensitivity of the MS for different masses. However, sensitivity changes differently with time (that's the reason why instruments must be recalibrated from time to time). Thus, producing MS-PW plots is best feasible on data achieved by consecutive runs. Thus, samples must be analyzed in a batch run.

In Fig. 2, evaporation was tested. Here, it is a fact that sample 6 is derived from source 1 because the samples originate from an experiment: source 1 has been evaporated, which revealed sample 6.

Consequently, in real cases it can be concluded that a spill sample is derived from a suspected source sample, if a PW plot such as given in Fig. 2 is found – without any scientific doubt.

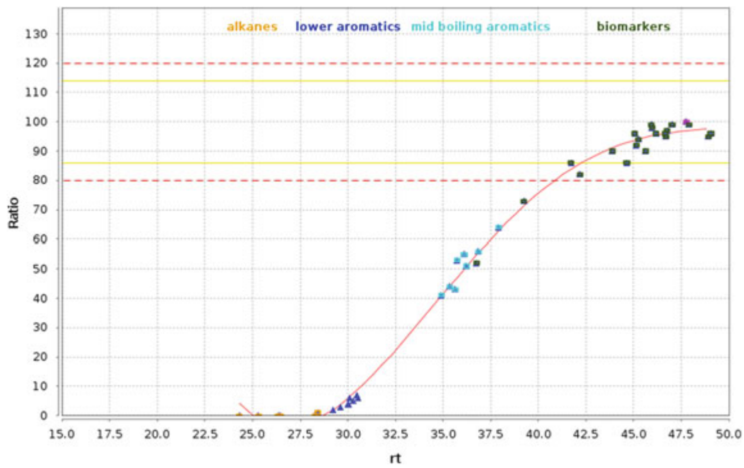

Fig. 2 HFO evaporated/distilled at 400° for 4 h (comparison of sample 6 with sample 1 in Round Robin 2007)

2.6 Additional Weathering Processes

The effects of weathering on oil are cumulative. In the Round Robin test in 2010, a crude oil was artificially biologically degraded: oil spiked with a fertilizer was left on seawater for several weeks.

In Fig. 3 one can clearly find the region of evaporation (area of red columns) and the region of bacterial degradation (purple columns). Whereas the *n*-alkanes are heavily affected by bacterial degradation, the isoprenoids, i.e., norpristane (nor), pristane (pr), and phytane (phy), are not. N-C17, for example, is reduced by about 45% by bacterial degradation and by about 25% by evaporation. The very even reduction of the lower boiling aromatics (*Methyl*-phenanthrenes and *Methyl*-dibenzothiophenes at about 30 min) is mainly caused by dissolution, whereas all higher boiling aromatics and all biomarkers are not affected at all.

In order to avoid oil on beaches, a crude oil spill, which had been discharged from a platform in the Nigerian oilfields, was heavily treated with dispersants. Nevertheless, it can be proved that the oil reached the shore (Round Robin 2012, sample 2). In addition to only weak evaporation and bacterial degradation, merely Methyl-Anthracene (MA) was heavily degraded by about 55% through photooxidation (Fig. 4) (cf. [5]).

It is confirmed that sample 4 from Round Robin 2011 originated from the sunken tanker "Erika" because samples from this site were continuously taken over the years. But the accident had happened more than 10 years ago. Very severe weathering can be seen in the PW plot of Fig. 5: all compounds up to the mid-boiling aromatics have disappeared. In addition, also higher boiling aromatics and even distinct biomarkers are severely affected by dissolution, photooxidation, and even bacterial degradation. In this case, the source was known ("Erika"). In an unknown case, it might be difficult to prove that every reduction, i.e., every

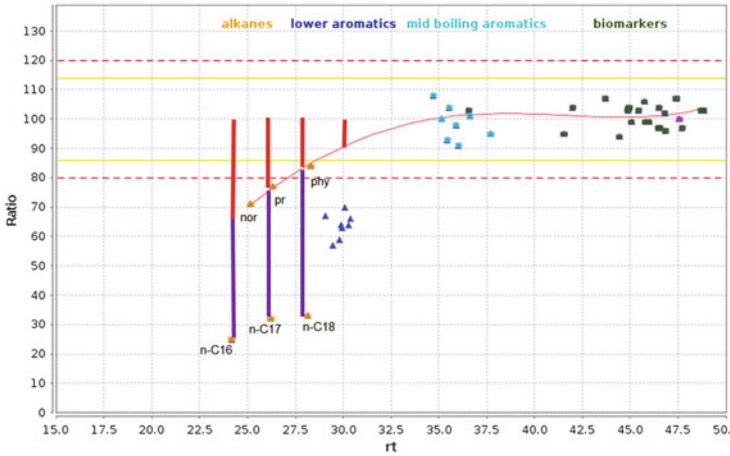

Fig. 3 Spilled crude oil from a fertilizer experiment (comparison of sample 3 with sample 1 in Round Robin 2010)

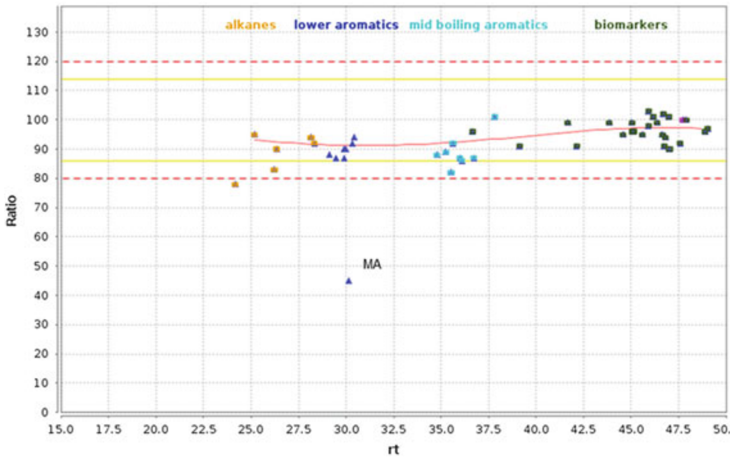

Fig. 4 Identification of spilled crude oil on the Nigerian coast after a bigger accident in the Nigerian offshore fields (sample 3 of Round Robin 2012, MA)

deviation from the 100% line, was caused by weathering effects. Hardly anything can be found in literature about such highly weathered samples and the degradation of biomarkers. All OSINet members agreed that in this case the conclusion should be reduced to a "probable match" because the number of still matching ratios is too low.

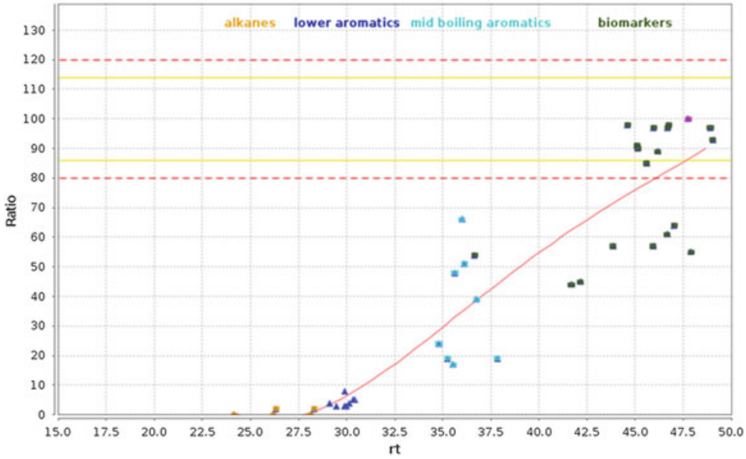

Fig. 5 Identification of spilled HFO from the sunken tanker "Erika" on the French coast more than 10 years after the accident had happened (sample 4 of Round Robin 2011)

2.7 PW Plots with Weathering Indication

For the correct interpretation of weathering, it might be useful to know which of the compounds mentioned in CEN/TR 15522–2:2012 [1] are affected by the different weathering processes. In Table 2, the weathering behavior of these compounds is indicated by stable (very resistant), bio(degradation), solub(ility), and photo(oxidation). Some of the PAHs have no indication. They are not stable enough to be indicated as stable and are also not specifically sensitive for one of the weathering effects.

The information given in Table 2 is used to create PW plots with indication of weathering. An example is shown in Fig. 6. Artificially biodegraded heavy fuel oil (HFO) from the Erika spill (RR2011) is compared with the original HFO. A small amount of oil has been weathered by Cedre (Fr) at room temperature for 2 months on seawater with a fertilizer in the dark in a large open beaker constantly mixed with a magnetic stirrer.

In Fig. 6, a sinus curved evaporation line is drawn through the compounds, indicated as stable in Table 2.

Markers for biodegradation are the *n*-alkanes. These *n*-alkanes have been reduced completely. In the PW plot of Fig. 6, these are represented by C17 and C18 and can be found at about 1% between 25 and 30 min, respectively. The branched alkanes pristane (Pri) and phytane however are more robust against biodegradation and can be found close to the evaporation line at 21% and 36% between 25 and 30 min. Figure 6 shows that besides the alkanes, also the PAHs are reduced in this experiment. All the biomarkers (sesquiterpanes, hopanes, steranes, and aromatic steranes), however, were unaffected and can be found on the evaporation line or at 100%.

Table 2 Weathering sensitivity of compounds mentioned in the CEN/TR 15522–2:2012 [1] (*bold*: stronger effect)

Normative compounds				Informative compounds and compound groups			
Compound	Ret. time	Sensitivity	Sulfur	Compound	Ret. time	Sensitivity	Sulfur
C17	26.22	**Bio**		C1-de	13.01	Stable	
Pristane	26.33	Stable		Naphthalene	14.48	**Solub**	
C18	28.19	**Bio**		C1-n	17.70	**Solub**	
Phytane	28.33	Stable		SES1	20.45	**Stable**	
4-MDBT	29.25	Bio	S	C2-bt	20.45		S
1-MDBT	30.05		S	C2-n	20.27	**Solub**	
2-MP	30.10	**Solub**		SES2	21.28	**Stable**	
1-MP	30.54	Solub		SES3	21.49	**Stable**	
2-MFL	34.90			SES4	21.79	**Stable**	
BaF	35.36	Photo		SES8	23.39	**Stable**	
Retene	35.45			C1-f	26.40		
B(b + c)F	35.62	Photo		C2-f	28.78		
2-MPy	35.75	**Photo**		MA	30.26	**Photo**	
4-MPy	36.12	**Photo**		C2-dbt	31.06		S
1-MPy	36.25	**Photo**		C2-phe	32.44		
TMP	36.84	Photo		C3-dbt	33.04		S
BNT	37.94		S	C3-phe	34.43		
27dbS	41.71	Stable		C4-phe	35.45		
27dbR	42.16	Stable		C23 Tr	36.76	**Stable**	
27bbR + S	43.88	Stable		C24 Tr	37.57	**Stable**	
27-TS	44.71	**Stable**		C2-fl	37.32	**Photo**	
SC26TA	45.03	Photo		C20TA	38.69	Photo	
27-TM	45.20	**Stable**		C25 Tr	39.24		
RC26 + SC27TA	45.91	Photo		C21 TA	40.05	Photo	
29bbR + S	46.18	**Stable**		C1-chr	40.75	Photo	
28ab	46.30	**Stable**		C28 (22S)	43.00	**Stable**	
SC28TA	46.63	Photo		C29 (22S)	43.75	**Stable**	
29ab	46.82	**Stable**		28bbR + S	45.24	**Stable**	
RC27TA	46.98	Photo		28aaR	45.61	**Stable**	
30O	47.63	**Stable**		29aaS	45.94	**Stable**	
30ab (hopane)	47.81	**Stable**		29bbR + S	46.16	**Stable**	
RC28TA	47.86	Photo		29aaR	46.68	**Stable**	
31abS	48.95	**Stable**		29Ts	46.88	**Stable**	
30G	49.32	**Stable**		30ba	48.24	**Stable**	
				32abS	49.81	**Stable**	

Sulfur-containing compounds are separately indicated

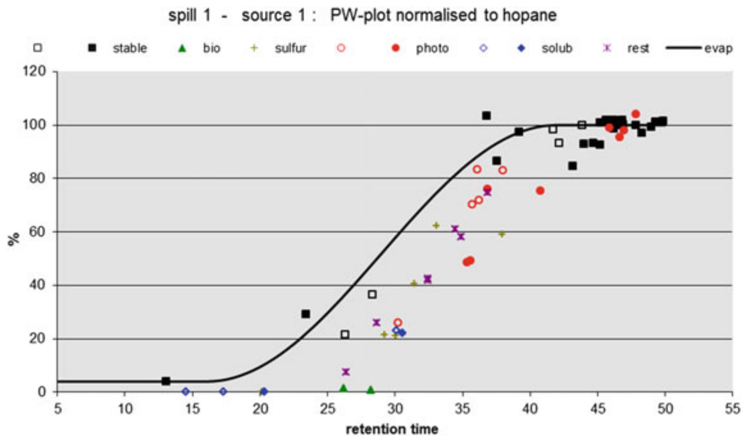

Fig. 6 The original HFO (source 1) compared with artificial biodegraded HFO from the Erika spill (RR2011, spill 1)

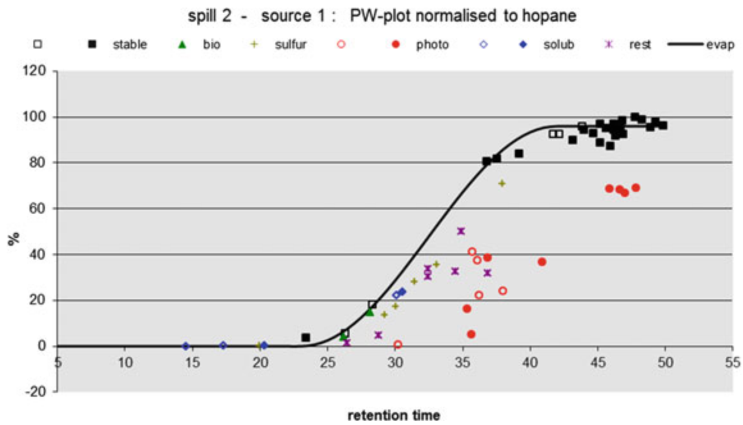

Fig. 7 The original HFO (source 1) compared with artificial weathered HFO from the Erika spill (RR2011, spill 2)

Figure 7 shows a comparison of source 1 with spill 2 of the RR2011 samples. A small layer of oil from source 1 was applied to the surface of a tile. To simulate an oil-contaminated rock, the tile was positioned outside on a wall, which was directed to the south, for 3 months. It was inundated by seawater at high tide. The main weathering effects to be expected were evaporation, photooxidation, and dissolution.

The evaporation line shows evaporation up to a retention time of 40 min. C17, pristane, C18, and phytane are all on the evaporation line, indicating that biodegradation has not occurred. The compounds specific for dissolution are mainly in the range of complete evaporation except 2- and 1-methylphenanthrene. These can be found slightly below the evaporation line at a retention time of about 30 min. The

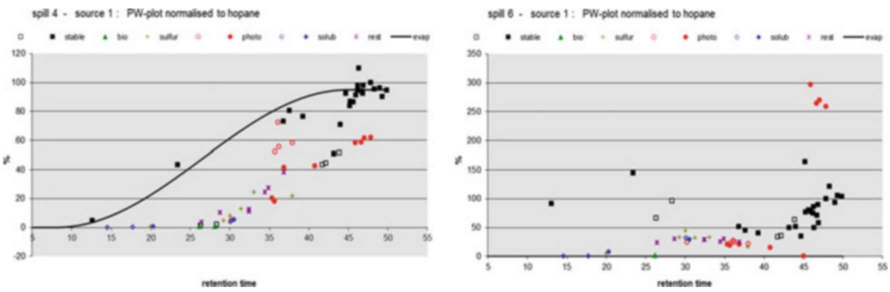

Fig. 8 *Left*: comparison between the original HFO (source 1) and a spill sample collected after 10 years. *Right*: comparison between source 1and HFO from the Prestige spill artificially biodegraded for 2 months

triaromatic steranes (red dots between 45 and 50 min) have been reduced to about 70% by photooxidation.

There might be the need, finally, to give an impression on how the PW plots of actually nonmatching samples generally look like. This is given on the right side of Fig. 8, where the PW plot points are simply spread and don't follow any rule. Figure 8 shows clearly the difference between a heavily weathered, but (probably) matching, sample on the left side and a nonmatching sample. Both are from RR2011.

On the left, the samples are the same as the samples of Fig. 5, which has already been discussed. However, the informative compounds are added here together with the information about the weathering sensitivity of the compounds as given in Table 2. The most stable compounds are on the evaporation line or close together at 100% (black squares).

