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Oil Pollution in the Mediterranean Sea: Part II

National Case Studies

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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 to Part II: National Case Studies

Angela Carpenter and Andrey G. Kostianoy

Abstract This book (Part II of a volume on “Oil Pollution in the Mediterranean Sea”) presents a review of knowledge on oil pollution in the Mediterranean Sea, through a series of national and regional case studies. Making use of a range of data on oil extraction and production activities, oil transportation, satellite technology, aerial surveillance, in situ monitoring, oil spill sampling and oil fingerprinting, for example, it presents a picture of trends in oil pollution in various areas of the region over many years. It examines national practices in a number of Mediterranean Sea states. A range of legislative measures are in place to protect the marine environment of the region. For example, the Mediterranean Sea and its various regions, such as the Adriatic Sea, have Special Status for the prevention of pollution by oil from ships under the International Convention for the Prevention of Pollution from Ships and its Protocols (MARPOL 73/78 Convention). At the same time, the Convention for the Protection of the Mediterranean Sea Against Pollution (Barcelona Convention, 1976) and its various protocols provide a legislative framework under which countries in the region can work together to cooperate in preventing pollution from ships, for example, and work together to combat pollution in the event of an emergency. National contingency planning and oil pollution preparedness and response activities and the work of the Regional Marine Pollution Emergency Centre (REMPEC) for the Barcelona Convention’s contracting parties are also discussed within various national case studies. This book brings together the work of scientists, legal and policy experts, academic researchers and specialists in various fields relating to marine environmental protection, satellite monitoring, oil pollution and the Mediterranean Sea.

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Contents

The Mediterranean Sea is bounded by the coasts of Europe, Africa and Asia, from the Strait of Gibraltar in the west to the entrances to the Dardanelles and the Suez Canal in the east [1]. It covers an area of approximately 2.5 million km^2 and has an average water depth of 1.5 km with a maximum depth of just over 5 km [1]. The Mediterranean Basin is approximately 4,000 km from east to west and has a maximum width of 800 km [1].

The Mediterranean Sea is divided into two deep basins, the Western and Eastern Basins, and is further subdivided into a number of sea areas. These are (from west to east) Alboran Sea, Balearic (Iberian) Sea, Ligurian Sea, Tyrrhenian Sea, Ionian Sea, Adriatic Sea and Aegean Sea (The Archipelago) [1]. The Mediterranean Sea also has 11 sub basins, as outlined in Table 1.

Travelling clockwise from the west at the Strait of Gibraltar (see Fig. 1), the Mediterranean Sea is bounded by Spain, France, Monaco, Italy, Slovenia, Croatia, Bosnia and Herzegovina, Montenegro, Albania, Greece, Turkey, Syria, Lebanon, Israel, Egypt, Libya, Tunisia, Algeria and Morocco. Two island states located in the Mediterranean are Malta (south of Sicily) and Cyprus (which lies south of Turkey and west of Syria). The Gaza Strip, together with the British Overseas Territories of Gibraltar, and Akrotiri and Dhekelia, also have coastlines on the Mediterranean Sea.

Table 1 List of the 11 Mediterranean sub basins

Sub basin	Bordering countries
Alboran	Spain, Morocco, Algeria
North-western	Spain, France, Monaco, Italy
South-western	Spain, Italy, Algeria, Tunisia
Tyrrhenian	Italy, France
Adriatic	Italy, Croatia, Albania (plus Montenegro, Slovenia and Bosnia and Herzegovina[a])
Ionian	Italy, Albania, Greece
Central	Italy, Tunisia, Libya, Malta
Aegean	Greece, Turkey
North Levantine	Turkey, Cyprus, Syria, Lebanon
South Levantine	Lebanon, Israel, Egypt, Libya
Marmara Sea	Turkey

Adapted from [2, p. 7]

[a] These states did not appear in the original table

Fig. 1 Shaded relief map of the Mediterranean Sea. Source: Wikipedia Commons – Mediterranean Sea Relief Location Map [3]

The Eastern Mediterranean Sea, and the east coast of Italy (in the Adriatic), is the location of the majority of oil and gas exploration and exploitation activities. In 2002 it was estimated that there was a reserve of around 50 billion barrels of oil and 8 trillion m^3 of gas in the region (about 4% of world reserves) [2], and, in 2005, there were over 350 wells drilled for offshore production in the waters off Italy, Egypt, Greece, Libya, Tunisia and Spain [2], of which the majority were located along the Northern and Central Adriatic coasts of Italy (around 90 of the 127 offshore platforms for the extraction of gas in Italian waters in 2007) [4].

In 2011, gas was discovered in what is the Leviathan gas field, 135 km off the coast of Israel, with an estimated volume of 16 trillion ft^3 of gas (approximately 453 million m^3) [5]. In August 2017, a contract was signed to drill two wells and complete four production wells in the Leviathan field [6].

There have also, in the last decade, been significant exploration activities off the coast of Cyprus, following the development of new technologies to assess and reach previously inaccessible reserves, worth an estimated $131 billion [7]. Most recently, the drilling of up to 25 new wells and installation of two new platforms were planned up to 2021 in the Prinos and Prinos North oil fields in the Gulf of Kavala offshore of Northern Greece [8].

Oil and gas exploration and production activities pose a hazard to the marine environment in a number of ways, both during the exploration phase and the production phase. Environmental monitoring frameworks have been in place in some regions for many years, including in the North-East Atlantic Ocean/North Sea region under the OSPAR Convention [9], where a framework for environmental monitoring of oil and gas activities was established in 1999 [10] and where a range of ever more stringent emission standards for discharges of oil in drilling fluids, cuttings and produced water from installations in the region have developed since that time [11].

Standards for the disposal of oil and oily waste from oil and gas installations in the Mediterranean Sea are set out in a protocol to the 1976 *Convention for the Protection of the Mediterranean Sea Against Pollution* (Barcelona Convention) [12]. The *Protocol for the Protection of the Mediterranean Sea Against Pollution Resulting from Exploration and Exploitation of the Continental Shelf and the Seabed and its Subsoil* (Offshore Protocol) was adopted in 1994 [13], although it did not enter into force until 2011, and by 2017, only 14 out of the 22 Mediterranean countries had signed the protocol, only 7 of which had ratified it [14]. Section III, Article 10 of the Protocol, which relates to oil and oily mixtures and drilling fluids and cuttings, sets out specific standards including a maximum oil content of 15 mg/L in undiluted discharges from machinery spaces and a maximum average oil content of 40 mg/L for production water and a maximum limit of 100 mg/L for any single discharge [14].

The European Union has also put in place offshore safety legislation, in order to reduce the risks of major accidents and their potential consequences for Mediterranean countries [15]. This legislation has to be implemented by EU member states and is therefore not applicable to non-EU countries bordering the south and east of the Mediterranean Sea. EU legislation includes:

- *Commission Implementing Regulation No. 1112/2014 of 13 October 2014* determining a common format for sharing of information on major hazard indicators by the operators and owners of offshore oil and gas installations and a common format for the publication of the information on major hazard indicators by the member states [16].
- *Directive 2013/30/EU of the European Parliament and of the Council of 12 June 2013* on safety of offshore oil and gas operations and amending Directive 2004/35/EC [17]. Paragraph 51 of the Directive sets out that the European Union has acceded to both the Barcelona Convention [12] and the Offshore Protocol [13], while Article 1 of the Directive notes that it "establishes minimum requirements for preventing major accidents in offshore oil and gas operations and limiting the consequences of such accidents (Art. 1, Subject and scope).
- *Commission Decision of 19 January 2012* on setting up the European Union Offshore Authorities Group [18], which has the task of serving as a forum for the exchange of experiences and expertise between national authorities and the European Commission (Art. 2, Task 1) and encompasses "all issues relating to major accident prevention and response in offshore oil and gas operations within the Union, as well as beyond its borders, where appropriate" (Art. 2, Task 2).

Shipping activities also pose a threat to the marine environment of the Mediterranean and wider seas and oceans. One report from the early 2000s estimated that the total amount of crude oil passing through EU waters could be over 1 billion tonnes and that the Mediterranean Sea was most affected by dumping of hydrocarbons into the sea from ships, with nearly 490,000 tonnes being released annually [19]. A 2007 report indicated that there were more than 200 accidental spills from ships annually in the region and this reflects the high commercial activity taking place in the region [20]. The diversity of shipping in the region includes fishing fleets, ro-ro ferries, leisure craft, military vessels, large container carriers and tankers and also fixed "vessels", including offshore oil exploration and exploitation vessels [21].

In 2017 it was noted that there has been a decrease in major accidental oil spills from ships worldwide, with the average number of large oil spills from tankers (over 700 tonnes) having fallen to an average of 1.7 spills per year between 2010 and 2016 [22]. One major oil spill in the region, that of the *MV Haven* in April 1991 off Genoa, was identified in the 2017 report, which notes that between 1 January 1994 and 31 January 2013, approximately 32,000 tonnes of oil entered the Mediterranean Sea as a result of accidents, that figure including 13,000 tonnes originating from an incident at the Jiyeh power plant in Lebanon in July 2006 (discussed below) [22].

The *MV Haven*, the biggest ever recorded in the Mediterranean, was one of the only two of the largest oil spills occurring globally since the late 1960s, to take place in the waters of the Mediterranean Sea (see Table 2 [23]). 144,000 tonnes of oil was spilled in the case of *MV Haven* (number 5 out of the top 20). The second incident was the *Irenes Serenade* spill in Navarino Bay, Greece, in 1980, where 100,000 tonnes of oil was spilled (number 9). In both of these cases, more than 100,000 tonnes of oil was spilled [23].

Table 2 World 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	*Jakob 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

Source: ITOPF [23]

Note: Quantities rounded to the nearest thousand tonnes. Spills in bold occurred in the Mediterranean Sea

Other incidents occurring in the Mediterranean include a spill of 18,000 tonnes from the *Cavo Cambanos* in 1981 and a spill of around 12,200 tonnes of heavy fuel oil and slops from the collision of the *Oil/Bulk/Ore Carrier Sea Spirit* and the *LPG carrier Hesperus* west of Gibraltar in 1990 [24]. While the latter incident took place outside the Mediterranean Sea, oil entered the region through the Strait of Gibraltar, carried by winds and currents, and presented a serious threat to the coasts and waters of Spain, Morocco and Algeria [25].

The most recent spill to occur in the Mediterranean Sea came from the shipwreck of the *Agia Zoni II* tanker, near the port of Piraeus and off the coast of Salamina, Greece, on 10 September 2017. In that case the oil tanker, loaded with fuel oil and marine gas oil, sank [26]. The vast majority of oil on board was contained through the deployment of oil spill cleanup units [27], and the volume of oil spilled was estimated at about 700 tonnes [26]. The *Agia Zoni II* spill was just over one tenth of the size of the *Prestige* spill, number 20 in the top 20 spills set out in Table 2.

As well as oil and gas production and shipping, oil can also come from a range of activities including land-based sources such as petroleum refineries and power stations. In this latter example, as noted previously, a large release of oil came from an incident at the Jiyeh power plant in Lebanon in July 2006 [22]. In that case, between 12,000 and 15,000 tonnes of fuel oil entered the marine environment following a missile attack on fuel tanks at the power plant [28]. Due to delays in initiating cleanup operations, as a result of conflict in the region, more than 150 km of Lebanese coastline was contaminated by oil as the spill was carried out to sea and also dispersed along the coast of Lebanon [28]. It was subsequently found that some sandy beaches and rocky shorelines were extremely contaminated, while others were moderately or lightly contaminated [28]. As well as incidents such as the Jiyeh example, oil can also enter the marine environment from coastal oil refineries through effluent outputs. A 2007 report estimated that, between 1988 and 1997, some 22,563 tonnes of oil entered the Mediterranean Sea in this way each year [20]. The largest sources came from coastal refineries in Algeria with 2,970.71 tonnes per year (tpy), Egypt (2,982.78 tpy), France (2,075.59 tpy), Greece (2,216.82 tpy), Italy (2,713.39 tpy), Spain (1,458.88 tpy), Syria (1,330.62 tpy) and Turkey (3,999.70 tpy) [20; Table 27]. The figures for France, Spain and Turkey do, however, include all their coastal waters, not just those located in the Mediterranean.

