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Conclusions

Angela Carpenter[1]

Abstract

This chapter examined Bonn Agreement annual statistics from aerial surveillance activities between 1986 and 2010 and examines the levels of flight hours, 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 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.

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Keywords

North Sea, oil pollution, European Union, Bonn Agreement, BE-AWARE Project, OSPAR Convention, MARPOL Convention, European Maritime Safety Agency, CleanSeaNet, aerial surveillance, oil spill monitoring, satellite monitoring, beached bird surveys, shipping, oil installations, Bonn OSINet, COSIweb, PRF Directive, OSPAR Quality Status Reports

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 in 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 regions 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 a 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 tons of crude oil and 250-300 million tons 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), for example [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 sub-regional 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 sub regions; the Atlantic, the Northern North Sea, the Eastern North Sea, the Southern North Sea and the 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 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 infra-red (FLIR) sensors, laser fluorosensor (LFS, lidar), 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 hours 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 spills observed in the EEZs of Bonn Agreement member states as a result of aerial surveillance activities between 1990 and 2013 [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 in 1987; 532 in 1988; and 1104 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].

Table 1. Number of spills identified by Bonn Agreement country, 1990 – 2013; confirmed as oil for 2003 - 2013

Year	Bel-gium	Den-mark	France	Ger-many	Neth-er-lands	Nor-way	Swe-den	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	1181
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]

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 (1181 spills) reflects the high figure for the Netherlands in that year [14].

Improvements in the accuracy of oil spill identification means 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 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 hours in all years since 1994, the resulting ratio of observed slicks to flight hours fell from 0.22 slicks/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, the Norwegian SATHAV programme, Germany's TerraSAR-X and Italy's COSMO-SkyMed, for example [21, 22].

In 2007 there were 1669 image acquisitions covering the waters of Belgium, Denmark, Germany, the Netherlands, Norway, Sweden and the UK (3189 in 2008, 2947 in 2009 and 3032 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, 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 hours of image acquisition, around 80% of spills identified by CSN images in Danish waters were confirmed as being oil; 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 has 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 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 Seas 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 fly about 200 hours 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 one hour 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 means 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 means 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 sea-birds, and inter-tidal nature reserves, for example. 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 to 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 [42]. 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, Noordhinder TSS and Westhinder TSS, while between 2006-2013 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, for example [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 inter-tidal 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 seaducks 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 400-700 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 range 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 north west 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 Straits of Dover/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, for example [38]. The legal situation in the UK is somewhat different from other North Sea states, as there are some 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 makes 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 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 MANCHEPLAN which includes measures relating to search and rescue and to counter pollution operations [42]. It has also developed multilateral agreements with Norway (NORBRITPLAN) which sets out arrangements for cooperation in the event of a blow-out from a platform but does not cover search and rescue activities [37], and an agreement with Belgium, the Netherlands and France (QUADRIPARTITE ZONE) [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 Representatives for Marine Salvage and Intervention (SOSREP). SOSREP, which represents the UKs 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, result in problems such as, for example, 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, 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 in the east and south-east borders 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, for example. The region contains major ship traffic routes which connect the river Elbe, south-western 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 Do228 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 spaceborne 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 (for example 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 spaceborne 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 north-western 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 spatial and 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 mid-winter 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 Ministers 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 Ministers 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 OSPARs 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 (auks, fulmar, for example) which saw the greatest drop in oil rates [47].

In recent years there has been a continuation in the decline in oil rate and an increase in the abundance of some over-wintering species. The declining trend in oil rates show 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 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[2] 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, different experiences between laboratories which had worked with different types of oil, for example [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 analyze samples using to methods: gas chromatography with flame ionization detection (GC-FID) and low resolution gas 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 are 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 con-

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[2] 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.

tamination since the composition of oil changes one 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 (Computerized 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 anti-collision 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 (AIS, EMSA SSN, for example), and tools 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, for example [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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