On the right, a biodegraded HFO from the Prestige spill is compared with the original HFO from the Erika oil. The biodegradation has been done in the same way as with spill 1 (see Fig. 6). The PW plot simply shows scattering without a pattern: the stable compounds between the retention time of 40–50 min. range between 40% and 150%. Additionally the TAS can be found at 250–300%. It is impossible to draw an evaporation line and a nonmatch has to be concluded.

3 COSIweb

All examples of sample comparisons given above can be found in the online database and evaluation system COSIweb (Computerized Oil Spill Identification, web based). This system, which can easily be assessed using any browser, includes samples from many major accidents (among others, “Macondo”, “Erika”, “Prestige”, “Tricolor”, “Baltic Carrier”) but also hundreds of different crude oils and many oil products and waste oils from real spill cases.

COSIweb has two functions:

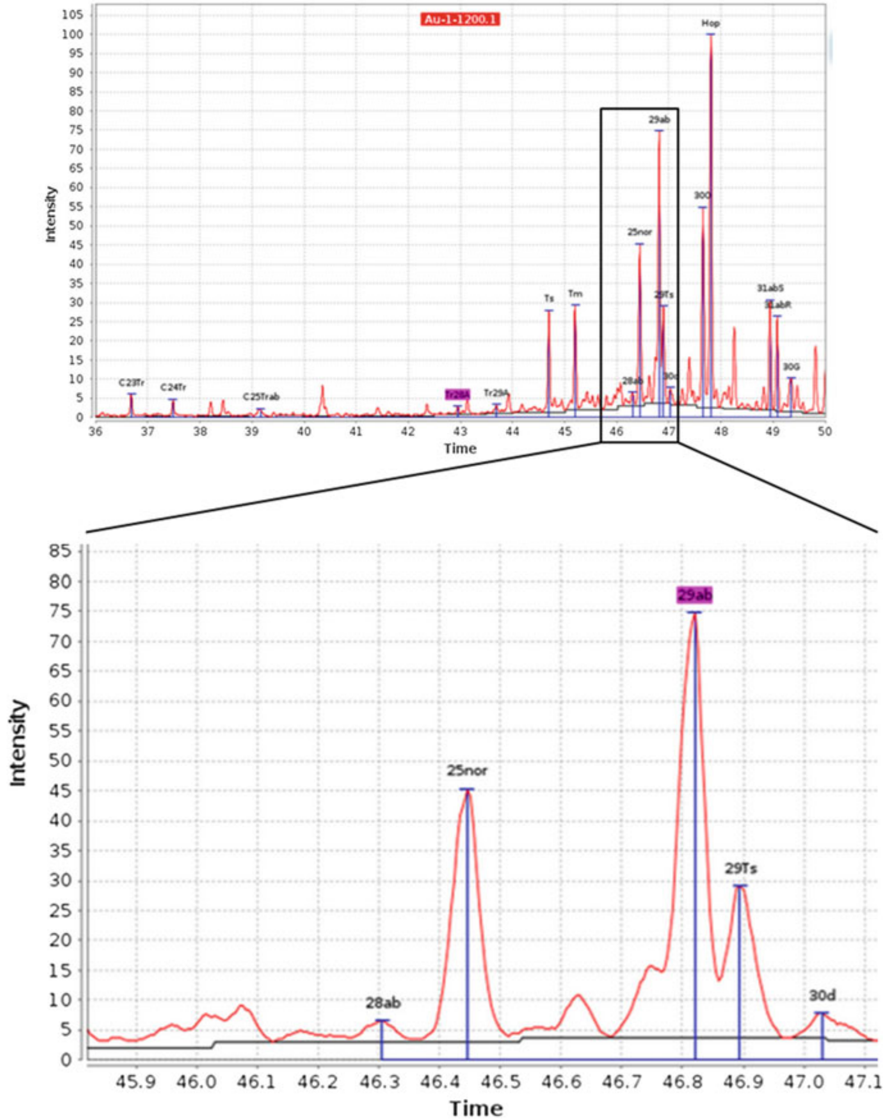

Fig. 9 Hopanes automatically detected, named, and measured by COSIweb (*above*, with zoomed area *below*)

- Searching for unknown samples by means of all or selected compound ratios as given in CEN/TR 15522–2:2012 [1] (statistical comparison)
- Comparing of two samples by producing all the means needed for coming to a conclusion according to CEN/TR 15522–2:2012 [1]

One of its most unique features is the automatic detection and measurement of all relevant peaks from raw GC and GC–MS data (Fig. 9). Gas and mass chromatograms consist basically of x and y values (representing time and intensity in this case). These data can then be exported by means of any acquisition software. As soon as these raw data files are uploaded into COSIweb, all relevant peaks are found and named. Their heights above baseline are measured and compound ratios ("diagnostic ratios") are produced for comparison, automatically.

All of this is done within seconds. COSIweb thus saves both time and resources.

COSIweb is hosted by the BSH and freely available to all OSINet members. At the time of writing, it includes data from 16 laboratories from all over the world. In order to participate in COSIweb, a username and password are required. In order to demonstrate the capabilities and reliability of the system, a special guest status has been produced: the system, available at http://cosi.bsh.de:8080/CosiWeb/, can be accessed freely and tested by using two times the word "guest" (without quotation marks).

4 Conclusion

Information about the development of the common method CEN/TR 15522–2:2012 [1] is presented together with examples of PW plots as one of the highlights of this method. The method itself is much more comprehensive and provides much more details about different oil products and possibilities for their comparison than can be presented here. The interested reader is encouraged to study the method itself. Although this method is written as a guideline, laboratories should collect experience through practice. Information about different oil spill cases and examples of how others have analyzed and compared oil samples is found in the online database and evaluation system COSIweb. COSIweb can easily be accessed by a web browser. This system might also be helpful in assisting users to learn its procedures. It provides many examples on how analytical GC and GC–MS results should appear. All means for sample comparison and for drawing a final conclusion about the connection between two samples are produced here automatically and within minutes. This includes overlays of chromatograms and mass chromatograms, measuring of chromatographic peaks, and producing and comparing of peak ratios as well as PW plots. Thus, this system saves much time and resources. Using this system must also be regarded as the strongest form of cooperation among laboratories as raw data of chromatograms and mass chromatograms uploaded from anywhere in the world can be treated and evaluated as if they were produced in the own laboratory. Samples can be used by all participating laboratories as soon as they are included in the database.

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OSPAR Review of the State of the North Sea: Oil Inputs and Their Impact on the Marine Environment of the North Sea

Angela Carpenter

Abstract The scope of the OSPAR Commission includes monitoring input of pollutants from sea, land and atmospheric sources entering the North Sea and wider North-East Atlantic. The OSPAR Commission is responsible for implementing the requirements of the OSPAR Convention on the protection of the marine environment of the North-East Atlantic. As part of its activities, the Commission published the results of those monitoring activities in Quality Status Reports in 2000 and 2010. Those reports set out the state of the environment in the OSPAR maritime area as a whole and its regional areas such as the North Sea. Data on oil inputs from the offshore oil and gas industry and from shipping that enters the North Sea is generally available, but less so for the broader OSPAR maritime area. Data on the impact of oil inputs on the marine environment has much more limited availability. This chapter provides an overview of the development of the OSPAR Convention and Commission and examines the findings of the Quality Status Reports, both for the wider OSPAR maritime area and the North Sea more specifically.

Keywords Monitoring, Oil and gas installations, Oil spills, Oslo Convention 1972, OSPAR Convention 1992, Paris Convention 1974, Quality Status Reports, Shipping

Contents

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1 Introduction

The OSPAR maritime area covers the internal waters and territorial seas of its contracting parties, the seas beyond and adjacent to the territorial sea of its coastal states and the high seas, seabed and subsoil within limits specified in Article 1 of the Convention [1]. The contracting parties to the OSPAR Convention are Belgium, Denmark, Finland, France, Germany, Iceland, Ireland, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the UK. Finland is a contracting party as some of its rivers flow into the Barents Sea, while Luxembourg and Switzerland are contracting parties as they lie within the catchment of the Rhine which flows into the North Sea.

The OSPAR maritime area is divided into five regions (see Fig. 1). Region I covers the Arctic waters, Region II the Greater North Sea, Region III the Celtic Seas, Region IV the Bay of Biscay and the Iberian Coast and Region V the Wider Atlantic.

This chapter examines the OSPAR maritime area in general and Region II the Greater North Sea more specifically. That region, which has a surface area of around 750,000 km^2, a volume of approximately 94,000 km^3 and a maximum depth of 700 m, lies on the continental shelf of north-west Europe. It is bounded by the coastlines of England, Scotland, Norway, Sweden, Denmark, Germany, the Netherlands, Belgium and France. Its southwestern boundary lies at 48°N latitude and 5°W longitude, and its most northerly boundary lies at 62°N latitude and between 5°W and 5°E longitude. Region II covers, at its north-eastern boundary, all of Norway South of 62°N latitude, including the Skagerrak and Kattegat; to the south at a point at 56°N latitude, the coast of Sweden; and, slightly further north, the coast of Denmark.

The North Sea contains a variety of marine landscapes including fjords, estuaries, sandbanks and bays. It is home to many species of fish and shellfish, together with seabirds, marine mammals and cetaceans, as well as many species of marine

Fig. 1 OSPAR maritime area. *Source*: OSPAR Commission

flora and plankton, for example. It has multiple uses including oil and gas production, fishing and mariculture, marine renewable energy from offshore wind farms, maritime transport and tourism, for example. It also has multiple inputs to the marine environment from land, sea and air. These include inputs from industry, agriculture and sediment deposition from rivers and ships (operational, accidental and illegal discharges) and atmospheric inputs from incinerators, for example.

This chapter examines the development of measures put in place since the late 1960s to protect the marine environment of the North Sea from pollution from ships and airborne and land-based sources. It considers the development of the OSPAR Convention in particular and the role played by the convention and the OSPAR Commission in protecting both the North Sea and the wider North-East Atlantic area. It then sets out the findings of reports into the quality status of the North Sea specifically, together with the wider OSPAR maritime area, as they relate to inputs of oil into the marine environment. Finally, this chapter draws some conclusions on the effectiveness of measures taken so far to reduce oil inputs and on the continued need to assess the state of the marine environment in the future.

2 Development of the OSPAR Convention and Commission

The Convention for the Protection of the Marine Environment of the North-East Atlantic (the 1992 OSPAR Convention) [1] was opened for signature at a Ministerial Meeting of the Oslo and Paris Commissions in Paris in September 1992. It was signed and ratified by all contracting parties to the Oslo and Paris Conventions of 1972 and 1974, respectively. Signatory states are Belgium, Denmark, the European Union, Finland, France, Germany, Iceland, Ireland, the Netherlands, Norway, Portugal, Spain, Sweden and the UK. Luxembourg and Switzerland are also signatories to the OSPAR Convention. This agreement therefore has a wider geographic scope than the Bonn Agreement, signatories to which are Belgium, Denmark, France, Germany, Ireland, the Netherlands, Norway, Sweden and the UK, while the EU is a contracting party to the agreement.

2.1 North Sea Regional Legislation Prior to the OSPAR Convention

The OSPAR Convention is one of a raft of legislative measures developed to protect the North Sea marine environment from pollution from various sources (Table 1). These included the Bonn Agreement of 1969 and its amendments of 1983 and also predecessors to the OSPAR Convention and the Oslo and Paris Conventions of 1972 and 1974. These measures are discussed in Sects. 2.1.1–2.1.3.

Table 1 Regional Marine Pollution Legislation on marine pollution with relevance to the North Sea Region

Year	Legislation
1969	Agreement for Cooperation in Dealing with Pollution of the North Sea by Oil (Bonn Agreement)
1972	Convention for the Prevention of Marine Pollution by Dumping from Ships and Aircraft (Oslo Convention)
1974	Convention for the Prevention of Marine Pollution from Land-Based Sources (Paris Convention)
1982	Memorandum of Understanding on Port State Control in Implementing Agreements on Maritime Safety and Protection of the Marine Environment (Paris MOU)
1983	Agreement for Cooperation in Dealing with Pollution of the North Sea by Oil and Other Harmful Substances (Bonn Agreement) – superceding the 1969 Agreement
1992 (ratified 1998)	Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR Convention) which supercedes the Oslo and Paris Conventions

Source: Adapted from Carpenter (2005) Table 4.1, page 67 [2]

2.1.1 The Bonn Agreement, 1969

The earliest regional agreement to deal with marine pollution entering the North Sea was the 1969 Agreement for Cooperation in Dealing with Pollution of the North Sea by Oil (Bonn Agreement) [3]. That agreement came about as a result of action following a major oil spill of around 117,000 tonnes of oil from the grounding of the 'Torrey Canyon' in 1967. The Bonn Agreement was subsequently amended in 1983 to cover 'other harmful substances' in addition to oil. Signatories to the Bonn Agreement are Belgium, Denmark, France, Germany, Ireland, the Netherlands, Norway, Sweden and the UK, while the EU is a contracting party to the agreement.

In the intervening period (1969 to 1983), developments in the protection of the marine environment in the North Sea region came from growing awareness of the dangers posed by pollution of the seas and oceans through the intentional dumping of a range of substances including oil, sewage, garbage and industrial waste from ships and aircraft.

One example of potentially damaging pollution was the planned dumping of chlorinated waste in the North Sea by the 'Stella Maris' which departed Rotterdam on 16 July 1971; that vessel was forced to return to port on 25 July having been unable to dump its waste as a result of both public pressure and government action [4]. Eight months after this event, in February 1972, the Oslo Convention was signed and it entered into force in April 1974 [5].

2.1.2 The Oslo Convention, 1972

The Convention for the Prevention of Marine Pollution by Dumping from Ships and Aircraft (Oslo Convention) [5] was developed in recognition of the need that international action was required to control pollution of the sea by the dumping of harmful substances from ships and aircraft. The original signatories to the Oslo Convention were Denmark, France, Ireland, Norway, Portugal, Spain and Sweden. Subsequently the UK, the Netherlands, Germany, Finland, Ireland and Belgium signed the convention, the last two around 10 years after the original agreement was adopted.

The geographic scope of the convention was the high seas and territorial seas including parts of the Atlantic and Arctic Oceans and their dependent seas (Article 2), with specific exclusions for the Baltic Sea and its intersection with the North Sea and for the Mediterranean sea and its intersection at the parallel of 36° north latitude and 44° west longitude. The convention area covers the North-East Atlantic and the North Sea. The Oslo Convention therefore had a much wider geographic scope than the Bonn Agreement [3], which covers the North Sea only.

The contracting parties to the Oslo Convention agreed to take all possible steps to prevent 'pollution of the sea by substances that are liable to create hazards to human health, to harm living resources and marine life, to damage amenities, or to interfere with other legitimate users of the sea' (Article 1) and to 'prevent the pollution of the sea by dumping [of harmful substances] by or from ships and aircraft' (Article 4). In recognition of the possibility that the dumping of harmful substances might be diverted to other marine areas, they also agreed to take action to prevent such diversion into seas outside the area to which the convention applied (Article 3). A list of prohibited substances was set out in Annex I to the convention and included various organic compounds, carcinogenic substances, heavy metals and persistent plastics, for example.

The Oslo Commission (OSCOM) was established under Article 16 of the convention and was made up of representatives of all contracting parties. The role of the commission was to regulate and control dumping of industrial wastes, sewage sludge and dredged material and incineration of liquid industrial wastes at sea with all but the dumping of dredged wastes being subsequently phased out [4].

OSCOM worked with the Paris Commission (PARCOM, see Sect. 2.1.3) through a common Secretariat. While each commission set up their own scientific groups with OSCOM establishing a Standing Advisory Committee for Scientific Advice (SACSA) and PARCOM establishing a Technical Working Group (TWG) [6], a Joint Monitoring Group (JMG) and ad hoc working groups also provided common support to both commissions, with mainly administrative activities under the conventions being coordinated through the common Secretariat.

The Oslo Convention was one of the earliest regional agreements relating to marine environmental protection and was seen as an international attempt to international regulation relating to marine pollution resulting from dumping of wastes at sea [7]. Particularly important was its requirement that no materials could be dumped unless all appropriate national bodies agreed to a permit for dumping, and that permit had to be obtained in advance of it taking place (Articles 6 and 7) [5]. Also important was the requirement that all contracting parties undertook to assist one another in dealing with pollution incidents and to exchange information on methods (Article 15, paragraph 4) and to work together to develop cooperative procedures to apply the convention on the high seas (Article 15, paragraph 5), thus extending their activities beyond their normal territorial boundaries [5].