This book follows on from an earlier volume on "Oil Pollution in the Baltic Sea" [29] and "Oil Pollution in the North Sea" [30]. Part I contains 15 chapters including an Introduction and Conclusions written by the volume editors. Part II contains a further 12 chapters including Introduction and Conclusions, again written by the volume editors. This Introduction to Part II provides a brief overview of the Mediterranean Sea and some of the problems of oil pollution facing it, including offshore exploration and exploitation activities, ship source pollution and oil pollution from land-based sources such as power plants and petroleum refineries. It is followed by ten country-specific chapters presenting case studies for nine Mediterranean countries (in the case of Italy, there are two chapters, one excluding and one specifically covering the Adriatic Sea).

In line with the earlier listing of Mediterranean countries, chapters are presented in a clockwise order, starting with Spain and moving round the region to Algeria. The chapter on oil pollution in Spanish waters considers the ecological and socio-economic importance of Spanish waters and shores as a means of illustrating the potential significant impact of an oil spill in that region. It then looks at major sources of oil pollution and the Spanish oil pollution prevention, preparedness and response system, together with surveillance, forecasting and source identification activities undertaken by a range of Spanish institutions and agencies. The next chapter examines oil pollution in French waters, including an overview of the French Mediterranean marine pollution prevention and response organization, examines both operational and accidental oil spills, and highlights the main areas of progress made under the French jurisdiction as regards oil pollution. Two chapters relating to Italian waters are included in Part II. The first of these focusses on oil spill monitoring in Italian waters through the satellite mission COSMO-SkyMed, the largest Italian investment in space systems for Earth observation, designed to provide data in a range of areas using synthetic-aperture radar (SAR) sensors for oil spill detection. The second Italian chapter focuses specifically on the Adriatic Sea, an area where oil pollution poses a threat from sources including offshore industry, natural seeps, oil and gas extraction and shipwrecks. While the entire Mediterranean Sea region has Special Area status under MARPOL Annex I [31], which places limits on legal discharges of oily waste, for example, the Adriatic Sea holds particularly sensitive sea area (PSSA) status, with even tighter restrictions than for the rest of the Mediterranean. The Italian chapter relating to the Adriatic Sea examines various sources of pollution including, for example, accidental and operational pollution from vessels in the region, offshore gas and oil activities and natural seeps. Also covering the Adriatic Sea are two further chapters. The first of these focuses on Slovenian waters in the northernmost part of the Adriatic Sea, an area of potentially high risk of significant damage to a short coastline full of important cultural sites, protected waters and coastal sites and a particularly sensitive shallow sea. The second chapter is on the Croatian Adriatic area and discusses the large number of SAR images obtained in the region between 2003 and 2016 through a number of research projects and identifies that there were a large number of oil slicks in the region, the main source of which were routine tank-washing operations and illegal discharges. This poses a particular threat in the Adriatic, a small semi-enclosed sea in which accidents can have far-reaching impacts on the coastal areas of all countries located within it. The chapter on oil pollution in the Turkish waters of the Mediterranean Sea, where there are significant vessel flows through the various Turkish Straits, examines the Turkish strategy for responding to accidental oil pollution through mechanical oil recovery techniques (chemical dispersants are not allowed without specific permission). The chapter also examines oil pollution monitoring, including both aerial and satellite monitoring, sources of pollution and penalties. The chapter on oil pollution in the marine waters of Israel has, as its main focus, the international legal framework and range of national legal measures in place to achieve Israel's commitment to prepare for, respond to, and combat all sources of pollution in the marine environment, particularly oil. It includes a discussion on oil pollution equipment in Israel. The chapter on oil pollution in the waters of Cyprus has, as its main focus, development of a National Contingency Plan (NCP) for Oil Pollution Combating, to which both the government of Cyprus and the private sector contribute. The NCP is considered to be extremely important as any new hydrocarbon discoveries in the region between Israel, Egypt and Cyprus has the potential to increase oil traffic and thus increase oil spill risks in the region. The final national case study chapter examines oil pollution in the waters of Algeria which, as one of the top three oil producers in Africa, is potentially a major source of oil pollution on the southern shore of the Western Basin of the Mediterranean Sea. Algeria has six coastal terminals for the export of petroleum products along its 1,644 km coastline, together with five oil refineries (three of which are in coastal cities). The chapter considers the state of pollution in Algerian waters including its major sources. It also identifies that it is a member of the Barcelona Convention and

REMPEC, has REMPEC approval for its National Contingency Plan to deal with such pollution, and is committed to reducing the quantities of petroleum hydrocarbons entering the marine environment. Part II then ends with some conclusions.

While it had been hoped to include chapters from every state bordering the Mediterranean Sea, geopolitical problems in the region (particularly in the east and along the North African coast) means that not all countries are included here. However, Part II does present a focused overview of the sources and risks of oil pollution in the Mediterranean Sea region in its various basins and is complemented by chapters on the international context which appear in Part I of this volume. Part I includes chapters looking at the history, sources and volumes of oil pollution at the Mediterranean scale; shipping and oil transportation; the roles of the IMO, Barcelona Convention and REMPEC; and numerical modelling in both the Eastern and Western Mediterranean Sea, for example.

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 environmental monitoring, for example. It is also aimed at graduate and undergraduate students in marine environmental sciences, as well as policy studies and legislative studies. The volume as a whole will provide a valuable resource of knowledge, information and references on oil pollution in the Mediterranean Sea.

Work started on this volume in November 2015 when a number of authors were approached to contribute to a volume on oil pollution in the Mediterranean Sea. The response to those invitations was overwhelmingly positive, with the large number of chapters making it necessary to produce the volume in two parts – Part I on the international context and Part II on national case studies. Following final agreement with Springer-Verlag, in December 2015 to go ahead with this volume, it took just over two and a half years to bring together all the chapters.

As noted previously, since commencing with this volume, there has been one major oil spill in the Mediterranean Sea, in the waters of Greece, from the sinking of the tanker *Agia Zoni II* near the port of Piraeus in September 2017. This can be seen as a very positive situation and illustrates the success of measures put in place to minimize oil pollution in the region over several decades. It also illustrates the need for countries in the region to continue to work towards oil pollution prevention and to cooperate in the event of an incident, in the event that an oil spill occurs.

This book follows on from the “Oil Pollution in the Baltic Sea” and the “Oil Pollution in the North Sea” volumes in the Springer-Verlag *Handbook of Environmental Chemistry* book series [29, 30], and following on from this Mediterranean volume, plans are already in place for a volume on “Oil Pollution in the Black Sea”, again to be presented in two parts.

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References

1. International Hydrographic Organization (1953) Limits of the oceans and seas. Special Publication No. 28, 3rd edn. IMP, Monte-Carlo. https://epic.awi.de/29772/IHO1953a.pdf
2. Laubier L (2005) Mediterranean Sea and humans: improving a conflictual partnership. Handbook of environmental chemistry, vol 5, pp 3–27. https://doi.org/10.1007/b107142
3. Wikimedia Commons (n.d.) Mediterranean Relief.jpg. https://commons.wikimedia.org/wiki/File:Mediterranean_Relief.jpg
4. Trabucco B, Maggi C, Manfra L, Nonnis O, DiMento R, Mannozzi M, Lamberti CV (2012) Monitoring of impacts of offshore platforms in the Adriatic Sea (Italy). In: Al-Megren H (ed) Advances in natural gas technology. IntechOpen, London, pp 285–300
5. Galil B, Herut B (2011) Marine environmental issues of deep-sea oil and gas exploration and exploitation activities off the coast of Israel. IOLR report H15/2011, Annex II. http://www.sviva.gov.il/subjectsEnv/SeaAndShore/MonitoringandResearch/SeaResearchMedEilat/Documents/IOL_deep_sea_drilling_Israel2011_1.pdf
6. Offshore Technology (2017) Noble Energy hires Ensco's drillship for offshore work in Israel. Offshore-Technology.Com, News. https://www.offshore-technology.com/news/newsnoble-energy-hires-enscos-drillship-for-offshore-work-in-israel-5907504/
7. Pappas J (2013) Mediterranean Sea plays offer new opportunities. Offshore Mag 73(7). https://www.offshore-mag.com/articles/print/volume-73/issue-7/offshore-mediterranean/mediterranean-sea-plays-offer-new-opportunities.html
8. Offshore Staff (2018) Energean, BP extend offtake agreement for the Prinos oil field offshore Greece. Offshore Mag https://www.offshore-mag.com/articles/2018/02/energean-bp-extend-offtake-agreement-for-the-prinos-oil-field-offshore-greece.html
9. OSPAR Commission (2015) 1992 OSPAR Convention. Convention for the Protection of the Marine Environment of the North-East Atlantic. Text as amended on 24 July 1998, updated 9 May 2002, 7 February 2005 and 18 May 2006. Amendments to Annexes II and III adopted at OSPAR 2007. http://www.ospar.org/html_documents/ospar/html/ospar_convention_e_updated_text_2007.pdf
10. OSPAR Commission (1999) Guidelines for monitoring the environmental impact of offshore oil and gas activities, adopted at ASMO 2001. 2004 version available at: https://govmin.gl/images/stories/petroleum/2004_OSPAR_offshore_guidelines_monitoring.pdf
11. Carpenter A (2015) Monitoring oil pollution from oil and gas installations in the North Sea. In: Carpenter A (ed) Oil pollution in the North Sea. Handbook of environmental chemistry, vol 41, pp 209–236. https://doi.org/10.1007/698_2015-4
12. UNEP (1976) Convention for the Protection of the Mediterranean Sea Against Pollution (Barcelona Convention). http://wedocs.unep.org/bitstream/id/53143/convention_eng.pdf
13. UNEP (n.d.) Protocol for the Protection of the Mediterranean Sea Against Pollution resulting from exploration and exploitation of the continental shelf and the seabed and its subsoils. https://wedocs.unep.org/rest/bitstreams/2336/retrieve
14. Carpenter A, Johansson T (2017) The Barcelona Convention and its role in oil pollution prevention in the Mediterranean Sea. In: Carpenter A, Kostianoy AG (eds) Oil pollution in the Mediterranean Sea: part I – the international context. Handbook of environmental chemistry. https://doi.org/10.1007/698_2017_168
15. Milieu (2016) Offshore activities in the Mediterranean. Milieu. http://www.milieu.be/offshore-activities
16. European Commission (2014) *Commission implementing regulation No. 1112/2014 of 13 October 2014* determining a common format for sharing of information on major hazard indicators by the operators and owners of offshore oil and gas installations and a common format for the publication of the information on major hazard indicators by the Member States. Official Journal of the European Union, L302/1 of 22.10.2014. https://euoag.jrc.ec.europa.eu/files/attachments/implementing_regulation_13_oct_2014.pdf