2.1.3 The Paris Convention, 1974

The Convention for the Prevention of Marine Pollution from Land-Based Sources (Paris Convention) [8] was signed in June 1974. It was subsequently amended by a protocol of March 1986. Entry into force took place in May 1978 following ratification by seven contracting parties – Denmark, the European Economic Community, France, the Netherlands, Norway, Sweden and the UK. Subsequently, Portugal, Spain, Iceland, the Federal Republic of Germany, Belgium and Ireland also became signatories, the last two in 1984. The main executive body of the Paris Convention was the Paris Commission (PARCOM).

The objective of the Paris Convention was to take 'all possible steps to prevent pollution of the sea ... of substances or energy into the marine environment (including estuaries) resulting in such deleterious effects as hazards to human health, harm to living resources and to marine ecosystems etc.' (Article 1, paragraph 1). In order to do so, it required contracting parties to adopt 'individually or jointly measures to combat marine pollution from land-based sources [by harmonizing] their policies in this regard' (Article 1, paragraph 2). The convention required all contracting parties to eliminate land-based pollutants including various organic compounds, heavy metals, synthetic materials and persistent oils (Annex A, Part I) together with radioactive substances including wastes (Annex A, Part III).

The main difference between the Oslo and Paris Conventions was that the Paris Convention was one of the first international agreements aimed at the prevention of pollution from land-based sources [7], rather than from marine or airborne sources. Those land-based sources included pollution entering the marine environment from watercourses; underwater or other pipelines, for example, sewage outfall pipes; man-made structures; and emissions into the atmosphere from land or man-made structures (Article 3) [8]. Man-made structures included offshore platforms.

The Paris Convention required joint cooperation between contracting parties in areas including working towards the elimination of pollution of the marine environment from land-based sources (Articles 4 and 5), joint programmes of scientific and technical research (Article 10), operation of permanent monitoring systems (individually or jointly) (Article 11) and offering assistance to one another to prevent incidents that might cause land-based pollution (Article 13). One area where PARCOM's work differed from that of OSCOM was its role in taking action to protect parts of the area where high levels of nutrients entering the environment led to algal blooms which are hazardous to the marine environment [4].

Although OSCOM and PARCOM held joint meetings and shared a Secretariat, 'which also served as the Secretariat to the Bonn Agreement' [9, page 333], as noted in Sect. 2.1.2, much of the cooperation took place at an administrative level and through the scientific Joint Monitoring Group, while each commission held their own meetings and set their own work programmes, for example [2].

2.2 Potential Issues Relating to the Oslo and Paris Conventions

A number of issues were identified with both conventions. First was that their focus was on prevention or reduction of pollutants entering the marine environment, rather than on any reduction in the production of those pollutants. As a result, the pollutants might end up being disposed of elsewhere [2].

The second issue was that monitoring for pollutants examined their concentration in the environment but not their biological effects. As a result, it was not possible to identify whether the marine environment was improving or deteriorating and whether it might therefore need further protection measures [9].

The third, and potentially the most significant issue, was that both conventions used a 'black' and 'grey' list approach in identifying how hazardous pollutants were and whether they could be disposed of in a way that they might enter the marine environment. 'Black list' substances could not be dumped at all, and there was a requirement that any land-based emissions should be eliminated. 'Grey list' substances could still be dumped with permission of competent authorities and based on strict limits. However, there was a question surrounding newly identified or developed substances entering the environment, i.e. those substances not covered by the relevant Annexes to the conventions. Those substances would require an amendment to the relevant Annexes and subsequent agreement by all contracting parties. This would also apply where improved scientific knowledge led to a better understanding of the environmental damage caused by various substances resulting in the transfer of a substance from the 'grey' to the 'black' list. There was, therefore, a level of inflexibility and potential for a delay in preventing those substances from being discharged into the marine environment [2].

3 The OSPAR Convention, 1992

The Paris Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR Convention) [1] was adopted at a Ministerial Meeting of the Oslo and Paris Commissions entered into force in March 1998. Signatory states are Belgium, Denmark, the European Union, Finland, France, Germany, Iceland, Ireland, the Netherlands, Norway, Portugal, Spain, Sweden and the UK. Luxembourg and Switzerland are also signatories to the OSPAR Convention.

The decision, taken in 1990, to establish the OSPAR Convention to supercede the Oslo and Paris Conventions was 'fuelled by developments in marine environmental policy and law which had taken place since the adoption of the two conventions' [9] including those issues discussed in Sect. 2.2. As a result, it was apparent that the work being undertaken by the separate commissions no longer corresponded to the requirements of the conventions, and action was required to make the conventions more relevant to the current time.

As noted in Sect. 2.1.2, the OSPAR Convention covers the same geographical area as the Oslo and Paris Conventions and is divided into five regions (see Fig. 1). This chapter considers, in particular, Region II (Greater North Sea), described in the Introduction, which covers the area from where the North Sea opens into the Atlantic Ocean to the north, where it meets the Baltic Sea to the east and where the English Channel meets the Bay of Biscay to the southwest.[1]

[1] Further information on the geographic area, together with a description of Region II (Greater North Sea), is available from the OSPAR Commission website at http://www.ospar.org/content/content.asp?menu=00470212000000_000000_000000.

3.1 General Obligations of the OSPAR Convention

The OSPAR Convention [1] set out a number of general obligations for all contracting parties at Article 2. These include that they take 'all possible steps to prevent and eliminate pollution and enact the measures necessary to protect the sea area against the adverse effects of human activities' in order to 'safeguard human health and to conserve marine ecosystems and, when practicable, restore marine areas which have been adversely affected' (Article 2, Paragraph 1(a)). In addition, contracting parties were to 'adopt programmes and measures [to] harmonise their policies and strategies' (Article 2, Paragraph 1(b)).

The sources of pollution covered by the convention are land-based sources (Article 3), dumping or incineration (Article 4), offshore sources (Article 5) and other sources 'not already the subject of effective measures agreed by other international organisations or prescribed by other international conventions' (Article 7).

3.2 Other Requirements of the OSPAR Convention

The most recent version of the OSPAR Convention [1] contains all amendments and updates up to 2007 and details 34 Articles, 5 Annexes and 3 Appendices.

Examples of these include Article 8 which sets out requirements that contracting parties undertake complementary or joint programmes of scientific or technical research; Articles 10 and 12 which, respectively, set out the make-up of the OSPAR Commission and its permanent Secretariat; Annexes I to III which relate specifically to pollution from land-based sources (Annex I), pollution from dumping and incineration (Annex II) and pollution from offshore sources (Annex III); Annexes IV and V which relate to the assessment of the quality of the marine environment (Annex IV) and to protection and conservation of ecosystems and biological diversity (Annex V); and Appendix I which sets out criteria for best available techniques and best available practice.

3.3 Marine Monitoring Under OSPAR

Contracting parties to OSPAR are required to carry out an assessment of the quality of the marine environment by undertaking and publishing regular joint assessments on the quality status of the marine environment (Article 6(a)). Included in those assessments is a requirement that they evaluate the 'effectiveness of the measures taken and planned for the protection of the marine environment etc.' (Article 6(b)).

Article 6 of OSPAR provided a solution to the issue identified in Sect. 2.2 in relation to the Oslo and Paris Conventions of not being able to identify whether the marine environment was improving or deteriorating due to a lack of biological monitoring. Article 6 put in place measures to do such monitoring on a regular basis, while publication of Quality Status Reports, initially by the Oslo and Paris Commissions in 1987 [10] and 1993 [11] and by the OSPAR Commission in 2000 and 2010 [12, 13], provides policy makers and the public with a condensed overview of current knowledge and trends in both pressures and impacts of various activities on the quality of the North-East Atlantic [13].

3.4 The Use of the Precautionary Principle and Polluter Pays Principle Under OSPAR

Article 7 of OSPAR [1] provided a solution to the third issue identified in Sect. 2.2., i.e. on categorising newly identified or developed substances or responding to new scientific knowledge of the impact of a substance on the marine environment and also the inflexibility of the ‘black’ and ‘grey’ list approach. Article 7, which deals with pollution from other sources, is much more responsive in taking action to prohibit or limit discharges of many more substances once they are identified as hazardous to the marine environment. Also relevant here are the requirements under Article 2 which, unlike the Oslo and Paris Conventions’ use of ‘black’ and ‘grey’ lists, requires contracting parties to apply the precautionary principle (Article 2, Paragraph 2(a)) and the polluter pays principle (Article 2, paragraph 2(b)) [2].

3.4.1 The Precautionary Principle

The precautionary principle, as defined by Principle 15 of the 1992 Rio Declaration [14], states that: ‘In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation’.

3.4.2 The Polluter Pays Principle

The polluter pays principle, as defined by Principle 16 of the 1992 Rio Declaration [14], states that: ‘National authorities should endeavour to promote the internalization of environmental costs and the use of economic instruments, taking into account the approach that the polluter should, in principle, bear the cost of pollution, with due regard to the public interest and without distorting international trade and investment’.

4 Role of the OSPAR Commission

The work of the OSPAR Commission is formally governed by a set of rules and procedures [15], with each contracting party being represented on the commission (Rule 2) and providing a Head of Delegation to the commission (Rule 3). The commission meets at least once a year (Rule 4) with extraordinary meetings being held at the request of at least three contracting parties (Rule 5). A Chairman and Vice Chairman are elected (Rule 10) every two years (Rule 11), and those posts are rotated between all contracting parties to ensure equitable geographical representation (Rule 12). The OSPAR Commission has a Secretariat, based in London, and an Executive Secretary, appointed by the commission (Rule 15).

The commission works to implement all requirements of the OSPAR Convention through the adoption of decisions which are legally binding on all contracting parties and also through recommendations and other agreements on, for example, agreed programmes of monitoring and information collection and on actions that the commission takes on behalf of the contracting parties [16].

4.1 *Structure of the OSPAR Commission*

The commission has a number of committees on Hazardous Substances and Eutrophication, Offshore Industry, Radioactive Substances, Biodiversity and the Environmental Impact of Human Activities. It also has a number of groups such as the Coordination Group, various working groups and the Group of Jurists and Linguists [17]. Each main committee has an annual work programme with specific products to be delivered at the next meeting of that committee or subsequent meetings, and each product has a specific task manager from a lead country.

In addition to the OSPAR Committees, the North Sea Network of Investigators and Prosecutors (NSN) was established in 2002 to help enforce international regulations preventing ship-source pollution, and that body has direct links with the Bonn Agreement to carry out those activities [18].

4.2 *Observers to the OSPAR Commission*

There are a number of observers to the OSPAR Commission [19] including intergovernmental (IGOs) and nongovernmental organisations (NGOs). Examples of IGOs include the Baltic Marine Environmental Protection Commission (Helsinki Commission), the Common Wadden Sea Secretariat (CWSS), the European Environment Agency (EEA), the International Maritime Organization (IMO) and the United Nations Environment Programme (UNEP). Examples of NGOs include the Advisory Committee on Protection of the Sea (ACOPS), the International

Association of Oil and Gas Producers (IOGP), the Oil Companies' European Organisation for Environmental and Health Protection (CONCAWE) and the World Wide Fund for Nature (WWF).

4.3 Publications from the OSPAR Commission

The OSPAR Commission makes available, via its website [20], a wide range of publications that are freely available to the general public. These include an online version of the 2000 Quality Status Reports, Annual Reports (in both English and French), together with reports from the Oslo and Paris Commissions for 1989–1992 and 1992–1995. Also available are reports on discharges, spills and emissions to air from offshore installations between 2010 and 2012 [21] and on discharges, spills and emissions from offshore oil and gas installations in 2012 [22], for example.

5 Monitoring the Quality Status of the North Sea

There have been a number of publications relating to the quality status of the North Sea. These were published in 1987, 1993, 2000 and 2010. The North Sea region covered by the reports is delineated in Fig. 2, taken from the 1993 report [11] which covered the North Sea only. Fig. 2 shows defined geographical boundaries for subregions within the North Sea and lead countries responsible for reporting on the individual subregions.

The OSPAR reports of 2000 and 2010 set out the quality status of the entire OSPAR maritime area, together with regional reports for each of the five OSPAR Regions, of which the Greater North Sea is OSPAR Region II.

5.1 The North Sea Quality Status Report 1993

In 1987 an early North Sea Quality Status Report was prepared for the Second International Conference on the Protection of the North Sea held in London in November 1987 [10]. The Ministerial Declaration arising from that conference identified that there were many shortcomings in scientific knowledge of the North Sea environment and that, without such knowledge, it was difficult to make strategic decisions on environmental protection or to assess the effectiveness of measures that had already taken place [23].

In order to tackle knowledge gap, it was decided to create a task force, the North Sea Task Force (NSTF), which would be the joint responsibility of the Oslo and Paris Commissions and the International Council for the Exploration of the Sea (ICES).

Fig. 2 Boundaries of the North Sea defined by the North Sea Task Force. *Source*: North Sea Task Force (1993), page 8 [11]

5.1.1 The Role of the North Sea Task Force

The role of the NSTF was to 'carry out work leading ... to a dependable and comprehensive statement ...' on the state of the North Sea, which included inputs and dispersion of contaminants and also the effects of human activities [11]. In addition, the task force was involved in the development of a monitoring master plan (MMP) for monitoring the whole North Sea environment [24].

The NSTF was made up of representatives from Belgium, Denmark, France, Germany, the Netherlands, Norway and the UK, together with representatives of the commission of the European Communities. The NSTF commenced its work in 1988 and the Secretariat of the NSTF worked with the Secretariats of the Oslo and Paris Commissions and ICES.

At the Third International Conference on the Protection of the North Sea in 1990, the NSTF was asked to carry out work to address a number of specific topics. These include the impact of fishing activities on the ecosystem, surveillance of chemicals not routinely monitored under existing programmes, the environmental impact of persistent chemicals and the role of atmospheric inputs as a source of contamination and environmental damage [11].

5.1.2 General Content of the QSR 1993

The QSR 1993 [11] examined both the geography of the North Sea and its physical oceanography – its depth, salinity, circulation, tides and climate – together with a wide range of inputs to the marine environment and their impacts. Those inputs included riverine and direct inputs, atmospheric inputs, incineration and dumping and radioactive substances. The report also considered the anthropogenic impacts of human activities including coastline modification for sea defences; the development of offshore drilling rigs, platforms and pipelines; and the impact of trawling on benthic species, for example.

In addition to considering inputs and their sources, the report made an overall scientific assessment of the North Sea in respect of habitat changes and physical disturbances; fish, bird and mammal mortality; the sources and patterns of contaminant inputs; and the overall health of the North Sea.

5.1.3 Oil Contamination in the North Sea

In considering sources of oil entering the North Sea, the QSR 1993 identified sources of contamination from the offshore oil and gas industry [11]. Those sources included drilling muds and cuttings from water-based muds, cuttings containing oil from the use of oil-based muds, produced water (water that comes from the reservoir along with oil) and spills and flaring. Those sources contained not just oil but other substances including heavy metals, corrosion inhibitors, defoamers, detergents and thinners, for example [11].

The report identified an area of relatively dense drilling activities in the central North Sea, generally the area lying between the north-east UK and southwest Norway and extending into the southern North Sea between the UK and Dutch sectors. They were located mainly in subregions 1, 2b, 7a, 7b, 3b and 4 as set out in Fig. 2.

Figures for the number of oil and gas platforms in production between 1990 and 1992 identified that there were 30 platforms in Danish waters in 1990, 68 in Netherlands waters in 1992, 50 in Norwegian waters in 1991 and 150 in UK waters also in 1991, and the QSR 1987 had identified offshore oil and gas installations as significant sources of hydrocarbons discharged into the North Sea [11].

No information was provided in the QSR 1993 on the amount of oil entering the marine environment from riverine or direct inputs or from atmospheric or from sources other than the oil and gas industry.

5.1.4 The Impact of Oil on Ecosystems

A number of impacts of man-made inputs of oil into the North Sea were identified in the QSR 1993 [11]. Estimates of the area of the seabed contaminated by oil in sediments ranged from 1,900 to 4,500 km^2 in 1986 to 8,000 km^2 by the time the QSR 1993 was written.

The accumulation of oil in sediments is identified mainly as coming from deposition of oil-contaminated drill cuttings. Two adverse effects from those cuttings are physical smothering of seabed organisms where large volumes of cuttings are deposited and chronic pollution which can result in the decline of some sensitive species in the area, increased abundance of other opportunistic species and reduction in biodiversity, for example.

Oil concentrations in sea water were identified as being generally low, with elevated levels being found in the inner German Bight and around some oil platforms. This was as a result of discharges in produced water, cuttings and flaring. Experiments with certain species such as mussels, cod and herring showed a range of problems including higher mortality.

Oil slicks, both from ships and offshore installations, were identified as causing the deaths of tens of thousands of seabirds each year, with some marine mammals also being fouled by oil slicks. Oiling rates for beached birds were identified as being stable over a 20-year period, with declining levels identified in only a few areas such as the Shetland and Orkney Isles and along the German coast.

5.1.5 Concerns and Agreed Measures from the QSR 1993

One issue, highlighted in the 1993 QSR, was that there were concerns about the volumes, duration and long-term effects of discharges of oil into the North

Sea and also the area affected by discharges as a result of oil cuttings from offshore activities [11]. The report highlighted that there were cases of contaminated fish caught in the vicinity of platforms.

While improvements in cutting cleaning technology, and the types of oils used in the process, had resulted in reduction in inputs from cuttings, with a 30% decrease in total discharges of hydrocarbons through the reduction in discharges of oil-contaminated cuttings [11], there was an expectation that produced water would make an increasingly greater contribution to total inputs of oil and from incomplete gas flaring from oil platforms.

A second issue of concern is related to the qualities of oil being discharged illegally from ships and from incomplete gas flaring from oil platforms. The abundance of oiled bird carcasses being found on North Sea coastlines was seen as an indicator of pollution levels.

A number of specific actions had been agreed at the Third International Conference on the Protection of the North Sea at The Hague in 1990 in order to reduce oil pollution, including the following: North Sea states should work with the International Maritime Organization to apply more stringent standards for ships discharging oily waste and residues in all sea areas; contaminated cuttings should no longer be discharged into the sea; and the feasibility of reducing the oil content in produced and displaced water from existing and new offshore installations was to be investigated.

A number of technical measures had already been identified, including the introduction of double hulls on new oil tankers in order to minimise the risk of oil spills in the event of an accident, new routing of ships carrying hazardous cargos and stricter standards for discharges from refineries and offshore installations [11].

Finally, the Third International Conference had agreed that there should be improved control and enforcement to deter ships from contravening the requirements of the MARPOL 73/78 Convention [25][2] and others, through increased coastal state jurisdiction using exclusive economic zones; improved legal instruments to minimise accidental oil pollution from ships; improved availability of shore reception facilities, i.e. facilities made available in ports so that ships could discharge wastes safely rather than dispose of them at sea; and improved effectiveness of airborne surveillance.

The QSR 1993 concluded that 'no real decreasing trend in pollution of the North Sea [could] be inferred' and that it would take some time before any beneficial effects of the agreed measures could be seen in terms of a reduction of oil pollution [11].

[2] Annex I of MARPOL 73/78 covers Regulations for the Prevention of Pollution by Oil. For further information on this convention, see http://www.imo.org/About/Conventions/ListOfConventions/Pages/International-Convention-for-the-Prevention-of-Pollution-from-Ships-(MARPOL).aspx.

5.2 OSPAR Quality Status Report 2000

The QSR 2000 [12] comprised six volumes, the first of which covered the entire OSPAR Region and the other five remaining covering each of the regional seas. The QSR 2000 was the result of a decision of the OSPAR Commission, in 1994, to implement a commitment made when the OSPAR Convention was signed in 1992. That commitment was to prepare a Quality Status Report for the whole of the North-East Atlantic region by 2000 [12].

5.2.1 General Overview Across the OSPAR Maritime Area in 2000

As with the QSR 1993 [11], the QSR 2000 outlined the principle physical characteristics of the OSPAR maritime area. This included the chemical and biological properties of the area [12] and the impacts of human activities [12], together with information on bottom topography, geology and sediments, coastal margins and waves, tides and storm surges, for example [12].

In relation to discharges from offshore oil and gas installations, these were identified as a significant source of oil inputs to the maritime area, particularly in Region II [12]. There had been an overall decrease in oil inputs from around 28,300 tonnes in 1985 to around 9,500 tonnes in 1997 (a reduction of approximately −66%). This was mainly as a result of a decrease in oil discharges via cuttings between 1985 and 1996 (from 25,800 tonnes to 6,000 tonnes). From 1997 there was a change to synthetic fluid muds, with 7,200 tonnes of oil discharged via cuttings in 1997. However, the QSR 2000 did identify an increase in the discharge of oil between 1985 and 1997 from produced water (from about 2,500 to about 8,500 tonnes).

The QSR 2000 also identified that much of the increase in produced water was a result of a greater number of offshore installations, discussed in more detail in Sect. 5.3.1, and that an increase in the levels of oil, polycyclic aromatic hydrocarbons (PAHs, naturally occurring components of coal and oil) and other substances being discharged via produced water was a result of the increasing age of oil fields. Strict regulations had, however, been put in place in respect of operational discharges, together with prohibitions on the use of oil-based muds, for example.

The increase in the number of oil and gas platforms in production was a result of major developments in the offshore oil industry in the North Sea, particularly in the UK and Norwegian sectors. There had been a doubling of offshore platforms between 1990/1992 and 1996, primarily in that area. Platforms in the shallower waters around the southern UK, together with the Dutch and Danish sections, were gas production platforms [12].

In relation to shipping as a source of oil, the QSR 2000 reported that there continued to be operational, accidental and occasionally illegal release of oil, along with inputs of hazardous chemicals through activities such as tank cleaning, releases of wastewater and loss of cargo, for example [12]. Across the whole

Table 2 Major shipping accidents resulting in oil spills

Year	Ship type and name	Location	Volume of oil spilled
1992	Tanker – 'Aegean Sea'	Spanish coast, off Galicia	80,000 tonnes
1993	Tanker – 'Braer'	UK, Shetland Isles	84,000 tonnes
1996	Tanker – 'Sea Empress'	UK, Milford Haven	74,000 tonnes
1998	Cargo – 'Pallas'	Germany, Amrum – Wadden Sea	25,000 m^3
1999	Tanker – 'Erika'	France, southwestern Brittany	14,000 tonnes[a]

[a]An additional 11,200 tonnes of oil was removed from the wreck in 2000
Source: QSR 2000, Table 3.10, page 34 [12]

OSPAR maritime area, operational discharges of oil from bilges and machine rooms were regulated so that there should be no visible signs of oil on the sea surface following any discharge.

Under the name North-West European Waters, OSPAR Regions II and III (the North Sea and the waters around Ireland) had received Special Area status under MARPOL 73/78 Annex I (oil) from August 1999. In Special Areas there was a total prohibition on the discharge of oily cargo residues at sea from any oil tankers, together with a limit of 15 parts per million in bilge waters and machinery space discharges [12].

Across the OSPAR maritime area, there had been five major shipping accidents between 1992 and 1999, resulting in the discharge of oil. They are outlined in Table 2.

5.2.2 Conclusions from QSR 2000 for the OSPAR Maritime Area

In terms of the overall assessment of the quality status of the North-East Atlantic, the QSR 2000 reported that discharges of both mineral and vegetable oil from ships continued to be a major concern [12]. Positive measures to limit deliberate oil discharges from ships have been put in place, including stricter rules on discharges of oil or oily mixtures from shipping, and there was also improved provision of facilities in ports to receive oily wastes. Despite those measures, pollution from illegal activities remained high and the QSR reported no apparent downward trend.

In respect of oil from offshore installations, 90% of those installations had met standards set by PARCOM in its Recommendation 92/6, a standard for oil of 40 mg/l in produced water from those installations [12]. While reiterating that there had been a reduction by over 60% in inputs of oil from offshore oil and gas installations between 1985 and 1987, the QSR 2000 identified that expansion of offshore oil and gas activities into deeper waters and environments that were seasonally covered by ice meant that there was an increased risk of accidents due to either the depth of operations or the difficulties of taking action to deal with operations in cold environments.

5.2.3 Review of Region II: The Greater North Sea

The Region II Greater North Sea volume of the QSR 2000 (Region II QSR 2000) [26] covers the area set out in Fig. 2 and provides a detailed description of that region. As shown in Table 3, the number of offshore oil and gas installations in the region has increased in the period 1990/1992 to 1996/1998 – from 300 to 475. During the same period, oil production almost doubled [26].

The quantities of oil discharged in Region II waters declined by almost 50% between 1984 and 1995 with 11,800 tonnes being discharged in that year, made up of 65% from produced water, 33% from cuttings and 2% from accidental spills. Flaring operations accounted for less than 0.01% [26]. In the case of accidental spills, there were 198 cases in 1986, increasing to 621 in 1995, but there was a decline in oil discharge from 3,800 tonnes to 270 tonnes during that same period [26].

The overall decline in Region II occurred despite the increase in the number of offshore oil and gas installations from 143 to 458 during the same period. Oil discharged from cuttings was also reduced by 83% between 1984 and 1995 [26]. By contrast, however, the volume of oil discharged in produced waters from ageing oil fields increased from 1,717 tonnes in 1984 to 7,648 tonnes in 1995, with produced water becoming the main source of oil input from offshore installations in 1993 [26]. 2,429 tonnes (32%) was discharged as a result of 46 installations failing to achieve the 40 mg/l water target standard set out for installations (PARCOM Recommendation, 86/1), with 77% of those installations being located in the UK sectors (18% in the Norwegian sector) [26].

In respect of oil from shipping, there had been an increase in the levels of airborne surveillance conducted under the Bonn Agreement during the period 1989 to 1996, while the total number of observed slicks had fallen during that period [26]. This is highlighted in Fig. 3 which also shows the ratio of observed slicks to flight hours for the period 1986 to 2004. The ratio of observed slicks to flight hours fell from 0.57 slicks/flight hour in 1987 and 1999 to 0.18 slicks/flight hour in 1996.

In addition to the trend of a reduction in observed slicks (apart from an increase in 1996), the Region II QSR 2000 reported that the average volume of identified oil slicks was also decreasing, with 519 of the 650 slicks in 1995 (79.8%) being less than $1m^3$ in volume and only 2 slicks being more than 100 m^3. The report does, however, offer a caveat that reported oil quantities may only represent around 10% of the actual discharges [26].

Table 3 The number of oil and gas platforms in production 1990/1992 and 1996/1998

OSPAR area	Total number of installations 1990/ 1992 (year in brackets)	Total number of installations, 1996/ 1998 (year in brackets)
Denmark	30 (1990)	36 (1996)
Germany	3 (1987–1990)	2 (1996)
Netherlands	68 (1992)	107(1996)
Norway	50 (1991)	80 (1998)
UK	150 (1991)	250 (1997)

Sources: 1990/1992 figures from QSR 1993, Table 1–6, page 17 [11]; 1996/1998 figures from QSR 2000 Region II Report, Table 3.8, page 41 [26]

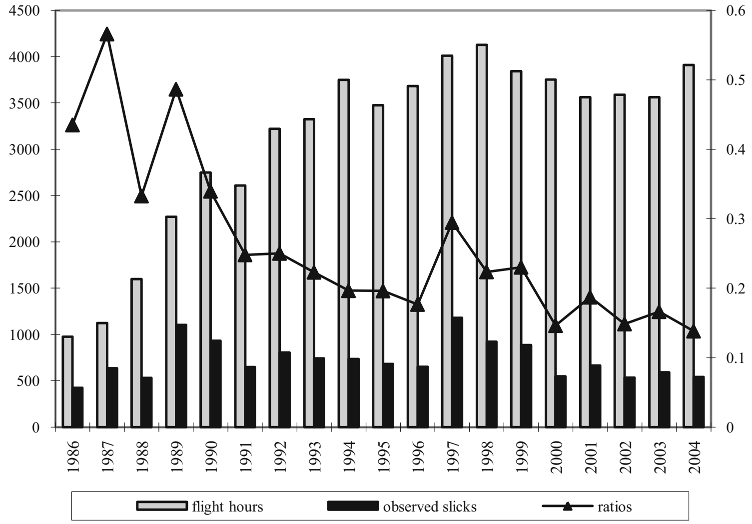

Fig. 3 Bonn Agreement figures for flight hours and observed spills in the North Sea, 1986–2004 (Figs. 3 and 4 have been compiled using data from Bonn Agreement Aerial Surveillance Reports. Reports for the years 2008 to 2013 are available at http://www.bonnagreement.org/publications). *Source*: Adapted from Carpenter, A (2007), Figure 6, page 155 [27]

Other sources of oil inputs included refineries, atmospheric deposition and the dumping of material dredged in harbours, together with riverine sources [26]. Fifty-eight refineries in nine OSPAR states were estimated to have discharged 607 tonnes of oil into coastal, estuarine and inland waters in 1997, compared to 9,047 tonnes in 1981 and 1,441 tonnes in 1993. Eighty-three percent of the 1997 discharge was into estuaries, mainly in the UK and the Netherlands.

Atmospheric deposition was estimated at 430 tonnes in the Dutch sector in 1995, while the dumping of harbour dredging was estimated at 2,000 tonnes in the Dutch sector in 1995. Finally, estimates of riverine inputs varied widely and are limited geographically, mainly to rivers discharging into the sea from the Netherlands.

5.2.4 The Impact of Oil on Ecosystems in OSPAR Region II

The Region II QSR 2000 has some discussion on the impact of various activities on ecosystems. There was little change in the information relating to drilling activities from the QSR 1993 and also limited information on the impacts of production discharges, although a number of studies have mentioned the impact of hydrocarbons in produced water on marine organisms [26]. While the potential for impacts from the construction or decommissioning of pipelines and offshore installations is mentioned, no information is available on those activities [26].

More information was available on the impact of spills and discharges from shipping, particularly in relation to beached bird data, with chemical analysis of both birds and contaminated beaches having been undertaken under an Oiled Seabirds Project which identified the main source of oil as discharged bunker residues from ships [26]. It was suggested that some of these discharges exceed the levels set out under MARPOL 73/78 Annex 1 [25] and that gradual implementation of that Annex may have contributed to a general trend of reduced levels of oiling rates of beached birds.

Some coastal areas of the Netherlands had seen a decline in oiling rates over a 30-year period, with the decline in those rates being greater in the Wadden Sea than along the Netherlands North Sea coast. The Netherlands is, however, identified as having higher rates than areas around the Shetland Isles, while the west coast of Denmark has a constantly higher level than other regions of the North Sea.

5.2.5 Conclusions from the Region II QSR 2000

Four classes of impact are set out relating to human pressures, Classes A (highest impact) to Class D (lowest impact), and there are a total of thirty-two pressures defined in the overall assessment of the North Sea and placed within those classifications [26]. Amongst the highest impacts are fisheries and the introduction of trace organic contaminants – excluding oil and PAHs – from land, air and water. The lowest impacts include physical disturbance such as noise from shipping and electromagnetic disturbances from power cables. Inputs of oil (and PAHs) from the offshore oil and gas industry and from shipping are categorised as Class B, upper intermediate impact [26].

The Region II QSR 2000 highlighted the difficulty of assessing the volumes of oil entering the marine environment of the North Sea and noted that the QSR 1993 indicated a range of anything from 86,000 to 210,000 tonnes/year from a range of sources. No more recent figure was provided.

In evaluating changes in inputs of oil over time and the effectiveness of the measures in place to reduce those inputs, it was reiterated that there was a lack of data on inputs from riverine sources, other than in the Dutch sector; there had been no systematic assessment of legal and illegal discharges from shipping, but stricter controls were in place in the North Sea under its designation as a Special Area under MARPOL 73/78 Annex I; the majority of refineries met the stipulated discharge standard of 5 mg/l total oil (PARCOM Recommendation 89/5), and oil discharges had decreased by over 90% between 1981 and 1997; and oil inputs from the offshore oil and gas industry had decreased significantly between 1985 and 1993, although factors such as the maturation of oil fields and the increased volume of produced water meant discharges from that source were increasing [26].

The report put forward a number of recommendations [26]. These were that action should be considered to establish better estimates of oil (and PAH) inputs from all land-based sources and that the objectives of the OSPAR Strategy for offshore gas and activities should be fulfilled. It also noted that existing measures to prevent illegal discharges of oil from ships should be strengthened through, for example, measures to increase provision of reception facilities in ports (being considered by the European Commission at that time) and by the development of tools for fingerprinting and tagging oil.

5.3 *OSPAR Quality Status Report 2010*

The Quality Status Report 2010 (QSR 2010) [13] once again considers the whole OSPAR area and follows up on both the QSR 2000 and earlier North Sea QSRs. It examines the collective efforts made by contracting parties between 1998 and 2008 to ‘manage, monitor and assess the many pressures on the diverse ecosystems of the North-East Atlantic and the impacts that they bring’ [13]. It notes that the OSPAR Convention is firmly rooted in global obligations and commitment including the 1994 United Nations Convention on the Law of the Sea, that OSPAR works closely with international organisations such as the IMO and UN Economic Commission for Europe (UNECE) and that the EU Marine Strategy Framework Directive (EU MSFD) [28] is an important driver for OSPAR’s future work.

The QSR 2010 [13] is available electronically and includes an interactive map allowing the reader to see comments on various issues and inputs such as chemical concentrations, threats to species and habitats, fish stock levels and amounts of litter. The website also offers brief summary pages on the key points from the report, together with links to download the individual chapters.