17. European Parliament and Council (2013) *Directive 2013/30/EU of the European Parliament and of the Council of 12 June 2013* on safety of offshore oil and gas operations and amending Directive 2004/35/EC. Official Journal of the European Union, L178/66 of 28.6.2013. https://euoag.jrc.ec.europa.eu/files/attachments/osd_final_eu_directive_2013_30_eu1.pdf
18. European Commission (2012) *Commission Decision of 19 January 2012* on setting up of the European Union Offshore Authorities Group. Official Journal of the European Union, C18/8 of 21.1.2012. https://euoag.jrc.ec.europa.eu/files/attachments/commission_decision_setting_up_euoag.pdf
19. Oceana (n.d.) The dumping of hydrocarbons from ships into the seas and oceans of Europe: the other side of oil slicks. Oceana. https://eu.oceana.org/sites/default/files/reports/oil-report-english.pdf
20. GESAMP Joint Group of Experts on the Scientific Aspects of Marine Pollution (2007) Estimated of oil entering the marine environment from sea-based activities. Rep. Stud. GESAMP #75. IMO, London. http://www.gesamp.org/data/gesamp/files/media/Publications/Reports_and_studies_75/gallery_1042/object_1042_large.pdf
21. Girin M, Carpenter A (2017) Shipping and oil transportation in the Mediterranean Sea. In: Carpenter A, Kostianoy AG (eds) Oil pollution in the Mediterranean Sea: part I – the international context. The handbook of environmental chemistry. https://doi.org/10.1007/698_2017_6
22. UNEP MAP (2017) Barcelona Convention – Mediterranean 2017 quality status report. Results and status, including trends (CI19). https://www.medqsr.org/results-and-status-including -trends-ci19
23. ITOPF (2015) Oil tanker spill statistics 2014. International Tanker Owners Pollution Federation Limited (ITOPF), London. http://www.itopf.com/fileadmin/data/Documents/Company_Lit/Oil_Spill_Stats_2014FINALlowres.pdf
24. REMPEC (2002) Protecting the Mediterranean against maritime accidents and illegal discharges from ships. REMPEC, Malta. http://www.rempec.org/admin/store/wyswigImg/file/Information%20resources/Publications/World-Summit_2002_%28E%29_-_light.pdf
25. REMPEC (2011) Statistical analysis: alerts and accidents database, Regional Information System – RIS C2. REMPEC. http://www.rempec.org/admin/store/wyswigImg/file/Tools/Operational%20tools/Alerts%20and%20accidents%20database/Statistics%20accidents%202011%20EN%20FINAL.pdf
26. World Maritime News (2018) ITOPF: two large oil spills reported in 2017. https://worldmaritimenews.nom/archives/241402/itopf-two-large-oil-spills-reported-in-2017/. Posted 22 Jan 2018
27. World Maritime News (2017) Tanker sinks off Greece, oil clean-up ops launched. https://worldmaritimenews.nom/archives/229593/tanker-sinks-off-greece-oil-clean-up-ops-launched/. Posted 12 Sept 2017
28. Greenpeace (2007) The Mediterranean: from crimes to conservation – a call for protection. Greenpeace, July 2007. https://www.greenpeace.org/arabic/Global/lebanon/report/2009/6/lebanon-oil-spill.pdf
29. Kostianoy AG, Lavrova OY (2014) Oil pollution in the Baltic Sea. The handbook of environmental chemistry, vol 27. Springer, Berlin
30. Carpenter A (2016) Oil pollution in the North Sea. The handbook of environmental chemistry, vol 41. Springer, Berlin
31. International Maritime Organization (2015) International convention for the prevention of pollution from ships, 1973, as modified by the Protocol of 1987 (MARPOL 73/78). IMO, London. http://www.imo.org/About/Conventions/ListOfConventions/Pages/International-Convention-for-the-Prevention-of-Pollution-from-Ships-(MARPOL).aspx

Oil Pollution in Spanish Waters

Laura de la Torre and Joan Albaigés

Abstract Spain has one of the largest coastlines in Europe (ca. 8,000 km) which constitutes an important source of economic revenue (e.g. fisheries, tourism, etc.). This chapter firstly discusses the ecological and socio-economic importance of Spanish waters and shores, to show the potential impact that an oil spill may have on the provision of goods and services from these areas. This is followed by an overview of the major sources of oil pollution, from maritime accidents and operational discharges, and the description of the Spanish oil pollution prevention, preparedness and response system, which has been supported by an ambitious investment plan after the *Prestige* incident. Finally, the importance of an efficient coordination between the surveillance and source identification services of oil spills is illustrated with several case studies.

Keywords Aerial surveillance, Marine oil spills, Oil fingerprinting, Oil pollution, Operational forecasting, Preparedness and response, Spanish waters

Contents

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1 Introduction

Spain, located in southwestern Europe and surrounded by the Atlantic Ocean and the Mediterranean Sea, has one of the largest coastlines in Europe (ca. 8,000 km) which are the source of important economic revenue (e.g. fisheries, tourism, etc.). In addition to the mainland territory, two archipelagos, the Balearic and Canary Islands, enlarge the Spanish territorial waters and increase the area of marine surveillance to nearly 1.5 million of km^2, three times the size of the national territory (Fig. 1). This very large area is highly exposed to the impact of maritime

Fig. 1 Area for SAR responsibility (1.5 million of km^2)

activities, mainly ship transport, which can be the source of accidents and operational discharges resulting in spills of oil and hazardous substances.

Being aware of its high risk of marine pollution and having experienced one of the largest oil spills in this century (the *Prestige* oil spill), Spain has worked to implement the international conventions and the European legislation and recommendations. Moreover, it has established a national solid system for preparedness and response to marine pollution [1]. Setting up the necessary policies and resources, ensuring coordination and cooperation at a national and international level and being at the forefront of technology have been the basis of this system. The system has been strengthened through bilateral and regional agreements with neighbouring countries.

Since 1989, specific action investment plans, covering the strategies in rescue and pollution issues, were established every 4 years by the state administration. The IV Plan (2002–2005) had to be reviewed due to the *Prestige* incident and an extra funding was approved. But the major investment effort was made under the V Plan (2006–2009), which allowed to substantially increase the human and material resources and to take a leading position in Europe. After the fifth plan, the most ambitious and comprehensive, an 8-year investment plan (2010–2018) was established. Today, this National Rescue and Pollution Response (NRPR) Investment Plan is in place and aims to ensure an efficient use of the owned resources.

This chapter will firstly discuss the ecological and socio-economic importance of Spanish waters and shores, to realise the potential impact that an oil spill may have. This is followed by an overview of the major sources of oil pollution, both intentional and accidental, and the description of the Spanish oil pollution prevention, preparedness and response system, which is reinforced by an efficient coordination between the monitoring and source identification of oil spills.

2 Ecological and Socio-economic Importance of Spanish Waters and Shores

Due to its geographical location, with around 8,000 km of coastline, the Spanish marine and maritime sectors play a very important role in delivering ecosystem goods and services [2], but they can be affected by external pressures, like urban development and maritime transport, being Galicia (1,720 km), Balearic Islands (1,342 km) and Canary Islands (1,545 km) the most exposed coastal zones [3].

The Spanish coast, both on the Mediterranean and Atlantic sides, is considered a strategic area given the many zones of great ecological, cultural, social and economic value. From the socio-economic perspective – both for tourism and traditional activities such as fishing and aquaculture – Spain's coastal zones are very valuable and their great diversity must be taken into account [4].

The most important coastal ecosystems of the Spanish coast include the following: seabeds (both rock and sandy); cliffs; beaches, sandbanks and dunes, and coastal wetlands, including inlets, estuaries, deltas, marshlands and coastal lagoons, fens, coastal lakes and salt flats. These different and special ecosystems are of great importance due to their landscape, socio-economic and educational values. In mainland, the abrupt relief, peripheral characteristics and high average elevation combine to produce an abundance of cliffs in several coastal regions (a total of 4,021 km of cliffs), although there are also 2,000 km of beaches. The rest of the coast is low-lying (1,271 km) or has been transformed as a result of artificial works (600 km).

This extremely varied range of ecosystems is further reinforced by the marked differences between Spain's Mediterranean and Atlantic coastlines. The Mediterranean zone has an abundance of beaches. The semi-enclosed Mediterranean Sea exerts a major influence on the characteristics of the zone, and accumulation processes are often seen in river mouths that lead to the formation of the giant Ebro Delta. On the Mediterranean side, unlike the Atlantic, there are no significant tides and no large areas of low-lying coast flooded by tides. The most ecologically valuable parts of this coast are the coastal wetlands, the dunes, the rocky mountains that produce the cliffs, the small islands and islets and some areas of seabed, notably the fields of *Posidonia oceanica* seagrass.

Extensive cliff systems are common on the Atlantic coast. Here the sea dynamics is more pronounced and the tidal range is considerably greater, as is wave intensity (the tidal range is 10–50 times greater on the Atlantic coast compared to the Mediterranean). The Galicia coast is extremely rugged with many water entries and exits (rías) of high ecological importance. For its part, the Cantabrian coast is long and straight, with steep slopes running into the sea, an abundance of cliffs, few beaches and small 'rias'. Beaches and dune formations are common in the southern part. The dunes can occasionally be very tall or in some cases form mobile coverings which are displaced by the wind. Another notable characteristic of this part of the coast is the extensive wetlands, among them the impressive Doñana National Park, which contains a vast array of animal life.

The Canarias archipelago comprises seven main islands and some smaller islets of volcanic origin. The relief of most of the islands is extremely abrupt, with a northern coast formed by tall cliffs and a more open and sandy southern coast where most of the beaches are located. Compared to their overall size, the Balearic Islands have a large coastline, which is rugged in nature, with beaches in small inlets, as well as abrupt coastline, beaches and lagoons. The archipelago boasts a wide range of environments of ecological importance.

Natural conditions drive the distribution of the activities along the coast: tourism, industries, fisheries and agriculture can be seen as the main activities, with fisheries and industrial activities mostly concentrated in the north coast and tourism and agriculture in the Mediterranean and the Islands.

It is important to note that over the last 50 years, the Spanish coast has undergone extensive transformation and has become a strategic element of the country's economy. The importance of sun and sand tourism and of the energy sector – for which oil and gas are supplied by sea – and the ever-increasing role of sea trade are key economic factors behind this transformation. Most coastal zones in Spain have gradually adapted to these new economic roles, and traditional activities such as fishing and agriculture have been relegated to a place of secondary importance.

However, the intensive use of coastal areas has triggered a series of environmental, social and economic imbalances which need to be taken into account in keeping with the principles of sustainability.

One of the most visible aspects of the transformation undergone by the Spanish coast is the occupation of coastal areas by urban development. The occupation rate varies from region to region but has been high over the last 40 years. The zones most affected are without doubt the ones that have experienced the most rapid growth in tourism. Tourism in Spain has evolved from being a residual sector in the economy during the 1950s to become at present the main source of wealth in the country [5, 6]. Around 10% of the gross domestic product (GDP) of Spain is directly or indirectly linked to beaches, which are one of its most marketed products. The two archipelagos and the Mediterranean coast account together for 75% of the country's regulated accommodation and receive 85% of all foreign tourists as well as 60% of domestic tourists in Spain.

A second important factor causing imbalance is the increasing alteration of coastal dynamics due to the high amount of human intervention on the coastline. Yachting marinas are a good example of the proliferation of such structures along the Spanish coast, which can also be a source of marine pollution. Reduction in the quality of coastal water bodies may have serious repercussions on the vitality of marine ecosystems.

Besides these particular activities and uses of the coastal areas that can be affected by an oil spill, the open waters are also associated with different socio-economic activities, notably fishing and maritime transport, which should also be taken into account in the context of marine oil pollution because they can be severely impaired (fishing) or be a potential source of the problem (maritime transport).

As has been mentioned, Spain is an essentially maritime country, with a long, narrow continental shelf rich in fisheries resources. The bulk of the Spanish fleet (around 9,700 vessels) fishes in four fishing zones: the Cantabrian Sea (north-west), Gulf of Cadiz, the Canary Islands and the Mediterranean. Fisheries are often critical to particular coastal regions. This is notably the case in Galicia, in which most of Spain's fishing activity is concentrated. Specifically, over 50% of the Spanish catch is landed in this region. This makes it the most important fishing region in Spain and in the European Union as a whole and the most dependent on this activity [7].

However, Spain is Europe's second biggest consumer of fish products (40.5 kilos per person/year, behind Portugal's 59.8 kilos), and it became clear over the years that production in national fishing grounds was insufficient and fisheries have therefore been developed beyond Spain's territorial waters. To meet the demand not covered by traditional fishing, marine aquaculture has been constantly growing in recent years. In Spain, aquaculture is geared essentially to the cultivation of bivalve molluscs, especially mussels, and – to a lesser extent – fish farming. The Galicia coast is one of the first producers worldwide, with more than 200,000 tons/year.