As with the QSR 2000, there is a description of the geography, marine and coastal ecosystems, the physical system and biology of the OSPAR maritime area. Each region is then briefly described, as are challenges and common pressures. Separate chapters then consider issues including climate change (Chap. 3), eutrophication (Chap. 4) and hazardous and radioactive substances [13], for example. There are also brief Regional Summaries outlining key issues in the different OSPAR Maritime Regions [13].

5.3.1 General Overview Across the OSPAR Maritime Area in 2010

OSPAR’s work has, since 2003, been guided by an ecosystem approach which is also a main element of the EU MSFD. That approach allows the ‘sustainable exploitation of natural resources while maintaining the quality, structure and functioning of the marine ecosystems’ where a good understanding of the ecosystem, and the development of appropriate indicators and methodologies, means that the ecosystem can be assessed in response to pressures from human activities [13]. As a result of the ecosystems approach, a number of Ecological Quality Objectives (EcoQOs) have been developed for the North Sea on aspects of biological diversity, commercial fish stocks/food webs, eutrophication, contaminants and marine litter.[3]

Looking at the whole OSPAR maritime area, inputs from oil from a range of sources remain an issue. The total amount of oil and gas produced from the offshore oil and gas industry across the OSPAR area had declined by 14% between 2001 and 2007,

[3] For more information on the North Sea Ecological Quality Objectives, see http://qsr2010.ospar.org/en/media/chapter_pdf/QSR_Ch11_EN.pdf.

although the number of offshore installations had increased and around 60% of operational installations reported both air emissions and discharges to the sea [13].

Oil discharged in produced water had fallen by 20% on average across the OSPAR area, including in Region II, and this was achieved through a combination of injecting produced water into subsea formations and efforts by the industry to optimise processes and introduce new water treatment technology [13]. Most countries had met an OSPAR 15% reduction target, i.e. OSPAR Recommendation 2001/1 on management of produced water and 15% reduction target for oil discharges with produced water. However, the volume of produced water continued to increase, in line with the earlier QSRs [13].

The main environmental pressures from oil and gas operations were greatest in Region II, the location of the majority of production platforms and pipelines. However, QSR 2010 indicated that operations had peaked in that region and were declining [13]. Other areas were likely to see increased production, for example, the Barents Sea and offshore areas of Greenland, the Faroe Islands and northern Norway, all in Region I Arctic waters, where significant oil and gas reserves are located.

Spills from other sources were much reduced. Ninety-five percent of accidental oil spills were less than 1 tonne in volume, although ageing pipelines and other infrastructure may result in more spills over time. Discharges from contaminated cuttings from wells had largely ceased by 2005, and although oil-contaminated cuttings can be discharged at sea if they are below 1%, new technologies were available to reduce that still further. Cuttings remain an issue as there is the potential for the release from cutting piles through leaching or disturbance of the area around an installation (including decommissioning, trawling and dredging).

Shipping also remained a source of marine pollution by oil and other toxic substances through accidental, operational and illegal discharges [13]. No information on levels of spills are provided in the report, although it does indicate that there are some signs of decreasing oil pollution in the North Sea [13], and this is discussed in Sect. 5.2.3.

No major oil spills were identified since 1999, other than the oil spill resulting from the wreck of the single-hull tanker 'Prestige' off the Galician coast of Spain (Region IV Bay of Biscay and Iberian Coast) in 2002 [13]. In that case an estimated 64,000 tonnes of oil was spilled along 1,000 km of the coastline. 20,000 oiled birds were collected from beaches in the aftermath of the spill, but it was estimated that up to 100,000 were affected by the oil, the vast majority not washing ashore. While the measurable effects of the 'Prestige' oil spill were seen to decrease between 2002 and 2005, indicating an improvement in water quality, knowledge remained limited on the long-term effects of the oil pollution on the seabed and biological communities in the area.

5.3.2 Conclusions from QSR 2010

Across the whole OSPAR maritime area, although there have been significant reductions in some forms of oil discharges, there were still concerns about the impact of the offshore oil and gas industry on the marine environment. These included increased volumes of produced water required in maturing oil reservoirs and the impacts of historic cutting piles and atmospheric emissions.

A number of priorities for action were set out in relation to oil. These are as follows: continued work towards a reduction of discharges of oil in produced water to the sea; a guarantee that 'discharges will present no harm to the marine environment by 2020'; a move towards a risk-based approach to managing produced water; and, more generally, continued monitoring and assessment and improvement of the evidence base 'for future assessments of the impacts of the offshore industry on marine ecosystems' [13].

Action was also proposed to examine issues relating specifically to ageing installations and infrastructure and to whether current OSPAR measures were suitable for the northern part of Region I where, as discussed at Sect. 5.2.2, there are areas of deeper waters and environments that were seasonally covered by ice.

In respect of ship-source marine pollution, OSPAR has continued to work the IMO, the EU and the Bonn Agreement. While no data is provided on the number of observed oil spills in the North Sea in QSR 2010, data is available from the Bonn Agreement for the period 1984 to 2010, and this is presented in Fig. 4. This expands on the data presented in Fig. 3 (see Sect. 5.2.3) and illustrates that, apart from a spike in the number of observed spills in 1997, there continued to be a decline in the number of observed slicks between 1999 and 2010, and the ratio of observed slicks to flight hours had fallen from 0.22 slicks/flight hour in 1999 to 0.04 slicks/flight hour in 2010. As noted in Sect. 5.2.3, around 80% of slicks were less than 1 m^3 in

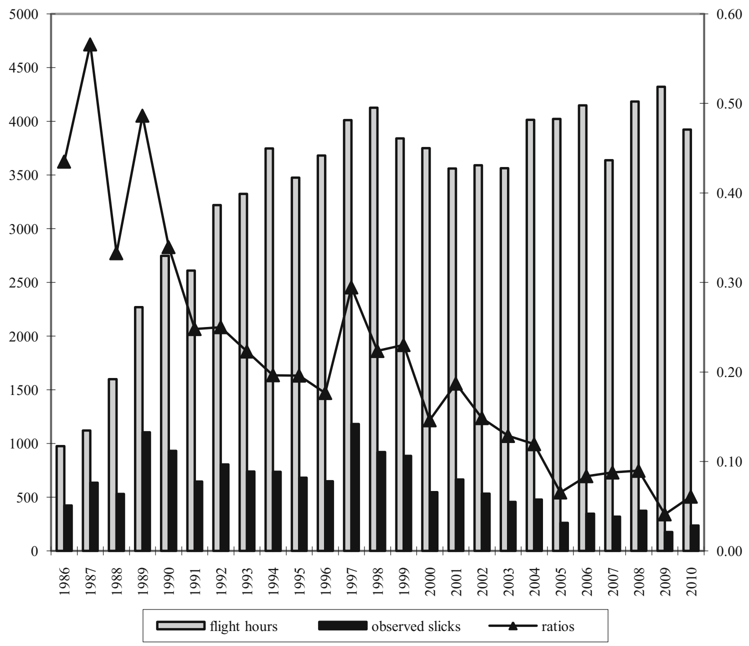

Fig. 4 Bonn Agreement figures for flight hours and observed spills in the North Sea, 1986–2010

volume in 1995, and Bonn Agreement Aerial Surveillance data indicates that slick sizes have remained at similar levels since 1998 with the vast majority (around 80%) of slicks being less than 1 m^3 in volume and only around 1% being greater than 100 m^2.

Special Status under MARPOL 73/78 [25], together with EU Directives to prevent accidents at sea and the establishment of the European Maritime Safety Agency (EMSA), should, it is suggested, help reduce oil inputs from shipping, together with substances such as chemicals or garbage. However, QSR 2010 notes that many of those measures had only recently taken place, and so it was not possible to assess their effectiveness. Effective surveillance, investigation and prosecution were therefore deemed essential to protect the marine environment from pollution from ships [13].

Despite the comment on the effectiveness of various measures, the QSR 2010 does provide some positive findings on the level of oil pollution in the North Sea. It highlights that based on the North Sea EcoQO on the average proportion of oiled common guillemots in winter months (November to April), there appears to have been an overall decrease in oil pollution levels in some parts of the North Sea. However, there are wide variations, with higher levels of oiled birds being found in areas around the Netherlands, Belgium and south-east England (southern North Sea) compared to areas around Orkney (northern North Sea) [13].

As accidental spills are less frequent, and there are strict limits for operational discharges, it is suggested that better enforcement of current regulations and awareness raising activities are necessary to reduce illegal oil discharges. One source of such illegal oil discharges is oily ballast and tank washing water or oily bilge water which should be retained by ships until they arrive in a port. Under EU Directive 2000/59/EC on port reception facilities [29], EU ports are required to provide waste facilities for a range of wastes, including oily wastes set out under MARPOL 73/78 Annex I [25]. However, a lack of data on volumes and types of waste handled by ports creates difficulties in identifying whether all wastes are discharged appropriately [13] presenting an opportunity for ships to discharge illegally into the sea.

6 Conclusions

The OSPAR Convention [1] was introduced in order to better prevent and eliminate pollution from the marine environment of the North-East Atlantic from sea, land and air and to protect the sea area against the adverse effects of human activities. It also sought to safeguard human health, to conserve marine ecosystems and, where practicable, to restore marine areas that had already been impacted by human activities such as the oil and gas industry and shipping, discussed in this chapter.

Through harmonised programmes and strategies, contracting parties to OSPAR are required to carry out monitoring activities to assess the quality of the marine environment and to produce regular reports on those assessments. In addition, a commitment was made to produce Quality Status Reports for the entire OSPAR Region, with reports being subsequently issued in 2000 and 2010 [12, 13], building in the framework of the earlier 1993 QSR [11].

The QSRs identify that, in the period 1984 to 2007, there was an increase in the total number of offshore installations in Region II Greater North Sea, together with an increase in the number of installations discharging to the sea. In the QSR 1993, the main source of oil entering the marine environment from platforms was from cuttings from the use of water-based and oil-based muds [11]. By 1997 oil inputs from cuttings were less than 25% of 1985 levels (down from 28,300 to 9,500 tonnes) [12]. By contrast, in 1985 oil in produced water formed only a small proportion of the total volume of oil discharged to sea (2,500 tonnes), but this had increased by 8,500 tonnes in 1997 [12].

The volumes of produced water have subsequently continued to increase as a result of, for example, the maturation of oil fields. This, in Region II, led to an increase in produced water from 1,717 tonnes in 1984 to 7,648 tonnes in 1995 [25]. Overall discharges of oil in produced water continued to increase despite most contracting parties achieving the OSPAR target for a 15% reduction of oil discharged with produced water, the increase being as a result of the volume of produced water being discharged [13].

While there is limited information on actual inputs of oil from shipping for the whole OSPAR maritime area, the number of major accidental spills in that area has fallen from five major shipping accidents in the years 1992 to 1999 (see Table 2) to a single major spill from the Prestige in 2002 (see Sect. 5.3.1).

More comprehensive information on oil spills from shipping is available for Region II as a result of aerial surveillance activities conducted under the Bonn Agreement [3], the Bonn Agreement having direct links to the OSPAR Commission through OSPAR's North Sea Network of Investigators and Prosecutors, established in 2002 (see Sect. 5.1). As highlighted in Fig. 3, there was an increase in the number of flight hours conducted under the Bonn Agreement between 1989 and 1996 and a decline in both the number of observed slicks and the volume of oil in those slicks (see Sect. 5.2.3). While the QSR 2010 does not make reference to Bonn Agreement Aerial Surveillance data, Fig. 4 shows that, other than a spike in the number of oil spills in 1997, the ratio of slicks to flight hours has continued to decline with the vast majority of slicks being less than 1 m^3 by volume.

Overall, since the inception of the OSPAR Convention [1] and its predecessors, the Oslo and Paris Conventions [5, 8], there has been a reduction in the volumes of oil entering the North Sea since the late 1980s. Work has been undertaken to identify oil inputs from all sources – land, sea and atmospheric inputs. Work has also been undertaken to identify the impacts of oil pollution on ecosystems and marine organisms, for example, an ecosystem approach that is a main element of the EU's Marine Strategy Framework Directive [27].

Targets put in place by OSPAR have already resulted in a reduction in oil discharges. However, the ageing oil and gas production infrastructure in the North Sea presents challenges for the future of the region, with the QSR 2010 identifying a need to examine specific issues in that respect [13]. In order to continue to reduce oil inputs, OSPAR has therefore set as a priority for future action the 'reduction of oil in produced water discharged to sea to a level which will ensure that the discharges will present. No harm to the marine environment by 2020' [13].

Finally, in relation to shipping as a source of oil pollution, OSPAR also identifies the need to continue to assess the effectiveness of measures developed internationally by the IMO and also by the European Union, for example. In particular, this relates to illegal oily discharges where there is a need to improve existing enforcement measures and raise awareness of current regulations [13]. It also relates to better collection of data associated with ships discharging oily wastes into port reception facilities in EU ports, to ensure that ships do not intentionally discharge wastes at sea [13].

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Conclusions

Angela Carpenter

Abstract This chapter examined Bonn Agreement annual statistics from aerial surveillance activities between 1986 and 2010 and examines the levels of flight hours for observed and confirmed oil spills in the North Sea. It also looks at the results of EMSA CleanSeaNet satellite imagery for the region between 2007 and 2011 for observed and confirmed spills. In terms of observed spills, there has been a significant decline in the numbers of spills and volume of oil entering the marine environment over more than two decades. This is also the case for discharges from oil and gas installations, where OSPAR Commission monitoring data identifies a very large fall in operational discharges from installations over the last decade in particular. The decadal OSPAR Quality Status Reports have also identified improvements in the region while identifying areas for further action in reducing oil inputs still further, especially from ageing oil and gas infrastructure. Projects such as Bonn Agreement BE-AWARE have mapped and identified the risk of oil pollution across the region, while Bonn-OSINet and COSIweb have resulted in improved methods to not only identify the make-up of an oil spill but also to increase the likelihood of matching samples from a spill to samples from potential sources. Beached bird surveys also provide a tool in monitoring not only the impacts of large spills from accidents but also levels of chronic oil pollution in coastal and offshore areas. The results of investigations into oil pollution in the waters of Belgium, the Netherlands, Denmark and Germany are discussed, while an examination of the legal structure for monitoring and dealing with oil pollution in UK waters is presented. Legislative measures such as the MARPOL Convention, EU Directive on Port Reception Facilities and national legislation have contributed to a reduction in oil being discharged through operational activities from ships, while accidental spills have also been reduced as a result of better vessel standards and improved traffic management in the southern and eastern North Sea. While

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illegal discharges continue to present a problem and there remains a need to reduce pollution in offshore areas, it is clear that there has been a significant improvement in the state of the North Sea in terms of oil over several decades.

Keywords Aerial surveillance, Beached bird surveys, BE-AWARE project, Bonn Agreement, Bonn-OSINet, CleanSeaNet, COSIweb, European Maritime Safety Agency, European Union, MARPOL Convention, North Sea, Oil installations, Oil pollution, Oil spill monitoring, OSPAR Convention, OSPAR Quality Status Reports, PRF Directive, Satellite monitoring, Shipping

Content

The North Sea region is located between Norway, Sweden, Denmark, Germany, the Netherlands, Belgium and the UK. The population of the areas of those countries that border the North Sea was approximately 60 million (13% of the total EU-25 population) in 2007 [1]. It is a heavily used maritime space facing many environmental problems from a range of sources, both anthropogenic and naturally occurring. Pollution enters the marine environment from atmospheric deposition; industrial, domestic and agricultural inputs from land-based sources and rivers; and coastal sewage, for example [2]. Oil inputs can come from coastal refineries, from oil terminals and reception facilities, from offshore oil and gas production and from accidental or illegal discharges from ships [2]. It can also come from operational activities of tankers such as cleaning of oil cargo residues from tanks or, in the case of fishing vessels, from discharges of oil residues in bilge water.

Shipping and the maritime transport of goods and people are an important activity in the North Sea. The region's shipping lanes are some of the busiest in the world. It was estimated that there were 420,000 shipping movements per year within its limits in the early 1990s [2], increasing to around 600,000 ship movements between the region's top 50 ports in 2010 [3]. In the Dover Strait, the narrowest point between the UK and France, there are around 200 ferry crossings daily and around 400 other vessels crossing the Strait every day, with further 400 ships a day sailing through the Strait using separate lanes for vessels inbound to outbound from the North Sea [3].

In respect to the maritime transport of goods, either from outside the EU or between EU member states, the European Commission [4] identifies North Sea ports as being: all ports of Norway, the Netherlands and Belgium as well as the ports of Germany on the North Sea; Swedish ports on the North Sea from Helsingborg (excluded); Danish ports on or north of the Helsingborg–Korsor–Nyborg–Kolding line, North Denmark (excluding Helsingor), and the Faroe Islands; and UK ports on the east coast of Great Britain from Ramsgate (included) to Cape Wrath in Scotland, the Shetland Islands and Orkney Islands.

Using the geographic limits set out above, in 2013, seven of the top 20 ports for the transport of goods between EU member states using short sea shipping (SSS; the maritime transport of goods over relatively short distances, as opposed to the intercontinental cross-ocean deep sea shipping) were located in the North Sea [4]. SSS transported around 58% of goods between ports in EU member states, together with non-EU countries on the coastlines of the Mediterranean, Black and Baltic Seas [5]. In terms of maritime freight transport globally in 2013, 63% of seaborne goods were transported to or from ports outside the EU [6].

The top three ports for SSS transport of goods in Europe in 2013 were Rotterdam, Antwerp and Hamburg, handling around 188 million, 90 million and 50 million tonnes of goods, respectively [4]. Those ports were also the largest for maritime freight transport in Europe in that year [5] and were ranked 6th, 18th and 25th in the world by gross tonnage in 2013 [6]. Other North Sea ports in the top 20 for SSS transport were Immingham (5th), Amsterdam (6th), London (9th) and Tees and Hartlepool (16th) [3]. Two ports located in the English Channel through which large numbers of vessels enter the North Sea from the south are Le Havre and Dover, and those ports were 10th and 15th, respectively, in the top 20 for SSS [4]. Other North Sea ports in the top 20 for cargo included: Immingham (8th), Bremerhaven (11th), Bergen (13th – the only non-EU port on the list) and London (15th) [4]. Rotterdam was the largest port in terms of shipping of liquid bulk cargoes (117 million tonnes or 12% of liquid bulk transported by SSS in 2013), while Antwerp was the largest port for goods shipped by SSS in containers (11% of EU total tonnages) [4]. Much of that liquid bulk cargo would have been crude oil or refined products, with a report from 2003 indicating that Europe's ports received nearly 500 million tonnes of crude oil and 250–300 million tonnes of refined products each year [7].

With the high number of vessel movements daily in and around the North Sea, there is the potential for operational, accidental or illegal inputs of oil to enter the marine environment of the North Sea. However, ships operating in the region are required to comply with the requirements of the MARPOL 73/78 Convention which sets out strict controls on discharges including oily wastes (Annex I) and noxious liquid substances (Annex II) [8]. Annex I also sets out standards for tanker design to minimise operational and accidental spills from tankers and regulations for the treatment and disposal of engine room bilge water and ballast and tank-cleaning wastes [8]. Annex I of MARPOL 73/78 also includes the total prohibition of discharges of oily mixtures from ships into the waters of Special Status Areas (SSAs).

While the North Sea was designated as an SSA under MARPOL 73/78 in 1999, signatories to the 1969 Agreement for Cooperation in Dealing with Pollution of the North Sea by Oil (Bonn Agreement) and its subsequent amendments [9] have worked for nearly 40 years to try and eliminate illegal and accidental oil pollution from ships in the region. Those amendments included extension of the agreement to cover other harmful substances in 1983; the European Commission becoming a contracting party, also in 1983; extension to cover cooperation in surveillance in 1987; and Ireland joining the Agreement in 2010 at which point the geographical scope was extended to include Irish waters [9].

Risk assessments for marine pollution had been undertaken by Bonn Agreement signatories at a national level, but it was recognised that there had been no overall risk assessment of the whole Greater North Sea region using a common, comparable methodology [10]. Contracting parties therefore established the Bonn Agreement Area-Wide Assessment of Risk Evaluations (BE-AWARE) project [11] which took place between 2012 and 2014 in order to map and compare risks of marine pollution at regional and subregional levels [10]. Those risks included: accidental spills or oil or other hazardous and noxious substances (HNS) from shipping, collisions with offshore installations (oil, gas and wind farms) and spills from installations [10]. A second phase of the project (BE-AWARE II) took place between 2013 and 2015.

Using a range of data including accident statistics, automatic identification system (AIS) data, cargo data and other information, BE-AWARE phase I developed models of risk from shipping accidents and from offshore installations for five subregions; the Atlantic, the northern North Sea, the eastern North Sea, the southern North Sea and the English Channel [10]. They identified different levels of risk between those regions, with the northern part of the North Sea having high levels of risk from spills from oil platforms, while areas of high traffic in the English Channel and southern North Sea (coasts of the Netherlands, Belgium and Germany) were at higher risk of ship–ship collisions [10]. A further measure taken by the Bonn Agreement was the development, in 1993, of a manual on 'Oil Pollution at Sea – Securing Evidence of Discharges from Ships' [10]. Subsequently this has been developed as the 'North Sea Manual on Maritime Oil Pollution Offences' [3] which offers a common understanding of oil pollution impacts, how evidence of marine pollution can be gathered and the reliability of methods used [10].

Aerial surveillance activities have been undertaken under the auspices of the Bonn Agreement for many years to monitor oil inputs to the sea from ships and oil and gas installations. More recently (since 2004), this has been combined with the use of satellite imagery and other methods to confirm whether spills are made up of mineral oil or not. Aerial surveillance is undertaken by a fleet of around 15 aircraft, together with some helicopter support [12]. Most of the aircraft were equipped with a range of remote sensing equipment including side-looking airborne radar (SLAR), IR and UV line scanners or cameras, microwave radiometer (MWR), forward-looking infrared (FLIR) sensors, laser fluorosensor (LFS, lidar) and low-light-level television camera (LLLTV) to operate in the UV range and also with video and digital cameras [12]. Those aircraft undertake a range of activities including national and regional flight operations, Coordinated Extended Pollution Control Operations (CEPCO) with a minimum of 24 h of surveillance activities over areas at high risk of illegal or operational discharges, and Tour d'Horizon flights which primarily monitor oil and gas installations [13].

Table 1 sets out the number of spills observed in the EEZs of Bonn Agreement member states as a result of aerial surveillance activities between 1990 and 2013

Table 1 Number of spills identified by Bonn Agreement and country, 1990–2013; confirmed as oil for 2003–2013

Year	Belgium	Denmark	France	Germany	Netherlands	Norway	Sweden	UK	Total
1990	0	65	0	130	362	0	26	180	763
1991	16	91	0	51	273	66	15	135	647
1992	60	27	0	135	202	98	6	191	719
1993	60	4	0	99	279	113	6	180	741
1994	82	10	6	122	283	80	6	147	736
1995	57	17	7	98	238	72	16	176	681
1996	42	13	5	121	247	93	21	108	650
1997	58	36	28	125	771	60	14	89	1,181
1998	70	57	45	120	458	72	31	69	922
1999	61	74	22	118	450	65	36	58	884
2000	54	33	25	120	187	46	8	75	548
2001	54	114	16	93	266	64	15	54	676
2002	45	74	54	94	130	55	15	66	533
2003	82	47	22	53	191	23	9	31	458
2004	36	43	27	3	109	65	10	46	339
2005	3	57	22	54	71	14	15	27	263
2006	9	69	29	92	98	17	7	26	347
2007	25	75	22	47	37	25	3	85	319
2008	22	134	32	48	42	14	6	77	375
2009	13	34	16	30	47	19	3	38	200
2010	22	125	10	30	69	13	4	10	283
2011	7	40	20	24	18	50	7	50	216
2012	5	55	8	20	15	28	3	7	141
2013	16	37	4	22	31	38	15	13	176

Source: Bonn Agreement (various years) [14]

[14]. For 1986 to 1989, only information on the total number of spills for the North Sea region is available, rather than national data. In 1986, there were 425 spills, 635 spills in 1987, 532 spills in 1988 and 1,104 spills in 1989. As they are signatories to the Bonn Agreement, data for France and Sweden is also provided in Table 1 which has been compiled using data from Bonn Agreement Aerial Surveillance Programme Annual Reports [14].

While there are large variations within the data for individual states, particularly the Netherlands with a spike in the number of observed slicks in 1997 (771 slicks compared to 247 in 1996 and 258 in 1998), the general trend has been a fall in the number of detected spills over more than 20 years, from 763 in 1990 to 176 in 2013 across the whole of the North Sea. The high total in 1997 (1,181 spills) reflects the high figure for the Netherlands in that year [14].

Improvements in the accuracy of oil spill identification mean that, from 2003 onward, the figures presented in Table 1 are detections confirmed as oil spills rather than just the total number of detections which may not be oil spills but rather things like sheen from biogenic origin, i.e. from algal blooms, or slicks that are identified as not being oil upon closer investigation. As an example, prior to confirmation of the type of spill, there were 290 detections by flights out of the Netherlands in 2003. However, only 191 were confirmed as oil and so the smaller number has been used. With all other reductions based on confirmation of detections, the number of confirmed slicks across all countries was 458 compared to 592 prior to confirmation [14].

Table 1 illustrates that there has been a decline in the annual total number of oil spills occurring in the North Sea over more than two decades. Combined with high numbers of flight hours across the region, over 3,500 hin all years since 1994, the resulting ratio of observed slicks to flight hours fell from 0.22 slicks per flight hour in 1999 to 0.04 slicks per flight hour in 2010 [15]. The majority of slicks are also quite small. Between 1998 and 2010, around 80% of identified slicks were less than 1 m^3 in size other than in 2002 when 74% were less than 1 m^3 (26% were between 1 and 10 m^3 in that year) [14]. The proportion of slicks over 10 m^3 in size was less than 5% in all but three years (7% in 2005 and 2006, 5.5% in 2009); the proportion over 100 m^3 was 1% or above only in 2006 and 2009 (1% and 1.08%, respectively) [14]. The 2009 figure was a result of two slicks, 1 in Norway and 1 in the UK [16]. While data is not available on total oil inputs into the North Sea, based on the number of spills and data on spill sizes, it can be concluded that volumes have declined in line with the reduced number of spills.

Since its establishment in 2002 [17], the European Maritime Safety Agency (EMSA) has been tasked with providing a number of services to EU member states. Those services include operational tasks such as tracking vessels sailing in EU waters under the EMSA SafeSeaNet service [18] and a pollution response service with more than 20 oil spill response vessels located around the EU [19]. Four vessels cover the North Sea, two of which are based in Sunderland, UK, and cover the northern region, while two are based in Ostend, Belgium, and cover the southern North Sea [19]. EMSA also undertakes monitoring of European waters to detect oil pollution under its CleanSeaNet (CSN) Service [20], with around 2,000 satellite images being analysed each year and potential oil spills being notified to the relevant country [21]. Those images are in addition to satellite images obtained by North Sea states from various sources including Canada's Radarsat-2, Norway's SATHAV programme, Germany's TerraSAR-X and Italy's COSMO-SkyMed [21, 22].

In 2007, there were 1669 image acquisitions covering the waters of Belgium, Denmark, Germany, the Netherlands, Norway, Sweden and the UK (3,189 in 2008, 2,947 in 2009 and 3,032 in 2010) [23]. This includes the Baltic Sea areas of Denmark, Germany and Sweden. From those images, there were 460 spills detected in 2007 (950 in 2008, 624 in 2009 and 458 in 2010) [23]. Only small numbers of oil spills were detected using CSN images between 2007 and 2010, ranging from less than 0.1 spills per image for Belgium in all years to up to 0.57 and 0.46 spills per image for the Netherlands in 2008 and 2009, respectively, and 0.41 spills per image for the Netherlands and UK in 2007 [21]. Once those spills had been checked and verified by aircraft within 3 h of image acquisition, around 80% of spills identified by CSN images in Danish waters were confirmed as being oil and only 16% in Netherlands waters [21]. Since 2011, across all EU maritime areas, there has been a fall in the number of spills detected by CSN [21].

From Bonn Agreement data on satellite surveillance for the period 2004 to 2013 (excluding data for France), it is also apparent that the proportion of spills detected in satellite images that are subsequently confirmed as mineral oil is quite low [14]. In 2004, only 46 out of 378 spills detected by satellite were confirmed as mineral oil (12.17%). By contrast, 429 out of 540 spills detected by aerial surveillance were confirmed as mineral oil (79.44%). In 2013, confirmation rates had fallen to 3.80% for satellite detections (24 out of 631) and 42.04% for aerial surveillance detections (140 out of 333) [14]. While it is unclear what is being detected by satellite imagery and aerial surveillance activities, this data again supports the conclusion that there has been a decrease in the number of oil spills in the North Sea.

The second potential source of oil pollution in the North Sea is from the large numbers of oil and gas production installations, pipelines and oil storage facilities located in the region. In 1990–1992, there were around 300 oil and gas platforms in the North Sea and 475 in 1996–1998 [14]. Oil platforms are mostly located in the northern part of the North Sea in Norwegian and UK waters for oil. Gas platforms are generally located in shallower waters, for example, in southern regions in the UK and the Netherlands, together with some platforms in Norwegian waters [24]. Between 2001 and 2012, the number of oil production installations rose slightly from 151 (10 Danish, 8 Dutch, 39 Norwegian and 94 UK) to 161 (14 Danish, 9 Dutch, 50 Norwegian and 88 UK), although that number fluctuated over the years with a high of 168 oil installations in 2010 [25]. During the same period, the number of gas installations rose from 220 (94 Dutch, 7 Norwegian and 119 UK) to 326 (118 Dutch, 12 Norwegian and 196 UK) [25].

Oil production in the North Sea doubled between 1990–1992 and 1996–1998 [26] but fell from 513 million total oil equivalents (toeqs) in 2001 to just over 290 million toeqs in 2012, a fall of almost 44% [26]. During the same period, the types of discharges from oil and gas installations have changed. In the 1980s and early 1990s, the main source of oil discharge came from cuttings, solid material removed from drilled rock together with any solids and liquids associated with the drilling process [26]. In 1984 discharges from cuttings accounted for around 88% of all oil discharges from platforms [26]. Since 1996 virtually no cuttings containing mineral oil-based fluids have been discharged to the sea [27] while only limited volumes of cuttings containing organic-phase drilling fluids (OPFs; an emulsion of water and other additives) have been discharged at sea with prior authorisation of national authorities [28].

Produced water (PW), a by-product of oil and gas operations, has been the main source of oil entering the sea from installations since 2000, with displacement water (DW), seawater used to ballast storage tanks of those installations, contributing only very small amounts [13]. The volume of PW fell from almost 400 million m^3 in 2001 to just over 318 million m^3 in 2012, with a fall of almost 24% between 2004 (the year with the highest recorded volume of 423 million m^3), while the volume of DW almost halved from 67.75 million m^3 in 2001 to 34.4 million m^3 in 2013 [13]. These falls can be accounted for by increasing volumes of PW being injected back into the oil or gas reservoir (up from 30.27 million m^3 in 2001 to 92.13 million m^3 in 2012, an increase of over 300%) [13]. The total quantity of oil discharged in PW from installations fell from 13,892 tonnes in 2001 to 3,990 tonnes in 2012 (a fall of 70%) while discharges in DW fell from 262.6 tonnes in 2001 to 61.4 tonnes in 2012 (a fall of around 80%) [13].

Accidental spills from oil and gas installations also fell between 2003 and 2012, with 621 spills of one tonne or less by volume and 19 spills greater than 1 tonne in 2003, down to 411 and 10 spills, respectively, in 2013 [13]. Most spills occur in Norwegian and UK waters, the locations of the highest numbers of installations, with far fewer spills occurring in Danish and Netherlands areas of the North Sea [13].

The number of platforms exceeding OSPAR performance standards for dispersed oil in discharges of PW has also fallen over time. In 2001 a total of approximately 312 tonnes of dispersed oil was released from 22 installations (151 oil installations, 220 gas installations), with those installations failing a 40 mg/L oil in water standard [29]. A stricter 30 mg/L oil in water standard was introduced in 2007 [30] and, in 2012, there were only 17 installations failing that standard with a total release of dispersed oil in PW of 47.44 tonnes [13]. Strict monitoring of installations through in situ manned equipment, sampling against agreed standards for releases, aerial surveillance and satellite imagery show that the amount of oil entering the North Sea from platforms has fallen over recent years, while less than 5% of accidental discharges come from those installations [13].

As noted previously, a reduction in oil spills entering the marine environment of the North Sea has been identified through aerial surveillance and satellite imagery, using both Bonn Agreement and EMSA CSN data, for example [13, 21]. In terms of ship-source pollution, much of the reduction has occurred since 1999, the year in which the North Sea became an SSA under MARPOL 73/78. At that time, oil discharges from oil tankers or other vessels exceeding 400 gross tonnage were prohibited, and stringent discharge standards for discharge of oily waters also became applicable [31]. Operational (or intentional) discharges are not illegal outside designated areas, with ships being permitted to leave oily water not exceeding 15 parts per million (ppm) in their wake. However, in the North Sea, the Wadden Sea (designated as a particularly sensitive area) and Baltic Sea, such discharges would be considered illegal, with legal measures put in place under MARPOL 73/78 Annex I to restrict such inputs [31]. Operational discharges are of particular concern as they present the greatest threat of ecological harm from vessels, particularly from illegal discharges of oil as part of routine operations [31].