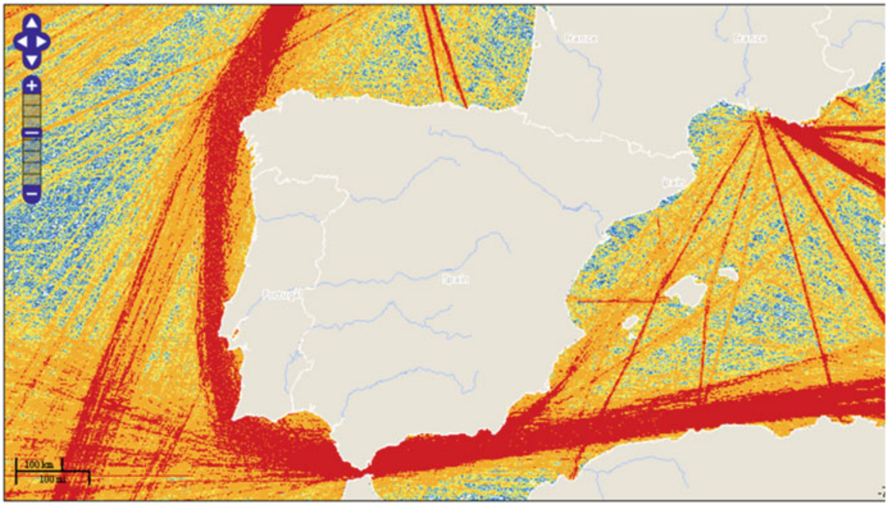


Fig. 2 Density of commercial shipping around the Spanish coasts (http://globalmarine.nceas.ucsb.edu/)

On the other hand, maritime transport is of major importance today due largely to the more open economies now present in developed countries. Much of the European Union's foreign trade is conducted by sea. In the specific case of Spain, maritime transport accounts for 53% of Spanish foreign trade. Spain can therefore be considered a strategic area for international shipping and a logistics platform in southern Europe. Due to its geographical location, it holds a high sea traffic density (Fig. 2).

At present, the network of primary ports in Spain is state-run and is managed by a public body which coordinates and regulates the system and has considerable operational autonomy. For their part, ports not belonging to the 'general interest' category (commercial and fishing ports, marinas) are the responsibility of the regions.

All issues described above are implied, as actors or receptors, of the environmental and socio-economic impact of an intentional or accidental oil spill. Establishing connections between ecosystem characteristics and human's benefit can lead to develop a much more proactive approach in the integrated management of the coastal zones (IMCZ) and the design of an adequate response in the case of incidental events. In this respect, the assessment of the ecological and economic oil spill impacts for a set of management options has been investigated, and several models have been proposed as a result of the *Prestige* accident [8].

The ecosystem service concept can be also useful at that point because it emphasises the real notion of both protecting nature and benefiting man at the same time [9]. Understanding of provision of ecosystem services (quantification), understanding of the benefits to human well-being from ecosystem services (valuation), and creating incentives for the sustainable provision of such ecosystem services (policies, good governance, alliances, etc.) should be recognised as a precondition for a sustainable future of our seas and coasts. In this way, innovative schemes for linking public and private efforts to protect ecosystems by ensuring the provision of ecosystem services need to be raised because whoever benefits from those services should have a responsibility in its proper care [2].

3 Major Sources of Oil Pollution

Considering the data of the last 10 years, an average of 374 pollution incidents are managed every year by the Spanish Maritime Safety and Rescue Agency (SASEMAR), approximately one per day (Fig. 3).

Figure 4 shows the distribution of these emergencies according to the geographical area (a) and to the different pollution sources (b). The number of pollution emergencies is decreasing since 2013 considering the average of the second subperiod, established from 2009 when the surveillance system was consolidated. Places with higher maritime traffic density, with greater port activity and with a larger number of installations, have more pollution incidents. Although the source is unknown in 77.5% of the cases, vessel polluting represents a 17.5%, installations from land a 3.5% and rigs just a 0.5%.

3.1 Maritime Transport

Maritime transport is driven by the increasing flows of energy products and containers. In this respect, shipping activity is characterised by a significant volume of traffic which only transits around the Spanish coasts, without entering any port (Fig. 2).

The Maritime Rescue Coordination Centres (MRCCs) (SASEMAR) in Spain provide the vessel traffic service (VTS). They are equipped with state-of-the-art monitoring systems and communication technologies to give VTS in the Traffic Separation Schemes and in the Particularly Sensitive Areas in which vessel reporting is mandatory.

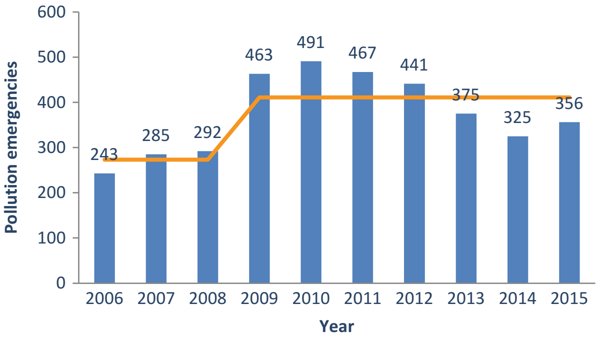


Fig. 3 Number of pollution emergencies managed by SASEMAR

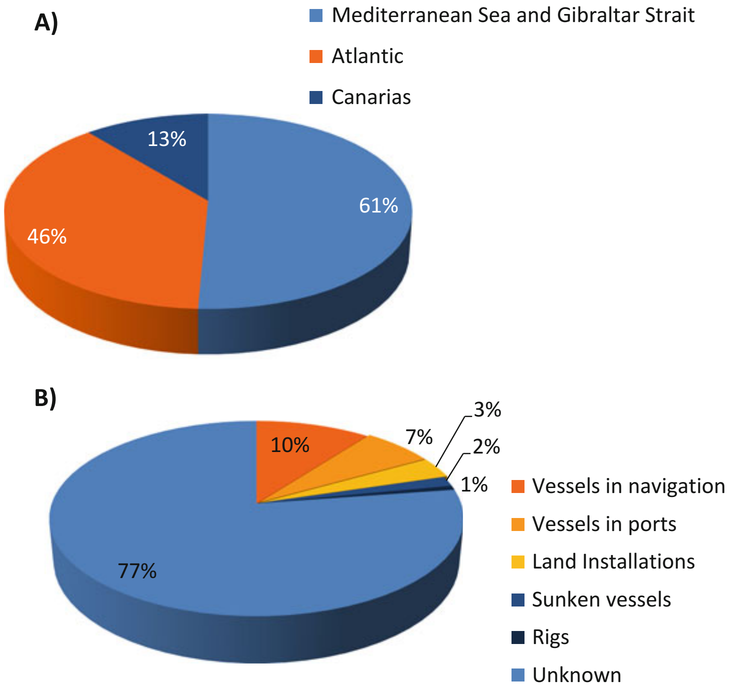


Fig. 4 Distribution of pollution emergencies managed by the Spanish Maritime Safety Agency. Average data in a 10-year period time (2006–2015), according to the geographical area (**a**) and to the different pollution sources (**b**)

Spain has eight IMO-adopted Traffic Separation Schemes (TSS): four in the Atlantic Ocean and four in the Mediterranean Sea. Off Finisterre, Banco del Hoyo and two in Canary Islands (Eastern TSS between Grand Canary and Fuerteventura and Western TSS between Grand Canary and Tenerife) are located in the Atlantic. In the Strait of Gibraltar, Off Cabo de Gata, Off Cabo de la Nao and Off Cabo de Palos are located in the Mediterranean Sea. In Finisterre and Strait of Gibraltar TSS, mandatory reporting systems are in place, while in Cabo de Gata reporting is voluntary. The Traffic Separation Schemes are equipped with monitoring systems to detect and track vessels (VTS radar, radio direction-finding systems, Automatic Identification System (AIS)) and communication technologies between MRCCs and vessels (digital selective calling system LLSD and VHF and MF/HF radio).

Spain has two Particularly Sensitive Sea Areas recognised by IMO: the Western European Waters, shared with UK, France and Belgium, and the Canary Islands. Ship reporting is mandatory in these areas through WETREP report in Western Europe and CANREP report in Canary Islands.

According to the traffic controlled in the two most important established TSS, around 106,000 of vessels are passing every year through and crossing the Strait of Gibraltar, and approximately 39,000 of ships are going through Galicia's maritime motorway (Table 1).

Table 1 Maritime traffic through the Traffic Separation Schemes (TSS)

TSS	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Off Finisterre	41,942	42,067	42,508	40,331	40,530	38,946	36,532	35,687	35,979	35,749
Gibraltar Strait	96,188	84,691	106,497	104,596	112,943	116,691	109,395	106,366	108,354	111,092

Table 2 Results of the aerial and satellite surveillance of Spanish waters [10]

	Aerial surveillance		Satellite surveillance	
	Detections/100 flight hours	Red-handed/100 flight hours	Detections/10 satellite images	Red-handed/10 satellite images
2010	13.2	2.1	–	–
2011	8.0	1.8	–	–
2012	4.6	0.95	2.7	0.00
2013	3.8	1.2	3.1	0.04
2014	2.1	0.5	2.3	0.05

Maritime traffic can cause oil pollution either coming from accidents or operational discharges. The most common source of oil pollution from maritime traffic is that generated as a result of vessel's operations. Some of the operational discharges are accidental, due, for example, to fuel transfer; and some are deliberated. Through overflight and satellite surveillance, Spain controls ship's compliance with MARPOL's pollution prevention standards (Table 2). Vessel discharges from tank cleaning have been detected failing to meet MARPOL requirements, because they were above the water line or near the coast. Discharges of sewage from passenger ships were found to have oil through samples taken in the water. But the most frequent illegal discharges are coming from bilge waters, oil-bearing residues produced in all types of vessels, to be retained on board, separated from fuel and discharged into reception facilities on land for treatment and disposal. Furthermore, the Mediterranean Sea is defined by MARPOL as a special area due to its oceanographic and ecological conditions, and all operational pollution is illegal. But still a lot of spills are detected there as shown in Fig. 4a.

In addition to operational pollution, accidental pollution may occur from time to time due to structural damages, collisions or explosions, which may conclude with the grounding or sinking of the vessel. The figures show that 15 major marine oil spills have occurred during the last 50 years in Spanish waters (Table 3). The geographic distribution of these accidental spills shows that the north-west coast has been the most affected, where the heavy traffic with adverse meteorological conditions concurs (Fig. 5). Of particular importance was the *Prestige* oil spill, in 2002, which extended the pollution over 800 km of the Atlantic coastline [11]. Fortunately, these oil spills have been significantly reduced both in number and released quantity during the last decades, due to the improvement in pollution prevention measures adopted by public authorities and the tanker industry.

3.2 *Port Facilities, Oil Terminals and Oil Refineries*

In 2014, the traffic of merchant ships in the Spanish harbours was of more than 100,000 units [13]. Due to the high shipping density and the navigation risks, ports need traffic monitoring systems. Three Traffic Separation Schemes have been

Table 3 Marine oil spills in Spanish waters

Major marine oil spills (1965–1999)[a]

Name	Date	Location	Cause of spill	Quantity of oil spilled
Bonifaz	July 3, 1964	9 miles W off Cape Finisterre, Galicia	Collision	500 tonnes of bunker fuel
Spyros Lemnos	November 1, 1968	Cape Finisterre, Galicia	Structural damage	15,000 tonnes of Venezuelan heavy crude oil
Polycommander	May 5, 1970	Vigo Bay, Galicia	Grounding	15,000 tonnes of Arabian light crude oil
Golar Patricia	November 5, 1973	130 miles N off Canary Islands	Explosion	10,000 tonnes of bunker oil
Splendid Breeze	December 6, 1973	Between the Canary Islands and Madeira	Structural damage	2,000 tonnes of bunker fuel
Urquiola	May 12, 1976	Entrance to La Coruña harbour	Grounding	101,000 tonnes of Kuwait crude oil
Andros Patria	December 31, 1978	Off the coast of La Coruña	Explosion	60,000 tonnes of Iranian heavy crude oil
Turgut Reis	December 15, 1979	170 km N off La Coruña	Structural damage	220 tonnes of diesel oil
Khark 5	December 19, 1989	400 miles N off Las Palmas (Canary Islands)	Explosion	70,000 tonnes of Iranian heavy crude oil
Sea Spirit	August 6, 1990	14 miles off Tarifa, Andalucia	Structural damage	9,860 tonnes of heavy fuel oil
Aegean Sea	December 3, 1992	La Coruña, Galicia	Grounding	67,000 tonnes of light crude oil

Marine oil spills (2000–2015)[b]

Name	Date	Location	Cause of spill	Oil on board or spilled	Oil removal from wreck
Prestige (oil tanker)	November 13, 2002	Off Cape Finisterre, Galicia	Structural damage	77,000 tonnes of M-100	X
Spabunker (barge)	January 21, 2003	Algeciras Port, Andalucia	Weather conditions	1030 tonnes of IFO 180 100 tonnes of MDO 100 tonnes of MGO	X
Sierra Nava (refrigerator ship)	January 28, 2007	Algeciras Port anchorage	Grounding	350 tonnes of IFO 380	

(continued)

Table 3 (continued)

Marine oil spills (2000–2015)[b]					
Name	Date	Location	Cause of spill	Oil on board or spilled	Oil removal from wreck
Don Pedro (ro-ro)	July 11, 2007	1 mile off Ibiza's Port	Collision with submerged rock	150 tonnes of IFO 180 60 tonnes of DO	X
New Flame (bulk carrier)	August 12, 2007	0.7 miles S off Punta Europa	Collision	700 tonnes of IFO 380	
Savinosa (barge)	September 9, 2008	Tarragona Port	Grounding	750 tonnes of FO 260 tonnes of GO	
Fedra (general cargo)	October 10, 2008	0.5 miles E off Punta Europa	Grounding	370 tonnes of IFO 380 60 tonnes of DO	
Tawe (bulk carrier)	October 11, 2008	Algeciras Port anchorage	Grounding	150 tonnes of IFO 180 60 tonnes of MGO	
Casablanca Platform	December 22, 2010	Casablanca Platform Tarragona	Operational spill	8,000 litres of crude oil spilled	
Nexo Maersk (container carrier)	May 22, 2013	38 miles ENE off Valencia Port	Operational spill	200 litres of HFO spilled	
Woodford (product tanker)	September 1, 1937 (sank) September 3, 2009 (pollution)	35 miles NE off Castellón	Spanish Civil War	450 m^3 HFO	X(2012)
Oleg Naydenov (fishing vessel)	April 14, 2015	16 miles SW off Punta Maspalomas (Gran Canaria)	Fire on board	1,400 tonnes IFO 380 70 tonnes of lube oil	X
Nele Maersk (container carrier)	September 7, 2015	70 miles SE off Barcelona	Operational spill	35 tonnes of IFO 380 spilled	

[a] CEDRE [12]
[b] SASEMAR

Fig. 5 Major oil spills in Spanish waters

established by the Spanish government in ports: these are the approaches to Vigo, Castellon and Barcelona ports.

Taking into account the pollution incident records from the Spanish Maritime Safety Agency in the last 5 years, an average of 28% of the pollution incidents have taken place in ports. A large number of incidents resulting in small discharges of oil products in the inner waters of the harbours are registered every year. The usual causes are cargo-handling operations, bunkering, oil transfers on board and cleaning operations on the deck. Normally, spills are easily contained with the available response systems provided by the shipowner or by the port, but sometimes oil spills spread on the port area with a great impact on the public opinion.

On the other hand, eight harbours are the major load and discharge centres for oil products, which hold the oil terminals of coastal refineries (Fig. 1). In 2014, 11,494 laden oil tanker movements carrying 110 million tons of oil products were recorded in all Spanish ports. In this case, spills are usually due to operational accidents during the charge and discharge of the oil products.

Moreover, almost all oil refineries are located in coastal areas and their effluents are directly discharged to sea. However, these effluents are conveniently treated in wastewater treatment plants and discharged following strict environmental regulations, so that oil spills have been recorded very rarely.

Finally, there are three offshore rigs: Casablanca, in Tarragona, where crude oil is obtained, Gaviota in Vizcaya and Castor in Castellón, where gas is stored. Additionally, there is an underwater installation Poseidón, in the Gulf of Cádiz, where gas is obtained. In Spanish waters, an average of 1 pollution incident per year comes from rigs, taking into account data from the last 10 years (2006–2015).

3.3 Land-Based Sources

Urban and river discharges are the main land-based sources of oil pollution in coastal zones. All Spanish coastal urban areas are served by wastewater treatment plants whose final effluents are directly discharged to the marine environment, usually through submarine outfalls. These effluents may contain oily wastes and lubricant oils from domestic spills, commercial and industrial activities and urban runoff. Urban runoff may also incorporate wet and dry atmospheric deposition. Storm waters will eventually reach rivers or coastal wastewater treatment plants (WWTPs) or will be directly discharged through the sewage system in coastal cities, which may increase the levels of hydrocarbons in the coastal environment and nearshore sediments, although no visible slicks are observed. In the Mediterranean coast, the major loads of hydrocarbons can take place in short periods, e.g. during flood events, due to a wash-out effect of pollutants originating from vehicular emissions accumulated during the dry summer season [14].

On the other hand, river water incorporates pollutants from non-coastal land-based runoff, and municipal and industrial effluents. As rivers represent a transport pathway for hydrocarbons to the marine environment, hydrocarbon loads are tightly linked to the water cycle and dominant uses of drainage basins. The hydrography of Spanish rivers is typically characterised by great irregularity, with marked reductions in river flow during summer and occasional flooding.

The attempts to estimate the oil inputs to the sea from land-based sources have frequently used data of per capita releases of hydrocarbons in municipal wastewater or urban runoff. Some recent studies on coastal municipal WWTP in the Mediterranean provide additional data to refine the above estimations [15].

A comprehensive assessment of the oil pollution in the Mediterranean basin has recently been published [16]. An overview of the main oil marine pollution sources and estimations of their inputs, including offshore oil production, port facilities, shipping, refineries and land-based activities (e.g. urban runoff), as well as the levels and trends of hydrocarbons in the different marine compartments and their biological effects, is presented.

4 Oil Pollution Prevention, Preparedness and Response

4.1 Organisation

Marine pollution prevention, preparedness and response in Spain are responsibility of different authorities, some national and others belonging to the nine coastal autonomous communities.

At a national level, the Maritime Authority plays the most important role. The General Directorate of the Merchant Marine (DGMM), part of the Ministry of Public Works and Transport, is responsible for the management of the maritime navigation and the civil fleet, as established in the consolidated text of the Spanish Law for State Ports and the Merchant Marine, approved by Royal Decree 2/2011 of September 5 [17]. Among its duties, the Maritime Authority must prevent marine pollution coming from ships, platforms and other installations in waters where Spain has sovereignty, sovereign rights or jurisdiction and must protect the marine environment.

Attached to the Maritime Authority stands the Spanish Maritime Safety Agency (SASEMAR). It is a national body that operates under the Maritime Authority and provides the services of search and rescue, maritime traffic control and pollution prevention and response. This public agency, created in 1993, has its own resources and is fully empowered to act in order to meet its tasks. Together, the Maritime Authority and SASEMAR need to establish the regulations and procedures to respond to pollution at sea.

In addition, other state directorates take part in the marine pollution prevention, preparedness and response mechanism. The Directorate General for the Sustainability of the Coast and the Sea, being part of the Ministry of Agriculture, Food and Environment, is responsible for the protection of the marine and coastal environment, ensuring its public and unrestricted use. And the Directorate General for Energy Policy and Mines, part of the Ministry of Industry, Energy and Tourism, is responsible for licencing the offshore oil and gas industry.

The coastal autonomous communities, according to their own statutes, are responsible for pollution prevention and response in their coastline and interior waters. Some coastal autonomous communities' statutes even go further and can participate with their own resources in pollution incidents in their territorial waters.

In Spain, there are 46 ports of general interest which are coordinated by the agency Puertos del Estado, part of the Ministry of Public Works and Transport. These ports are managed by 28 Port Authorities. Although the duties of the Port Authorities are listed in the Consolidated Text of the State Ports and Merchant Navy Act, the Act 14/2014 on Maritime Navigation dated July 24 includes a new responsibility [18]. This is to prevent and control pollution incidents, performing the cleaning if necessary, in the port area where the Port Authorities provide services.

This complex network has been put together in the National Response System for Marine Pollution, approved by the Royal Decree 1695/2012 of December 21 [1], meeting the requirements of the OPRC Convention and OPRC-HNS Protocol. Before, a National Contingency Plan for accidental marine pollution issued in 2001 as an Order by the Ministry of Public Works and Transport organised the various bodies involved in the response and even included guidelines to develop the local and territorial plans. But a new and broader approach was needed. The actual response system puts in place the different plans and covers the overall organisation and coordination for responding to marine pollution incidents. The system consists of a multilayered regulatory framework and establishes two subsystems depending on the affected area: the marine waters and the coastline.

At the bottom layer of the marine water subsystem, interior plans of ports, terminals, platforms and installations are in place in order to be activated if necessary. At the top layer is the National Maritime Plan for pollution response, established by Order FOM/1793/2014, of September 22 [19], ensuring that national resources will be available for emergencies beyond the capabilities of port and industry responders.

At the bottom layer of the coastline subsystem, local plans may be activated, followed by territorial plans of the coastal autonomous communities and cities in case their coastline may be affected by the pollution. And finally, at the top layer the State Plan for Coastline Protection Against Pollution (Plan Ribera), established by Order AAA/702/2014, of April 28 [20], ensures that national resources will be available for emergencies beyond the capabilities of local and autonomous communities' responders.

In case plans from both subsystems are activated (level 1 or 2), a coordination body will command the incident. If level 3 is activated, the Ministry of Public Works and Transport will command the incident or the Ministry of Interior if there are threats for the population and the emergency is declared of national interest.

International cooperation will be demanded in case a neighbour country is affected by the pollution or extra resources are needed. To this end, Spain has in place bilateral agreements which cover SAR and pollution incidents with annexes containing practical and operational information: the Lion Plan (cooperation agreement between the Spanish Maritime Safety and Rescue Agency and the French Prefecture Maritime of the Mediterranée) since 2002 and the Biscay Plan (cooperation agreement between the Spanish Maritime Safety Agency and the French Prefecture Maritime of the Atlantic) since 1999. Spain has signed also the SARMED Plan (SAR and Maritime Pollution Cooperation Plan) with Morocco and Algeria. The Lisbon Agreement signed with France, Portugal, Morocco and the European Economic Community came into force in 2014.

On a daily basis, the 20 Maritime Rescue Coordination Centres (MRCCs) from SASEMAR, located along the coastline, are responsible for the operational coordination of marine pollution incidents. The MRCC operators, available 24 h a day, 7 days a week, follow the established procedures, contact the responsible party, mobilise the resources if necessary and log the information. The Emergency Director is the Harbour Master, who represents the Maritime Authority in the different areas and works side by side to the MRCC Chief.

Before the Act 14/2014 on Maritime Navigation [18], the Harbour Master was responsible for managing pollution incidents and the Port Authority collaborated. But since the forenamed act, the Port Authorities respond with their own resources, and if these are not enough the Maritime Administration will step in. Actually some Port Authorities have signed contracts with SASEMAR to cover the services of traffic control and pollution response. This is the case for Tarragona, La Coruña, Bilbao, Cartagena, Castellón, Cádiz, Huelva, Ría de Marín, Villagarcía de Arousa, Ferrol and Gijón.

The different authorities are therefore prepared to give a quick response until the polluter, either the shipowner or the industry, gets its own resources ready or in case these are not enough. A plan may be necessary in important spills or when there is a high pollution risk and must be accepted by the Maritime Authority. If the polluter fails to respond in time or according to the Maritime Authority demands, SASEMAR will respond. In any case, monitoring will be carried out to control the operations and minimise the damage.

The Maritime Authority is responsible for taking the decision to accommodate ships in need of assistance in a Spanish place of refuge as established by the Royal Decree 1593/2010, November 26 [21]. The pollution risks will be considered in this decision-making process, in which a technical committee will advise if necessary and a specific tool will be used to help in the overall evaluation.

Monitoring measures are the basis of the national approach when dealing with marine pollution. Nevertheless, the main response strategy is to ensure safety of human lives on response units, vessels in distress, offshore installations and mainland. Never forgetting this goal, all pollution incidents are monitored using maritime and aerial units together with satellite services. The drift of the spillage can be studied and predicted through the use of models and drifting buoys.

The experience gained in pollution incidents in the past years has determined the Spanish level of preparedness as well as its response strategy. In one hand, the *Prestige* (Galicia 2002), together with other pollution incidents in which heavy oils were involved, such as *Don Pedro* (Ibiza 2007) and *Oleg Naydenov* (Gran Canaria 2015), has led Spain to focus in the mechanical recovery as the first response option. In this way, the necessary equipment like sweeping arms, booms and skimmers are used by the maritime units to contain the oil and to recover it from the sea surface and store it in the oil recovery operation (ORO) tanks of the oil response vessels or in fast tanks located in towing rescue vessels.