Legislating oil and other discharges of polluting substances from ships is a complex situation, with the notion of civil liability being laid down by the IMO under the Civil Liabilities Convention (CLC) of 1969, amended by the CLC of 1992 [32]. In contrast, the EU has put in place measures based on stringent criminal liability such as the directive on ship-source pollution and penalties (Directive 2005/35/EC as amended by Directive 2009/123/EC) [33]. However, the IMO plays an important role in preventing and controlling marine pollution from ships, while striking a balance between the needs of ships operating in the North Sea and protecting the environment of the region through its status as an SSA [31].

In addition to measures at IMO, EU and regional level to minimise oil pollution from ships, the nations bordering the region also have in place their own measures. This book contains 4 chapters on 'national activities', written by experts in oil pollution and covering measures in Denmark, Belgium, the Netherlands and the UK [34–37]. In the case of the UK, that chapter [37] looks specifically at the development of legislation relating to oil pollution and oil discharges. A further chapter then examines monitoring oil pollution in the German North Sea area and the range of sensors and methods used to undertake that monitoring [22].

The waters around Denmark, and particularly around the Skagen which is the main route for ships entering and exiting the Baltic Sea, are used by thousands of ships, including oil tankers, every month [34]. The Danish Ministry of Defence undertakes a range of activities to protect the marine environment from oil, including aerial surveillance, oil spill and chemical pollution response and enforcement, and collecting evidence of pollution from ships. It also works with emergency services and municipal councils to rehabilitate coastlines following pollution incidents and to control pollution in ports. National legislation is set out under the Danish Act on the Protection of the Marine Environment [38].

A wide range of equipment is available for pollution monitoring and response in Danish waters. The Danish Defence Command (DDC) undertakes aerial surveillance of Danish waters, including production platforms, using Royal Danish Air Force CL-604 Challenger aircraft, and flies about 200 h annually. German aircraft also operate surveillance flights on occasion, especially close to Danish platforms [34]. DDC is also responsible for oil and chemical pollution response at sea, with vessels available for deployment in the event of an incident. Two environmental vessels, the *Gunnar Thorson* and *Gunnar Seidenfaden*, are available for use in the North Sea, while two smaller vessels, the *Mette Miljoe* and *Marie Miljoe*, are available to operate in coastal waters and up to 45 nautical miles from the shore.

Three barges are also available to operate in conjunction with environmental vessels [34]. DDC can also arrange for vessels from other authorities or from civilian agencies, coordinating operational deployments at sea via the Maritime Assistance Service.

A wide range of agencies also play a part in pollution response in Danish waters. For example, in the event of spills along the Danish coast or in harbours, municipal councils are responsible for contingency planning and implementation of rehabilitation activities [34]. The Danish Naval Home Guard [NHG] also provides support in the event of spills through the towing and laying of booms and towing barges, while volunteers work both within the NHG and in cooperation with Danish Navy personnel to assist in environmental operations. NHG vessels have a 1-h response time to deal with major environmental disasters and will generally be the first on scene as they have vessels located around the Danish coast [34].

Responsibility for fixed offshore installations such as production platforms and drilling rigs falls under the remit of the Danish Ministry of the Environment. There are five production facilities in the Danish licence area and the companies operating concessions for those facilities are responsible for initial response, such as mobilisation of equipment in the event of pollution taking place from them, and also bear the cost of oil spill combating, for example [34]. They are also responsible for drawing up contingency plans to deal with pollution with plans being approved by the Danish Environmental Protection Agency.

Only one major shipping incident took place in the Danish sector of the North Sea between 2010 and 2014. This was the collision, in September 2011, between the Maltese flagged bulk carrier *MV Golden Trader* and the Belgian flagged fishing vessel *Vidar*. A severe pollution incident resulted off the west coast of Sweden, with oil being washed ashore from a heavy fuel storage tank on the *MV Golden Trader*. Approximately 450 m^3 of heavy fuel oil was lost from that vessel [34]. Between 2010 and 2014, there were no major oil spills from platforms in the Danish EEZ. The last major spill in Danish waters took place at the *Syd Arne* platform in December 2008 when around 650 m^3 was released to the sea during bunkering of crude oil from a seabed storage facility to a tanker. Teams out of Esbjerg Harbour were used to recover the oil from this incident, while Danish and German environmental aircraft were used to help focus the recovery activities [34].

Overall, in the Danish North Sea area, while there have been a number of groundings, collisions and loss of vessels at sea, those incidents have had only minor impacts. Between 2000 and 2010, the number of observed oil spills in Danish waters ranged from 33 in 2000 to a high of 164 in 2008 (125 in 2010). There were also wide variations in flight hours undertaken, with the highest ratio of observed slicks to flight hours being 0.45 in 2001 (the highest recorded was 0.96 slicks per flight hour in 1992) [34]. The ratio was just over 0.1 in 2009 and just over 0.4 in 2010, illustrating that there are wide variations year on year in the region. However, satellite imagery and methods to confirm the nature of spills mean that the data is much more accurate, as is identification of the source of spills. The number of observations of possible spills in the region rose from 175 in 2009 to 232 in 2013 (an increase of 33%). The number of spills reported from platforms and offshore wind facilities rose from 30 to 91 during that same period (an increase of 203%). However, that increase is likely to be due to the increase in the number of offshore wind facilities in the region and the majority of spills are very small [34]. There was also a decline in the number of spills identified as coming from ships, despite continued high levels of shipping traffic in the region [34].

In Danish waters, improved methods to detect and identify the source of spills mean that it is more likely that the companies responsible for spills can be held accountable for clean-up costs and the cost of environmental impacts. There is also a clear structure of responsibility to deal with spills and a range of assets in place to do so.

The Belgian North Sea region, an area of around 3,500 km^2 and with a coastline of approximately 65 km, is around 0.5% of the total area of the North Sea [35]. It is, however, an area of high risk of environmental, ecological and economic damage in the event of an oil spill. The region contains valuable marine habitats including fish spawning grounds, overwintering and foraging grounds and breeding areas for seabirds and intertidal nature reserves. As such, there are a number of protected areas in the region [35]. Belgian coastal areas and beaches are visited by around 15 million commercial overnight stays per year and 19 million day visitors annually making it an important area for the Belgian tourist sector [35]. Fisheries, sand and gravel extraction and, increasingly, offshore wind farms are other important activities in the region, but the most important activity is maritime shipping and transport. Belgium is close to the port of Dover in the UK and to Rotterdam and Antwerp in the Netherlands and has four main sea ports – Antwerp, Ghent, Zeebrugge and Ostend [35].

Under the Bonn Agreement, there is a zone of responsibility for Belgian waters which is shared between Belgium, France, the UK and most recently the Netherlands [9]. The narrow shipping lanes in the region, together with shallow sandbanks close to the shore and the central traffic separation system connecting the southern North Sea with the Dover Strait, mean that the region is at major risk from deliberate and accidental marine pollution from ships [35]. The result has been chronic oiling of seabirds and sensitive coastlines over decades [39, 40] with illegal discharges of engine room bilges and fuel oil sludge from merchant and other ships, together with oil cargo residues from tankers being a main source of oil [35].

Belgium has undertaken aerial surveillance under the Bonn Agreement [9] since 1991. It uses Britten-Norman Islander aircraft with SLAR on board and undertakes around 200–250 flight hours each year. During the 1990s, there was around 1 slick for every 4–5 flight hours (0.2–0.25 slicks per flight hour) and around 50 slicks per year. Since the early 2000s, this has fallen to 1 slick for every 10 flight hours or around 20 slicks per year [35]. An initial fall in the number of deliberate ship-source oil pollution incidents is associated with the designation of the North Sea as an SSA under MARPOL 73/78. A subsequent reduction from around 2004–2005 is identified as being associated with the introduction of the Port Reception Facilities (PRF) Directive 2000/59/EC of the European Commission which entered into force in December 2002 and required ports to provide facilities for ships to discharge oily wastes and residues into [41]. A comparison of oil slick numbers and their surface area before and after designation as an SSA shows that, in Belgian waters, there was a reduction of around 50% in the number of spills identified before and after 1999, although total oil volumes did not significantly decrease [42]. Following introduction of the PRF Directive, a comparison of spills before and after 2004–2005 saw no further decrease in the number of slicks but a significant decrease in the volumes of oil of almost 90%, with ships finding it more difficult to discharge large quantities of oil into the sea [35].

Mapping of oil spills in Belgian waters shows that, in 1991–1998, the majority of spills were found in the primary shipping lanes of the Dover Strait, Noord Hinder TSS and West Hinder TSS, while between 2006 and 2013, they have been located away from primary shipping routes and closer to secondary shipping routes used by short sea shipping vessels [35]. In addition to the reduction in numbers of operational discharges attributable to SSA status and the PRF Directive, measures to prosecute vessels illegally discharging have resulted in a number of prosecutions and fines, with one prosecution imposed by a Belgian court of 1.5 million euros for a major illegal oil discharge [35].

Historical data for shipping accidents shows that, since 1985, there have been 28 maritime accidents in and around the waters of Belgium with 23 involving accidental oil pollution and 5 having a significant risk of such pollution occurring. Two thirds of those accidents were as a result of collisions, half of those accidents occurring in the waters of France, the Netherlands and the UK but with the pollution posing an immediate threat to Belgian waters [35]. However, most of those accidents took place between 1985 and 2003; between 2004 and 2014, there were three accidents in Belgian waters and two in Belgian ports. Since 1985 there have been three major spills: 7,000 m^3 of oil was released in the waters off Dunkirk in 1997 from a collision between the *Bona Fulmar* and the *Teotal*; around 350–500 m^3 was released from the *Borcea* which suffered a structural failure in the waters off Zeeland in 1988, and around 500 m^3 was released from the *Tricolor* in 2002, when it collided with the *Kariba* in French waters [35]. The *Borcea* resulted in around 5,000–5,500 oiled birds which stranded along Dutch coastlines while *Tricolor* resulted in almost 20,000 birds stranding on French, Belgian and Netherlands beaches [35].

Risk assessment studies have shown that, with the introduction of offshore wind farms in Belgian waters, the risk of accidental marine pollution in the Belgian EEZ has increased by 8.5% as a result of the increased collision risk between ships and turbines [35], with the BE-AWARE study supporting this conclusion [11]. Risk reduction measures have therefore been put in place by competent authorities in Belgium, particularly the Flemish Agency for Maritime Services and Coastal Affairs. Those measures include activation of the 'Oostdyke' radar tower of the Scheldt radar chain in 2003, establishment of a common Flemish–Dutch nautical maritime system in 2008 and introduction of safety zones around offshore wind farms [35]. A national contingency plan, the 'General Emergency and Intervention (GEI) Plan North Sea', has also been put in place to provide a multidisciplinary response structure to deal with emergency situations and incidents [35].

Overall, in the Belgian North Sea zone, it is apparent that there has been a significant decrease in illegal oil discharges from shipping, although the risk of accidental spills remains high given the nature of the shipping lanes in the region, together with increasing offshore wind farm developments [35]. International cooperation with France, the Netherlands and the UK plays an important role, given the risk of accidents impacting on all four coastal states in the southern North Sea area [35].

The Netherlands has many coastal areas with soft coastlines and sandy beaches. It also has areas with artificial dykes along the mainland and delta coasts, and the Wadden Sea islands have sandy beaches and are located in shallow intertidal waters. The mudflats and salt marshes within the Wadden Sea are particularly sensitive to oil pollution [35]. The Netherlands sector is around 57,000 km^2 which extends from its boundary with Belgium to as far north as the Dogger Bank area [36]. In addition to the ports of Rotterdam, Antwerp and Amsterdam, served by shipping lanes, deep water routes and traffic separation systems, there are anchorages for vessels off the coasts of Vlissingen/Westkapelle in the delta area, off Hoek van Holland on mainland Zuid-Holland and off Ijmuiden on the mainland Noord-Holland coast. There are also around 150 oil and gas installations, served by underwater pipelines which transport oil and gas to the land [36].

Oil pollution monitoring in Dutch waters has taken place for far longer than anywhere else in the North Sea, with reports dating as far back as 1915, and reported on oiled birds being washed ashore around the Dutch coastline. Examples include birds being affected by the grounding of two American vessels in the Wadden Sea in 1920 and the grounding of the oil tanker *South America* on Maasvlakte (off Rotterdam) in March 1966 [35]. High numbers of oiled seabirds, which are seen as indicting offshore spills or leakages of oil, occurred in many years between 1921 and 1967, most occurring in the winter [36]. One of the largest spills in terms of its impact on mortality of wintering seabirds took place in January–February 1969 north of the Wadden Sea islands, with between 30,000 and 40,000 sea ducks affected. Pollution incidents were reported in all but a few years from 1969 to 1991, with the source of the spill known for the majority of spills [35].

Aircraft surveillance of spills has been undertaken by the Netherlands Rijkswaterstaat since 1975, with systematic visual surveillance starting in 1976 and remote sensing techniques introduced in 1982. While beached bird surveys seemed to indicate that spills occurred in the winter, these surveillance activities identified oil slicks year-round, the majority of which being found near or in shipping lanes north of the Wadden Sea, together with a cluster off Rotterdam harbour [35]. Monitoring flights from the late 1970s identified between 400 and 700 oil slicks annually, although that rose to 1,000 in some years. Detection rates were, however, lower in windy conditions and spills may therefore have been missed in autumn and winter months when prevailing winds made observations more difficult [35]. Detection of oil slicks for the years 1982 to 1991 ranges from a high of 1,024 in 1983 to a low of 378 in 1986 (712 in 1991). Those detections included both aerial surveillance and other detection methods and identified ships, rigs and platforms as being the source of many of the spills [35]. However, large numbers of spills were from unknown sources. More than half of the identified spills between 1982 and 1991 were from ships (57.6%), while 13.9% came from drilling operations from oil rigs and 28.5% from fixed production platforms or wellheads [35].

More recently, between 1992 and 2011, there have been a number of spills resulting in mass mortality of seabirds. These include the *Tricolor* in 1992, mentioned previously, which contaminated beaches in four countries, and the *Assi Euro Link* in 2003 which collided with the *Seawheel Rhine* and leaked bunker oil 50 km northwest of the Wadden Sea island of Terschelling. There have also been spills of other unidentified substances or non-oil substances, together with oil spills from unknown sources [35]. The majority of aerial surveillance activities undertaken under the Bonn Agreement [9] take place around the main shipping lines and platforms, with far less taking place in the northern part of the Dutch sector [36]. Two Dornier 228-212 aircraft are operated by the Netherlands Coastguard representing the Netherlands Ministry of Defence, one of which started daily patrols in June 1992 [12, 35]. The number of flight hours rose from 600 in 1983 to around 12,000 per annum since the mid-1990s. Around 30% of all flights take place during the hours of darkness, making the Netherlands unique in this respect among the North Sea states [35]. Those flights, combined with satellite images provided by EMSA CSN, allow for monitoring day and night, under all sky conditions and most weather conditions.

Results of those surveillance activities show a decline in detection of oil spills which is attributable to a range of factors including changes in ship design, provision of reception facilities in ports and better crew awareness. Shipping intensity has remained fairly stable in the harbours of Rotterdam and Amsterdam, although they are being used by larger vessels and so the tonnage transported through them has increased over a number of years [4, 5]. The major shipping lanes together with the approaches to Rotterdam, Amsterdam, Antwerp and Ijmuiden have the highest incidence of radar-identified spots (unidentified slicks, possibly pollution, but type of substance unknown). These spots are primarily associated with shipping, and there are relatively few spots in areas with oil and gas platforms [35]. Only if a spill can be directly associated with an offender using aerial surveillance and then only if a spill has been visually confirmed as being oils can this be used in evidence and a prosecution occur. Between 2006 and 2012, there were between 10 and 15 vessels suspected of an illegal discharge annually, but a decision to prosecute was only taken in about half of the cases, all of which were subsequently settled out of court. Fines imposed by the Netherlands courts are also between 10 and 20 times smaller than those of courts in France and Belgium [35].

There has been a clear improvement in levels of oil pollution in Dutch waters over many years. Not only has the frequency of illegal discharges declined but so too has the oil rates for stranded seabirds. Levels of chronic oil pollution have also fallen between 2009 and 2013 [35]. Levels of oil pollution have also declined in the waters of the UK North Sea, both in the major shipping lanes around the Dover Strait/English Channel and around oil platforms located in the northern North Sea [15].