Additionally, there has been a considerable amount of subaquatic operations undertaken where oil has had to be removed from sunken vessels in past years, for example, the *Woodford* operation in 2012, and this has enabled Spain to be prepared to recover oil from sunken vessels. Two small remotely operated vehicles (ROVs) are available to conduct underwater inspections up to 150 m depth, one bigger ROV can work at 1,000 m depth, two wet diving bells may take divers safely until 90 m depth and one closed bell for saturation can dive up to 200 m depth. A total of 450 m^3 were removed from the vessel *Woodford* at 80 m depth 40 miles off the coast of Castellón.

In Spain, dispersants can be used under the approval of the local Maritime Authority on a case-by-case basis. Although some steps have been taken to push forward this option, especially after the *Deepwater Horizon* incident and European Maritime Safety Agency (EMSA)'s support, Spain is still not prepared to use dispersants as an effective response measure. Standards were published in 2014 for the efficiency, toxicity and biodegradability tests, but an updated regulation is needed to establish the national policy for the use of dispersants. Although this regulation is being drafted, from the operational point of view, no stockpiles or application equipment from maritime or aerial units are available, and no field training is being delivered. Nevertheless, Spain has an aircraft dispersant application capability to be provided by OSRL due to SASEMAR's associate member condition. On the other hand, EMSA's services will provide by 2016 200 tonnes of dispersant stockpile in Canary Islands to be applied by the vessel M/T MENCEY.

Spain's response strategy aims to reduce shoreline pollution by recovering at sea as much as possible and by protecting sensitive areas with booms and sorbents. Depending on the type of coastline and taking into account environmental analysis, different response options will be considered. Through aerial and satellite surveillance, pollution incidents are monitored allowing the coastline responders to get prepared in case the oil may wash ashore. If the oil reaches the coastline, cleaning operations will be done by trained professionals. In case volunteers are demanded, they must also have a minimum training to be able to participate in the cleaning operations.

The polluter must face the costs of the operations carried out by the different parties involved in the response, according to the polluter pays principle. From the very beginning, the polluter is reached and the EU Guidelines on Claims Management are followed in the process. The staff fills out daily log sheets including working hours, deployed equipment and work progress. And the necessary evidences of the pollution are collected during the response operations. The Ministerial Order 1634/2013 of August 30 [22] establishes the SASEMAR operations' fares for staff, maritime and aerial units and equipment deployed.

4.2 Resources

The actual capacity in Spain to respond to pollution incidents is a result of the strategic preparedness defined in the specific investment action plans approved by the state. These plans are not only for pollution response but also for search and rescue and maritime traffic control. This makes sense as most of the resources are used for the different tasks assigned to SASEMAR. The evolution of the pollution policies and resources can be followed throughout these investment plans: I (1989–1993), II (1994–1997), III (1998–2001), IV (2002–2005), Bridge Plan, and V (2006–2009). The fifth plan was the most ambitious and 50% of the expenditure was spent on new investments. It was then when the multipurpose vessels and the surveillance airplanes came into operation. Today, an 8-year investment plan under the name of the National Rescue and Pollution Response (NRPR) Investment Plan 2010–2018 [23] is in place and covers an efficient use of the available capabilities.

SASEMAR owns an important maritime and aerial fleet (Fig. 6). The maritime fleet includes 73 vessels, permanently on stand by or on duty. The geographical distribution of these vessels can vary depending on season and specific needs. The aerial fleet consists of 3 aircrafts and 11 helicopters. All the maritime units and the helicopters have sampling kits to take samples from the sea surface.

The maritime units are necessary to perform the mechanical recovery of oil in the sea surface. Fourteen vessels are especially prepared for towing (emergency towing vessels, ETVs), search and rescue (SAR) and oil spill response purposes. They all have self-operating cranes to load and unload equipment and oil booms and skimmers ready to load. Four of them are multipurpose vessels equipped with

Fig. 6 Maritime and aerial resources for responding to pollution and rescue incidents

sweeping arms, oil recovery operation (ORO) tanks that may be heated, dynamic positioning systems and FLIR cameras. Luz de Mar and Miguel de Cervantes are 56 m long with 128-tonne bollard pull and a recovery capacity of 290 m^3. Clara Campoamor and Miguel de Cervantes are 80 m long with 228-tonne bollard pull and a recovery capacity of 1,750 m^3. The vessel Clara Campoamor is additionally prepared to act as a support platform for subaquatic operations. The vessels Alonso de Chaves and Punta Salinas also have ORO tanks, increasing the total capacity for oil recovery up to 4,430 m^3.

The maritime fleet also includes 55 fast response vessels of a smaller size (15 and 21 m length) and four patrol boats (32 m length) positioned along the coastline for SAR and pollution activities. They are currently used as auxiliary units to tender booms and help the vessel tugs in response operations.

The aerial surveillance of pollution incidents is key to locate and evaluate the slicks and to guide the maritime units by night. Three CASA CN235-300 planes, fully equipped, patrol the Spanish waters. They cover the Mediterranean Sea, the Spanish North Atlantic Coast and the Canary Islands. A smaller plane replaces the owned aircrafts when they are out of service.

The aircrafts are fitted with specific antipollution sensors, SLAR, IR/UV, MWR and LFS, and with other equipment: FLIR/CALI, video recorder, digital photo camera, AIS and data link, managed by two operators placed in the mission consoles. The operators evaluate the data from the sensors, the information is analysed at the Mission Support Centre and finally a technical report is written.

The helicopters can support the marine pollution aerial surveillance in pollution incidents, and they can take samples of slicks located far away from the coast. SASEMAR operates eleven helicopter bases with nine medium-size helicopters and two heavy helicopters equipped with FLIR, video recorder and digital photo camera. Four of the helicopter bases cover the North Atlantic coast, two the Canary Islands, four the Mediterranean Coast and one the Strait of Gibraltar.

The pollution response equipment of SASEMAR is stored in six stockpiles known as strategic bases and located along the Spanish coastline: Santander, A Coruña, Sevilla, Cartagena, Castellón and Tenerife. A total of 60 km of oil booms, 46 skimmers, 40 fast tanks of 10 m^3 capacity, 18 portable tanks of 7.5 m^3 and other additional equipment are stored, maintained and repaired. Additionally, there are two bases for underwater operations, with diving equipment and intervention teams.

Five stockpiles from the Ministry of Agriculture, Food and Environment with counter pollution material for shoreline response are also located along the coastline: Pontevedra, Jerez de la Frontera, Tarragona, Las Palmas in Canary Islands and Palma in Balearic Islands.

4.3 Surveillance

Today, Spain has a solid system to prevent illegal pollution based on regulation and enforcement through aerial surveillance, inspections and sanctions. The fixed-wing crafts were delivered in 2007 enhancing the national capacity to prevent and combat marine pollution. In one hand, they could be used for monitoring operations in pollution incidents and, on the other, could patrol the Spanish waters so that surveillance is ensured. These aircrafts perform 4 h missions searching for illegal discharges, travelling at 165 knots and covering 20 nautical miles with the SLAR sensor, sweeping approximately 10,000 km^2 per hour. SASEMAR planes patrol approximately 1,200 h per year for pollution control. Around 50% of the surveillance is performed by night. Each aircraft monitors approximately 1,800 vessels in navigation in the Mediterranean Sea, 1,600 in the North Atlantic and 600 in the Canary Islands every 100 flight hours. These figures are dependent on the traffic of the covered areas. A general overview of the aerial surveillance results is shown in Table 2.

Coordination is essential among the different stakeholders that take part in the prevention system, in order to detect the pollution and the polluter, to collect the evidences and to prove the offence. There are procedures in place that establish the operational methodology, the data collection and the notification and reporting process. SASEMAR performs the surveillance operations. Two operators with experience collect and document the evidences. If the polluter calls in a Spanish port, the Harbour Master's office performs the vessel inspections. In any case, the Maritime Authority notifies the pollution incident and may even reroute the vessel to a Spanish port.

The Maritime Authority conducts the administrative procedures according to the criteria established by the Environmental Public Prosecutor 2011. Considering the sea polluted, the distance to coast and the area of the spill, the enforcement process will follow an administrative or a criminal procedure. Ship-source pollution crimes in the Mediterranean Sea in which polluted areas are over 2 km^2 and located within 12 miles off the coastline and those in which polluted areas are over 3 km^2 and located beyond 12 miles off the coastline can follow the criminal proceedings. The same happens for ship-source pollution crimes in the Atlantic Ocean when polluted areas are over 5 km^2 and located within 12 miles off the coastline and those in which polluted areas are over 10 km^2 and located beyond 12 miles off the coastline. These crimes will be dealt by the Public Prosecutor as offences against natural resources or the environment, covered in the Organic Law 10/1995, of November 23 of the Spanish Criminal Code.

However, most of the ship-source illegal pollution will be dealt by the Maritime Administration as MARPOL offences. The sanctioning procedure is covered in the Consolidated Text of the Spanish Law for State Ports and the Merchant Marine, approved by Royal Decree 2/2011 of September 5 [17], and follows the regulatory standards of the administrative system. The penalties established are up to €60,000 for minor offences, up to €601,000 for neglect discharges considered as serious offences and up to €3,005,000 for intentional discharges classified as very serious offences. Additional penalties can be imposed concerning the necessary measures to return things to its original state and to claim for damage compensation.

But the prevention air surveillance system as a whole has long-term outcomes. Once the sanctioning procedure is solved by the Maritime Authority, the responsible party may appeal and contentious administrative proceedings must be followed, increasing the duration of the process. As an example, a red-handed vessel detected in 2008 was finally solved in 2013. The plane SASEMAR 102 detected by night on September 2008 at 120 nautical miles off Cabo Ortegal, in the Galician coast, a pollution spill from a red-handed vessel. The discharge of 21 km long was connected to the wake of the vessel, being clean the surrounding area. The vessel was a product tanker with Panamanian flag coming from Denmark and heading to Las Palmas Port. The vessel denied the discharge when interrogated. An inspection was carried out in Las Palmas and oil was found in the discharge line of the oily water separator. The polluter appealed the administrative decision. And finally in January 2013, the decision of the High Court of Justice dismissed the appeal.

The creation of the European Maritime Safety Agency (EMSA) in 2002 has contributed significantly to the enhancement of the overall prevention system. The CleanSeaNet system, developed in 2006 and based on remote sensing surveillance, is progressively providing a clearer picture of the position on both accidental and illegal pollution, and potential slicks are spotted on a daily basis. Satellites cover a great area, being a powerful surveillance tool. During 2015, the satellite Sentinel was already in operation providing images with very high resolution. Spain gives feedback to EMSA for the satellite detections by sending an aerial or maritime unit.

Figure 7 shows the spills detected by aerial and satellite surveillance in Spanish waters. Table 2 shows the decreasing trend for both spills and red-handed vessels detected in the last 5 years. The deterrence effect is clear. Ten years ago, the vessels coming from northern Europe were waiting to reach Spanish waters to discharge bilge waters, and today they will give it a thought.

5 Operational Forecasting and Source Identification of Oil Spills

Oil spill forecasting together with oil spill identification are the main scientific and technical keys for a good management in a pollution incident in order to minimise the impact in the marine environment. This was highlighted during the *Prestige*, in which from the first stages of the accident, different Spanish institutions and public agencies started to work on both aspects.