Legislating oil and other pollutants entering the marine environment is complex with legislation such as MARPOL 73/78 [8] and the Bonn Agreement [9] being implemented by all North Sea states, in addition to national legislation such as the Danish Act on Marine Protection [38]. The legal situation in the UK is somewhat different from other North Sea states, as there are some minor differences between the legal systems in England and Wales compared to Scotland, but these are generally procedural differences [37]. A number of statutes have entered into UK law since the early 1970s including the 1971 Prevention of Oil Pollution Act, which repealed some earlier legislation and which has subsequently been amended on a number of occasions, and the 2005 Offshore Petroleum Activities (Oil Pollution Prevention and Control) Regulations which make certain types of oil spills a criminal offence [37]. A consolidated UK Merchant Shipping Act (MSA) of 1995 replaced around 30 other acts dating from as far back as 1894, together with measures which had been put in place in 1994 following the stranding of the oil tanker *Braer* off Shetland in January 1993. The 1995 MSA also brings into effect aspects of MARPOL 73/78 [8] including penalties for infringement of that convention [37]. It also ensures integration of international maritime law conventions relevant to protection of the North Sea into British law and includes a ban on discharges of oil from any vessels in British 'national waters' and is an important aspect as the UK does not have an exclusive economic zone (EEZ) unlike other North Sea states [37].

In terms of North Sea international agreements, the UK is a party to the Bonn Agreement and has also, under that Agreement, developed contingency plans for cooperation in dealing with major maritime disasters. In the English Channel, it worked with France to develop the MANCHE plan which includes measures relating to search and rescue and to counter pollution operations [42]. It has also developed multilateral agreements with Norway (NORBRIT Plan) which sets out arrangements for cooperation in the event of a blowout from a platform but does not cover search and rescue activities [37], and an agreement with Belgium, the Netherlands and France [42].

In dealing with oil spill intervention and 'places of refuge', the UK has given responsibility to deal with shipping and offshore incidents, and to assess risks to safety, to the Secretary of State's Representative for Marine Salvage and Intervention (SOSREP). SOSREP, which represents the UK's Secretaries of State for the Department of Transport, also has responsibility for national contingency plans and can override the powers of other government entities in the event of maritime casualties. That level of power may result, however, in problems such as failure to take adequate and appropriate actions in the event of a spill. If such a spill were to affect neighbouring North Sea states, the UK would be held responsible for any environmental damage [37]. Despite some opposition to UK legislation from certain sectors of the oil industry, particularly offshore operators, the UK National Contingency Plan, giving the UK the right to take unilateral action in the event of pollution, is identified as making the UK a pioneer in the field of oil pollution legislation [37]. In particular, UK legislation allows for a quick response by authorised agencies to deal mitigate or limit an oil spill as soon as it enters the marine environment [37].

In terms of oil entering the North Sea in UK waters, OSPAR monitoring activities for oil and gas production installations show that there were 94 oil and 119 gas installations in UK waters in 2001 and 88 oil and 196 gas installations in 2012 [15]. UK production in total oil equivalents (toeqs) fell from 211 million toeqs in 2001 to less than 86.5 toeqs in 2012 [15]. Across the whole North Sea, operational discharges of oil in produced and displacement waters (PW, DW) also fell over the same period. However, specifically in UK waters, there were some authorised discharges to the sea from UK installations (1 tonne in 2010, 4 tonnes in 2011 and 5 tonnes in 2012). Those discharges, done with the permission of the competent UK national authority, were the only ones occurring from installations within the North Sea region [15]. There were also a number of accidental spills from those installations with 372 spills of 1 tonne or less by volume in 2003 and 6 spills of more than 1 tonne by volume. That fell to 239 and 6 spills, respectively, in 2012. EMSA CSN data further identified that there were 343 images acquired in 2007 with 142 spills detected that year. In 2011, the figures were 582 images and 136 spills. These figures identify a small decline in detections per image from 0.41 in 2007 to 0.23 in 2010 [21]. Bonn Agreement aerial surveillance data for the period 1990 to 2010 also shows that there has been a decline in spills in UK waters, with 180 spills in 1990 at a ratio of 0.32 spills per flight hour, down to 10 spills (3 from rigs, the rest from unidentified sources) at a ratio of 0.01 spills per flight hour.

Overall, it is clear that there has been a general reduction in oil inputs to the UK North Sea region over more than two decades, with agreed discharges from oil installations being the main input taking place in recent years.

The German part of the North Sea, which is in the east and southeast borders of the Wadden Sea, covers an area of around 41,000 km^2 [22]. Within the German EEZ are a number of ports including Wilhelmshaven, Bremerhaven, Cuxhaven and Büsum. The region contains major ship traffic routes which connect the river Elbe, southwestern exit of the Kiel Canal and western Baltic Sea with the North Sea and also are the location of oil and offshore wind facilities [22]. The German North Sea coast also has three national parks, all of which are UNESCO World Natural Heritage sites [22]. The Wadden Sea is a nursery for young fish and a feeding and nesting ground for wading birds and wildfowl, while the coasts around the Wadden Sea have many sheltered tidal flats, salt marshes and estuaries which are highly sensitive to oil pollution [22]. In order to determine the sensitivity of particular areas to oil contamination, an automated expert model for the German part of the Wadden Sea area has been developed [43, 44] which provides a tool for decision making, precautionary measures and design of oil spill response strategies [22]. Using that automated system enables the Central Command for Maritime Emergencies (CCME) to calculate the spatio-temporal sensitivity of intertidal areas and have been used in conjunction with other data to produce sensitivity maps for the German North Sea coast [22].Actions such as the use of chemical dispersants for spills in intertidal waters have also been incorporated into oil spill models to help forecast the impacts of such chemicals on different habitats and ecosystems under different wind conditions and currents and can help determine the best action to take in the event of a spill in a specific area or weather condition [22].

Germany has undertaken aerial surveillance activities since 1984, using a Cessna 406 aircraft at that time. More recently, the German Federal Waterways and Shipping Administration owned two Dornier Do 228-212 LM aircraft, and these are operated by Naval Air Wing 3 based in Nordholz, on behalf of the CCME and the German Federal Ministry of Transport and Digital Infrastructure (BMVI) [12]. One of those aircraft was upgraded to a Do 228 New Generation in 2011 [22]. Bonn Agreement aerial surveillance figures for the period 1990 to 2010 for the German North Sea region identify that there were 130 observed spills in 1990 from a total of 432 flight hours, giving a ratio of spills to flight hour of 0.30 [14]. That year saw the highest number of observed spills but at that time the figure includes all spills, not just those confirmed as oil. From 2003 onwards, spills reported in Bonn Agreement annual reports are those confirmed as oil; in 2003 there were 53 observed spills from over 664 flight hours, at a ratio of 0.10 spills per flight hour. In 2010 the figures were 28 spills (1 from a ship, 27 from unknown sources) observed from 778 flight hours, at a ratio of 0.04 spills per flight hour [14]. From these findings, it is apparent that there has been a decline in the numbers of spills observed annually over two decades, while between 2000 and 2010, there was a fall of around 75% from 120 to 34 slicks in those years [14].

Germany has, since the 1980s, also been involved in a range of projects to use satellite data for detection of marine oil pollution. In 1994, field studies using space-borne imaging radar C/X-Band SAR (SIR-C/X-SAR) were carried out in the German Bight of the North Sea [22] with satellite data using SIR-C/X-SAR enabling research scientists at the University of Hamburg to differentiate between biogenic sea slicks (e.g. algal blooms) and anthropogenic oil spills and to discriminate between different types of surface films even in low to moderate wind conditions [45]. The use of combined aerial surveillance and space-borne radar satellite services has enabled Germany to develop a combined operational monitoring system. That system can deliver partly automatic first alerts for large sea surface areas up to 400 km^2 independent of cloud and report within half an hour of a satellite passing overhead. It can also be used to monitor hot spots at higher risk of oil spills [22]. In addition, the German EEZ is also covered by the EMSA CSN [20, 23]. EMSA CSN, which includes German waters in both the North Sea and Baltic Sea, acquired 1,111 images for Germany between April 2007 and 31 January 2011 (273 images in 2007, 544 in 2010) [21]. In 2007 there were 59 satellite detections at an average of 0.22 spills per image. In 2010 there were 50 detections at an average of 0.09 spills per image [21]. Across the period 2007 to 2010, the proportion of spills in German waters that were checked by aerial surveillance and verified as oil was 35% of all spills detected by satellite. In 2010 there were 19 verified oil spills out of the 50 detected spills [21]. These figures also support the Bonn Agreement data and indicate that there has been a reduction in the number of spills in German waters over recent years.

When a potential spill is detected by remote sensing, drift models are used to identify where pollution response may be needed (on land or sea) and may be used to hindcast a spill to identify its source by using AIS data to identify ships in the area around the time of a spill. A number of studies were also conducted at the University of Hamburg in the late 1990s for oil spill detection. These included examination and analysis of 700 images acquired between December 1996 and November 1998 covering the Baltic Sea, North Sea and northwestern Mediterranean Sea and using model wind speeds to estimate the influence of wind on detectability of spills [46]. Findings of such projects include that levels of pollution density remain high in the southern North Sea throughout the year, although less pollution was identified during winter months [46]. However, it is likely that this is a result of increased wind speeds rather than less pollution occurring [46] which supports the findings in the Netherlands chapter on variations in spill identification between summer and winter months [36]. Identification of the type of spill, together with decisions on the use of dispersants, is necessary to determine potential environmental damage and actions necessary to help mitigate such damage. Long-term simulations of atmospheric marine conditions are therefore important in such decision making in areas such as the German Wadden Sea [22].

As has already been discussed for the Belgian and Netherlands areas of the North Sea [35, 36], the use of beached bird surveys provides a tool for monitoring spatio-temporal trends in chronic oil pollution. Beached bird surveys are now used in around 10 European countries, while over four decades, they have been undertaken in Belgium, the UK, Denmark, Germany and the Netherlands [47]. Seabirds are particularly sensitive to marine pollution and high numbers of birds can be oiled and die as a result of oil, with many washing ashore depending on prevailing winds, for example. Particularly in the early years of such surveys, they often took place over a single midwinter weekend in February, making it difficult to compare results between years, since the prevailing winds differed between mild and severe winters [47].

At a North Sea ministerial conference in 1990, it was decided to investigate the use of beached bird surveys as an indicator of effectiveness of actions to reduce oil pollution, with a report being published in 1992 [48]. Subsequently, in 1993, at an interim ministerial conference, it was agreed that monitoring oiled seabirds was a useful indicator [47]. A range of studies took place in the 1980s and 1990s which found that oil rates tended to be high in the English Channel and southern and eastern North Sea where shipping intensities are high and that they were much lower in the northwest [49, 50]. Various factors such as bird species and whether the bird was alive or dead when it was contaminated by oil were used to develop oil vulnerability indices (OVIs) for a range of species using data from the 1970s through to the 2010s, with beached bird surveys being viewed as valuable, independent and cost-effective instruments to monitor chronic levels of pollution in the North Sea [47, 51]. Surveys measuring the proportion of oiled common guillemots among those found dead or dying on beaches are used as an ecological quality objective for the North Sea (EcoQC element f) [52], as part of the OSPAR ecosystem approach for the North Sea [25]. Other EcoQCs include eliminating eutrophication and reducing levels of hazardous substances in seabird eggs [25].

In the 1950s to the 1970s, chronic oil pollution, rather than pollution from incidents relating to shipping or oil rigs, was seen as a significant problem within the North Sea and beyond, particularly around shipping lanes, which posed an ongoing, continuous threat to marine wildlife [47]. Reported winter-oil rates in the Netherlands were probably the highest in the world at that time. During the 1980s and 1990s, there was a gradual decline in oiled bird rates together with a decline in the amount of oil washing ashore, with the oil rate for different species also falling, particularly in coastal seabirds [47]. This decline was seen in all North Sea countries, and similar declines were reported around the world and indicated that coastal waters were much better protected than offshore waters as it was coastal seabirds (common eider, coastal gulls), rather than pelagic bird species (e.g. auks, fulmar), which saw the greatest drop in oil rates [47].

In recent years, there have been a continuation in the decline in oil rate and an increase in the abundance of some overwintering species. The declining trend in oil rates shows that measures taken to reduce volumes of oil entering the North Sea have been effective and have reduced the levels of chronic oil pollution across the region [47]. While identifying that action is still necessary to reduce pollution levels away from coastal areas, as there continue to be illegal spills in offshore waters, it can be concluded that chronic oil pollution is no longer a threat in the region [47].

Monitoring and sampling spills against agreed standards also plays an important role in ensuring that when an oil spill occurs, it can potentially be matched to a source which can then be fined or made to contribute to clean-up costs. In order to establish an internationally agreed standard procedure for oil spill identification, Bonn-OSINet (Oil Spill Identification Network of Experts Within the Bonn Agreement) was established in 2005 [53], with Dr. Gerhard Dahlmann[1] as convenor [54]. This followed on from the sinking of the *Tricolor* in the English Channel in 2002, with oil from that vessel reaching the coasts of Belgium, France and the Netherlands. Despite knowing the source of the oil, it was not possible to prove that the oil came from the *Tricolor* and no match was found between source and spill samples.

Development of a common method for oil spill identification faced a number of challenges including variability of oil spill cases, different circumstances in which spills occurred and different experiences between laboratories which had worked with different types of oil [54]. However, with cooperation between laboratories and annual round robins to increase knowledge, OSINet participation increased from 6 members in 2005 to 50 scientists from 27 laboratories across 20 countries. Due to the fact that petroleum contains many thousands of different organic compounds, it was decided to analyse samples using two methods: gas chromatography with flame ionisation detection (GC–FID) and low-resolution gas

[1] Dr. Gerhard Dahlmann worked previously at Bundesamt fur Seeschifffahrt und Hydrographie (BSH; Federal Maritime and Hydrographic Agency) in Hamburg, Germany, and contributed to the chapter on Bonn-OSINet with permission from BSH. He subsequently retired from his post at BSH in early 2015.

chromatography–mass spectrometer coupling (GC–MS) [54]. The general concept for comparing oil samples is to look for differences between them since, for example, fuel oil cannot be identical with lubricating oil [54]. Detailed classification of oil is achieved based on compound concentrations and relationships between compound groups, and where the source of oil is known, a minimum set of compounds is chosen (normative compounds) to be used in every case. In addition, other compounds identified in a sample from an oil spill case (informative compounds) may also be used to compare spill samples with those from suspected sources [54]. There are some difficulties in comparing a spill sample with a suspected source sample including weathering processes and contamination since the composition of oil changes once it enters the environment. This can lead to difficulties in proving that a spill comes from a particular source, as there may be differences in their composition [54]. However, a specific method (NORDTEST method NTChem001) is used to identify how compounds and compound classes decrease under different weathering processes, with the result that it is possible to offer a 'probable match' conclusion between source oil and spill oil [54].

An online database and evaluation system, COSIweb (computerised oil spill identification, Web based), has also been developed, containing samples from many major accidents and of hundreds of different crude oils, oil products and waste oils from real spills of samples. COSIweb, which is hosted by BSH in Germany, can be used by OSINet members and can be searched for unknown samples. It can also be used to compare samples, with a response being produced automatically within minutes [54]. This system and the development of Bonn-OSINet have resulted in strong cooperation between laboratories and will clearly provide a very valuable resource in identifying the source of spills.

While oil discharges still take place in the North Sea, both from ships and from oil and gas installations, the number of such discharges has fallen over many years. Legal measures at international, regional, EU and national levels mean that operational discharges are much more strictly controlled. Monitoring activities, which have increased the possibility of a discharge being quickly identified, have also contributed to a reduction in oil entering the North Sea. Accidental spills from ships are now very infrequent due to better ship designs and anticollision measures in the region's busy shipping lines. However, illegal discharges do remain a problem, as highlighted by beached bird survey data, for example. The availability of tools to rapidly identify spills at sea (aerial surveillance, satellite imagery), to confirm whether a spill is oil or not, to identify vessels in the region of a spill (e.g. AIS, EMSA SSN) and to match a spill sample with oil from a potential source (COSIweb) should further drive down intentional, illegal pollution in the North Sea, as the risk of a polluter being caught, prosecuted and fined has increased.

Overall, therefore, it can be concluded that levels of oil pollution in the North Sea have improved significantly over many years, but work is still needed to maintain or even improve the situation in the future. OSPAR has, for example, identified that ageing oil and gas infrastructure in the North Sea presents a challenge for the future, as specific problems may arise from decommissioning and disposing of rigs [25]. As has been identified in the Baltic Sea [55], actions to continue to improve the state of the North Sea will require ongoing support and investment from state authorities in a range of areas, from pollution control to hazard management, and also the involvement from private companies operating in and around the North Sea.

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