A system (Fig. 8), composed of three main interconnected modules addressing different capabilities, was proposed: (1) an operational circulation subsystem that includes nested models at different scales, data collection with near real-time assimilation, new tools for initialisation or assimilation based on genetic algorithms

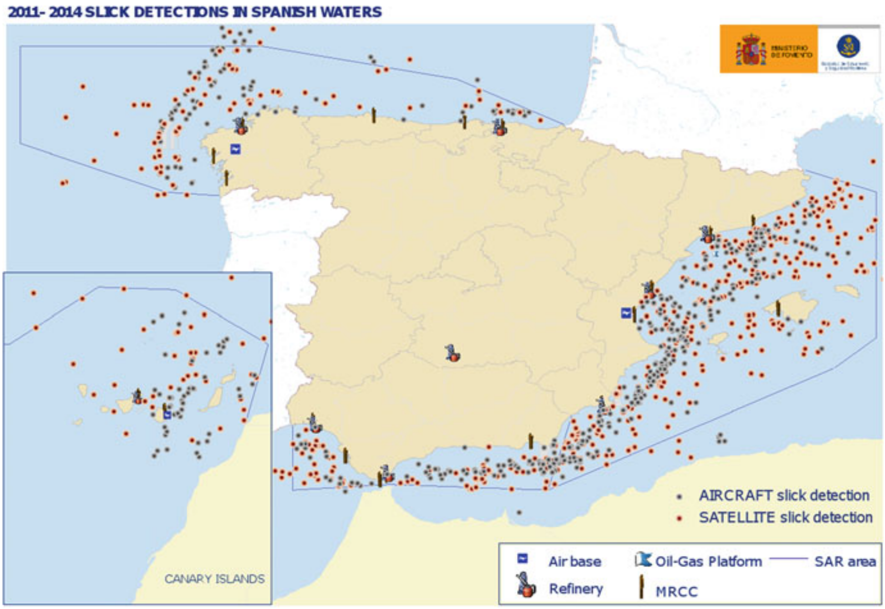


Fig. 7 Aircraft and satellite slick detections in Spanish waters 2011–2014

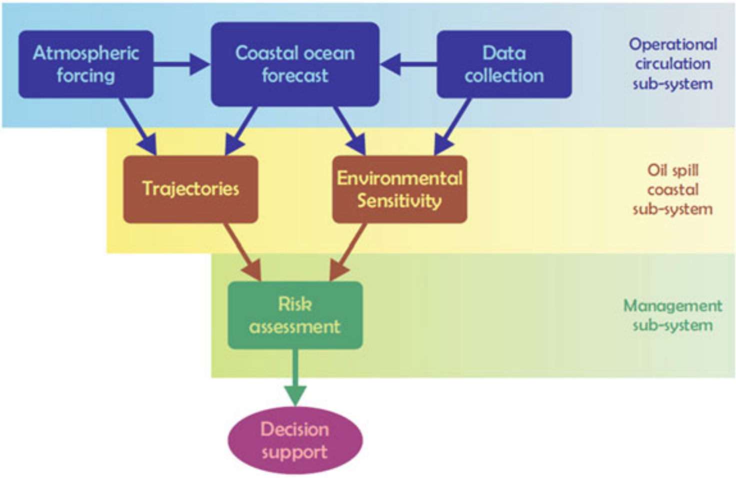


Fig. 8 Structure of the hybrid forecasting system for oil spill or search and rescue operations [24]

and feature-oriented strategic sampling; (2) an oil spill coastal subsystem that allows simulation of the trajectories and fate of spilled oil together with evaluation of coastal zone vulnerability using environmental sensitivity indexes; and (3) a risk management subsystem for decision support based on GIS technology.

The operational system was complemented with a monitoring component to feedback the whole system, validating the forecasting assumptions. Today, the satellite and aerial surveillance, the historical data from past incidents, the use of drifting buoys and sampling results are part of this monitoring element. But also oil spill forecasting and identification may be essential as evidences in the enforcement process to prove the polluter offence.

5.1 Oil Spill Forecasting

The Spanish Maritime Safety and Rescue Agency uses marine meteorological and oceanographic data to feed the pollution models. An Environmental Data Server (EDS) connects to the different data providers and manages the information. The EDS allows storing, analysing and displaying the environmental data. The system collects the information in different formats and makes it available to the operators at the MRCCs. The wind data is provided by AEMET (State Meteorology Agency), MeteoGalicia and NOAA. The current data is delivered by Puertos de Estado, Copernicus and local sources such as MeteoGalicia, SOCIB, AZTI and the Universities of Cadiz and Vigo. All the information is stored daily for environmental studies and currently there is historical data since 2013.

The 2D OILMAP model is used by SASEMAR to predict the drift of the oil. The MRCC operators receive a training course, and they are prepared to run the model for slicks detected in the sea in order to plan the response. And they can also perform a backtracking analysis to identify suspected vessels, by using Automatic Identification System (AIS) data. Of course this is a very difficult task especially in areas where there is a high traffic density, but a suspect can be identified and an inspection at port can be carried out by the Maritime Authority.

Drifting buoys are used in exercises and in real incidents. In small drills, the buoys are deployed to analyse the spill modelling. In larger exercises, feedback is given to Puertos del Estado and to scientific and research organisations. In real incidents, drifting buoys are key in supporting the model predictions.

The historical data obtained from real oil spill incidents which have been analysed are really important to feedback the models and to validate the operational system.

All started in 2002, when there was a need to establish an operational oceanography in order to monitor and forecast the oil spill from the *Prestige*. Several operational forecast systems were built in different regions with a common objective of helping to manage the crisis [25, 26].

The experience gained with the *Prestige* pre-operational systems and the funding opportunity provided by the Spanish Ministry of Education and Science gave birth to a 3-year project (2004–2006), the ESEOO (Implementation of a Spanish Operational Oceanography System (www.eseoo.org)). The ESEOO partners constituted a multidisciplinary team coordinated by Puertos del Estado with the basic objective of developing operational oceanography at the national level by creating new tools and by improving the inter-institutional and international coordination. Nowadays, the ESEOO modelling products are integrated into the Spanish Maritime Safety and Rescue Agency (SASEMAR) procedures, being used to provide forecasts of drifting persons and objects as well as providing basic tools for dealing with accidental marine pollution [27].

In order to test the accuracy of the prediction tools, a periodical comparison between ground truth information and numerical predicted paths was carried out. The model parameters were corrected by means of a trial-and-error procedure. Specifically, in Cantabria, a study on the relative importance of the different forcing (wind, wave, currents) was undertaken as part of the calibration process. This study found that although wind drift and surface currents were the major advective transport mechanisms, wave-induced Stokes drift could not be discarded and, on several occasions, wave-driven transport became the most important factor in the transport of the floating oil slicks.

Another way of testing the performance of the numerical models consisted of a continuous oil slick tracking. To this end, the overflight information from aircrafts was one of the main components of the forecasting system. Another valuable source of information was provided by satellite-tracked Lagrangian buoys.

The buoy data is particularly useful to calibrate the oil spill dispersion models. These tools were extensively used during the *Prestige* oil spill [28] and also during a recent spill originated by the grounding of the vessel *Oleg Naydenov*, 15 miles south of Gran Canaria Island, after towing it away from the port when a fire was declared on board (April 14, 2015). The oil slick position charts are elaborated and provided daily to the response team. The information obtained during the first week after the spill is shown in Fig. 9.

5.2 Source Identification

Efficient analytical methods for the unambiguous characterisation of oil spillages are needed from the standpoint of the enforcement of the pollution control laws, designed to protect the public health and the environment. Chemical analytical results are thus used to attach responsibilities, assess penalties and help recover clean-up costs incurred during an incident.

In Spain, the implementation of a solid source identification mechanism started just after the *Prestige* accident (2002) and was completed in 2012 with the accreditation of the official laboratory (Fig. 10). The laboratory has been actively participating in the annual Bonn-OSINet (oil spill identification network of experts within the Bonn Agreement) round-robin tests for enhancing knowledge and experience [29].

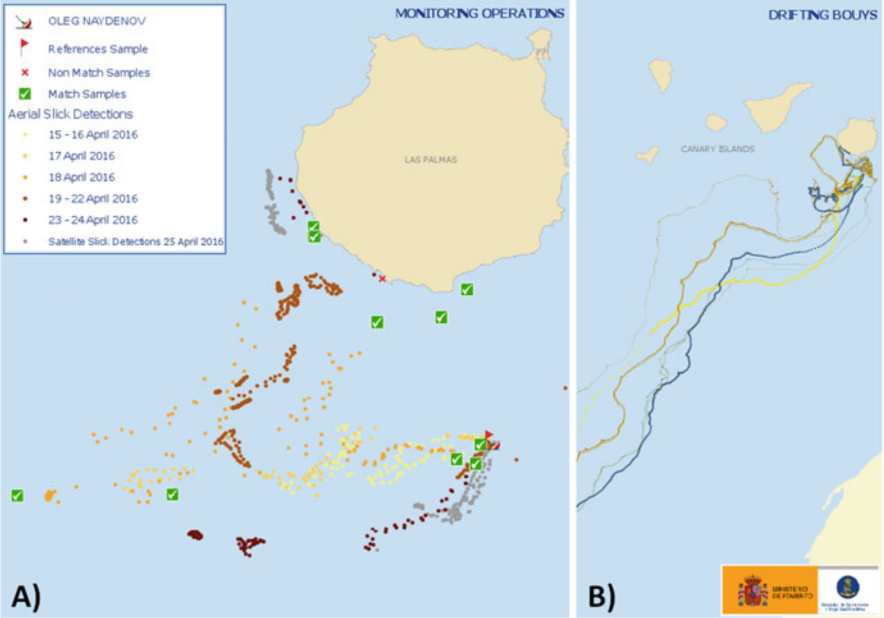


Fig. 9 Monitoring operations of the *Oleg Naydenov* spill (**a**) and buoy trajectory evolution during the study period (**b**)

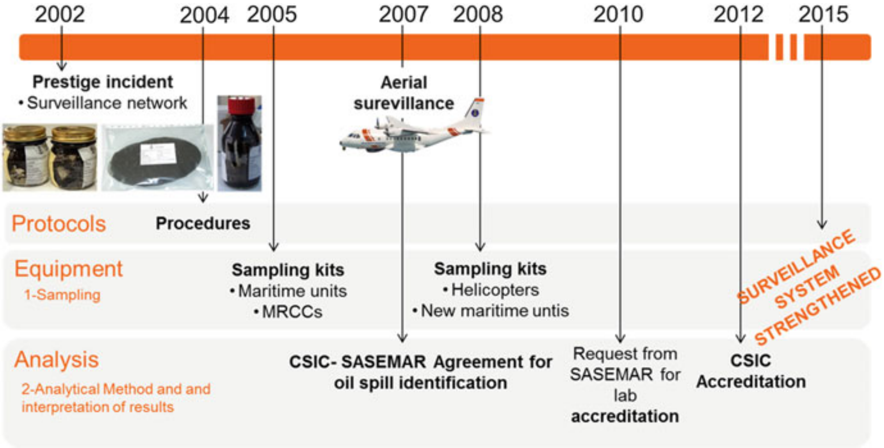


Fig. 10 Implementation of the Spanish surveillance system

The methodology used in the laboratory for oil spill monitoring and the prosecution of infringers is the one established in 2002 by the European Committee for Standardisation (CEN) [30], encompassing two guidelines:

Fig. 11 Sampling kit for oil spills

Part I: Oil spill identification – Waterborne petroleum and petroleum products. Sampling (CEN/TR 15522-1; 2006)

Part II: Oil spill identification – Waterborne petroleum and petroleum products. Analytical methodology and interpretation of results (CEN/TR 15522-2; 2012)

Sampling is the first step in the process of defensibly determining the source or impact of an oil spill. Designing a comprehensive oil source sampling plan is fundamental in the investigative efforts of an oil spill, and collection of oil from both the spill and the suspected source(s) is crucial to any forensic investigation.

In the sea, samples are collected using the devices described in the guideline (Part I), according to the type of sample, a Teflon net for thin oil films (slicks or sheens) and a polyethylene cornet for floating oil. A sampling suitcase with all necessary equipment has been designed and placed on board of the response vessels and helicopters (Fig. 11).

Special attention is paid to secure the representativeness of the collected samples, both at sea and from the vessel tanks. If the spill response operation continues for more than 1 day, samples are taken every day to make it possible to determine the degree of weathering of the oil as well as a possible contamination by other oils and as evidences in the claims management process. Together with the samples, all relevant information is recorded, e.g. the sampling conditions, the sample location (e.g. latitude-longitude-depth), the potential spill transport pathways, etc. These documents are also important for warranting the chain of custody of the samples.

Once in the laboratory, samples are analysed by gas chromatography-flame ionisation detector (GC-FID) and gas chromatography-mass spectrometry (GC-MS) and compared using a suite of diagnostic ratios of selected compounds (molecular markers) which constitute the fingerprint of the oil [31]. The selection of these series of compounds lies on the combination of their source specificity and their lower susceptibility to weathering. Any differences of compound ratios, not influenced by weathering, are only relevant if a difference is larger than the variability of the method itself.

The application of these concepts and methods is illustrated in the following case studies. They offer important examples of how to identify the oil spill source, if unknown, and additionally monitor changes in oil samples due to weathering in the longer term.

5.3 *Case Studies*

The CEN methodology was extensively used during the ***Prestige* oil spill** (November 13, 2002). Following the accident, an extensive survey was carried out by SASEMAR at the northern coast of Spain, to obtain a comprehensive picture of the fate of the spill in the marine environment and, indirectly, identify the possible occurrence of illegal discharges in the area after the spill. More than 200 oil samples were collected in the region (at sea, at the continental shelf and stranded on the coast) between December 2002 and December 2003 and characterised by chemical fingerprinting (Fig. 12).

From the total samples analysed during this period, 17% of them did not match the *Prestige* oil, and most of these (52%) were found off La Coruña where the city harbour and a refinery support an intense maritime traffic. This demonstrates the continued occurrence of oil discharges at sea and the need for a more strict surveillance of the areas holding heavy tanker traffic.

During that survey, the *Prestige* oil was drifting on the seawater surface for almost 1 year, and thus it was highly exposed to major weathering processes

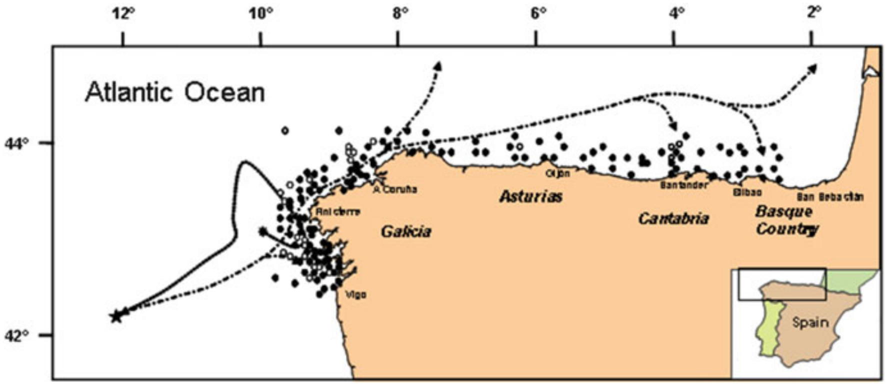


Fig. 12 Sample locations along the northern Spanish coast with indication of the main oil trajectories. *Solid arrow*, tanker towing route. *Filled star*, shipwreck position. *Dotted arrow*, oil trajectories. Oil samples (*full* and *empty circles* correspond to *Prestige* and non-*Prestige* samples, respectively). Reprinted from [32], with permission from the American Chemical Society

(e.g. emulsification, evaporation, dissolution, photo-oxidation and biodegradation). Thus, a good opportunity to monitor the resulting compositional changes for assessing the molecular indicators to be used for oil source recognition was presented [32]. Evaporation of the lower fractions (<n-C20 range) and dissolution (low-molecular-weight aromatic hydrocarbons) were the most apparent processes, which accounted for a 5% and 2% of oil loss, respectively. In summary, the data showed the high persistence of the spilled heavy oil at sea, 1 year after the accident, with very low incidence of the natural weathering processes, thus stressing the need for mechanical removal from the sea surface and the coastal areas.

However, 9 years after the accident, oil from the *Prestige* was still recurrently arriving to some beaches [33]. It was found that the morphodynamics of high-energy beaches favoured a cyclic burying of the oil, down to 4 m depth, and resurfacing, and its transport from the subtidal area to the intertidal area and vice versa. During this process, a clear biodegradation signal was observed within the aliphatic and aromatic fractions. *n*-Alkanes were totally depleted and the C1–C2 alkylphenanthrenes and dibenzothiophenes, proposed for source recognition and weathering assessment of spilled oils, exhibited an interesting sequence of events of increasing biodegradation, as shown in Fig. 13 and discussed elsewhere [34]. The

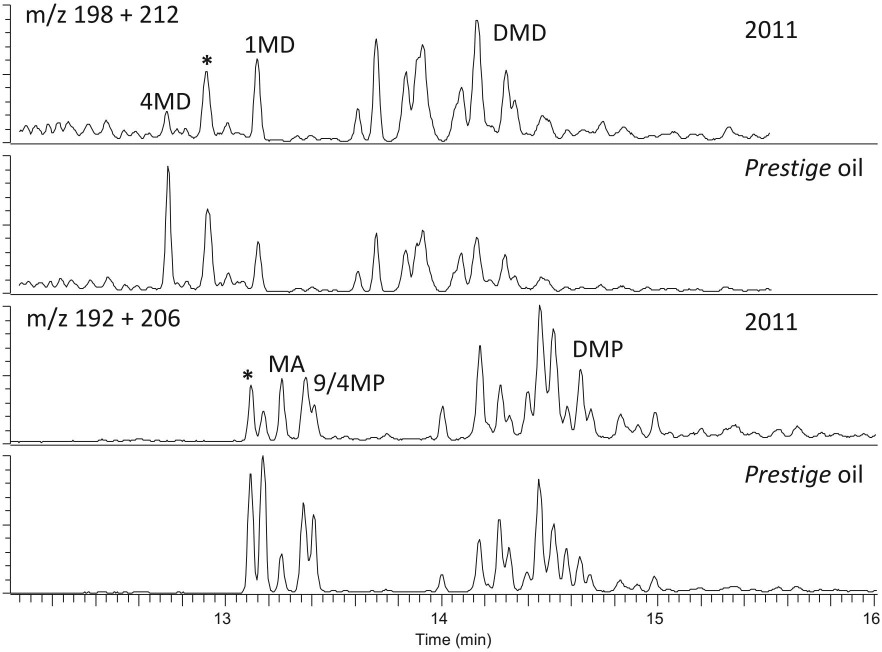


Fig. 13 Ion chromatograms of methyl- and dimethylphenanthrenes (m/z 192 and 206) and dibenzothiophenes (m/z 198 and 212) of the oil samples and *Prestige* oil. *MA* methylanthracene, *MP* methylphenanthrene, *MD* methyldibenzothiophene. *2-/3-methylphenanthrene and dibenzothiophene

more recalcitrant triterpene and sterane compounds provided the clue for source recognition.

All these findings were integrated in the strategy design of the *Prestige* oil spill assessment and hence the remedial treatment of oiled beaches.

More recently, on the morning of April 15, 2015, the Russian flag fishing **vessel *Oleg Naydenov*** sank 15 miles south of Punta Maspalomas, at a depth of 2,700 m. On April 11, the ship, with 1,400 tonnes of fuel, 30 of diesel and 70 of lubricating oil, was ready to leave the Port of Las Palmas (Gran Canaria Island) when a fire was declared on board. Due to the risk posed by the ship afire for the population and the environment, it was towed offshore, where it finally sank.

Since its downfall, a surveillance programme and monitoring pollution was established. Following the aerial surveillance (Fig. 9), around 30 sets of samples were collected from April 15 to May 15, 2015, which were sent to the laboratory for identification.

As in the *Prestige* case, the main aim of the monitoring was to obtain a comprehensive picture of the spreading of the spill in the marine environment and, indirectly, to identify the possible occurrence of illegal discharges in the area after the spill. However, the problem here was the mixing of the different products carried by the vessel during the spill. This is illustrated in the representative profiles displayed in Fig. 14.

The GC profiles of different samples show the characteristics of a heavy fuel oil with different proportions of lubricating oil (in grey). The matching of the fuel oil in all samples was confirmed by the coincidence of the mid-range profiles (e.g. C1-pyrenes and C4-phenanthrenes) and the associated diagnostic indices, whereas the contribution of different proportions of lubricating oil was evidenced by the differences in the characteristic sterane and triterpane profiles and the corresponding indices, as illustrated in Fig. 15. The profiles of C4-phenanthrenes (m/z 234) exhibit a full overlay, whereas the differences between the ββ-sterane distributions (m/z 218) are consistent with the increasing proportion of lube oil.

These features are common in spills of waste oils (e.g. bilge residues, sludge, slops) where different mixtures can be found in different tanks and samples. These differences should be considered in the assessment of diagnostic ratios in comparing the samples.

An operational incident occurred in May 22, 2013, when the captain of a container carrier communicated to the maritime authorities an accidental spill of fuel oil offshore Valencia. Spill samples were collected in the vicinity of the vessel and also from the suspected tank the same day of the accident, but some days later (from May 31 to June 15), new oil slicks appeared on the sea. At the same time, almost 1 month later, from July 6 to July 14, oil residues were widely spread on some Valencia and Castellón beaches. The question was to identify the source of these samples and, particularly, if they were related to the aforementioned spill.

The comparison of the diagnostic ratios of all collected samples at sea confirmed their coincidence with the reference sample from the vessel tank. Most of the ratios of the samples collected on the beaches allowed to conclude also a match. However, some ratios exhibited an increasing deviation with time (Fig. 16). These ratios were

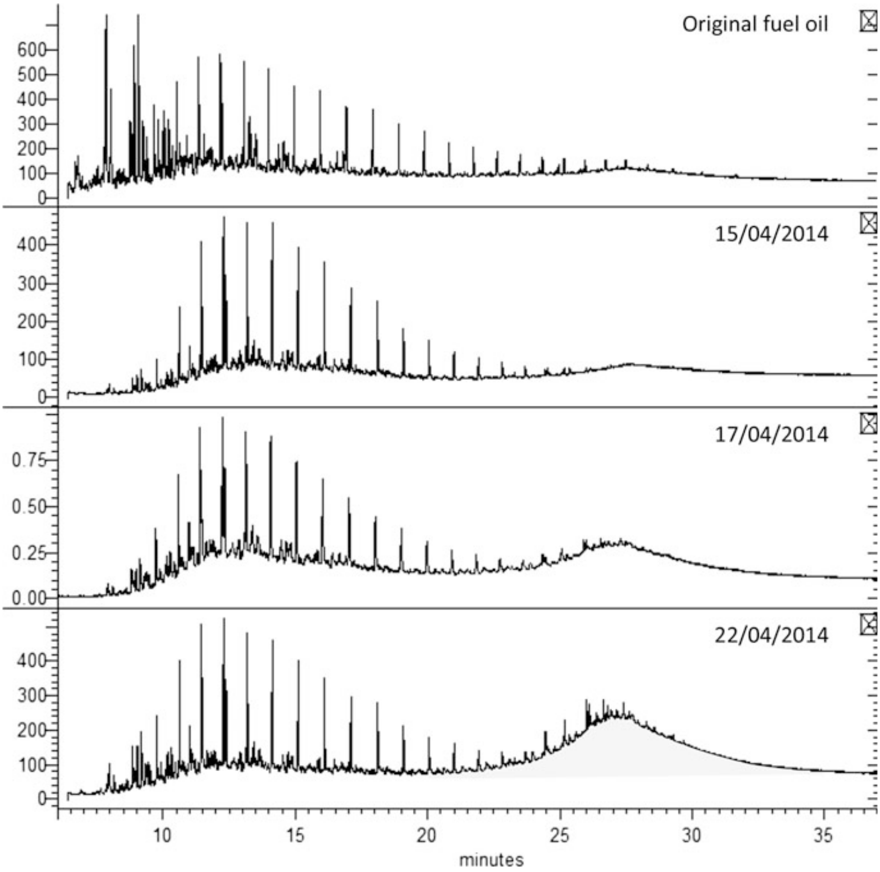


Fig. 14 Gas chromatographic profiles of the *Oleg Naydenov* fuel and samples collected at sea

those involving the fluorenes and benzofluorenes (2MF/4-Mpy, B(a)F/4-Mpy) and benzonaphtothiophenes (BNT/T-M-phen), which is known to be affected by photo-oxidation [35]. This is a rather fast process in low-latitude areas, whereas sunny conditions predominate, as it was the case in the present incident that, in addition, occurred in summer.

A practical way to quantitatively illustrate these compositional changes in weathered samples is by the so-called ‘percentage weathering’ plots (PW plots) [30]. They can be obtained when the individual compounds of the original and weathered sample are normalised to the 17α(H),21β(H)-hopane (C30-hopane), highly refractory to weathering. Next, the calculated remaining percentage of the compounds in the weathered sample relative to the original oil is plotted against the retention time, linked with the boiling point of the corresponding compounds. If the samples are identical (e.g. a duplicate analysis), the result will be a straight line at

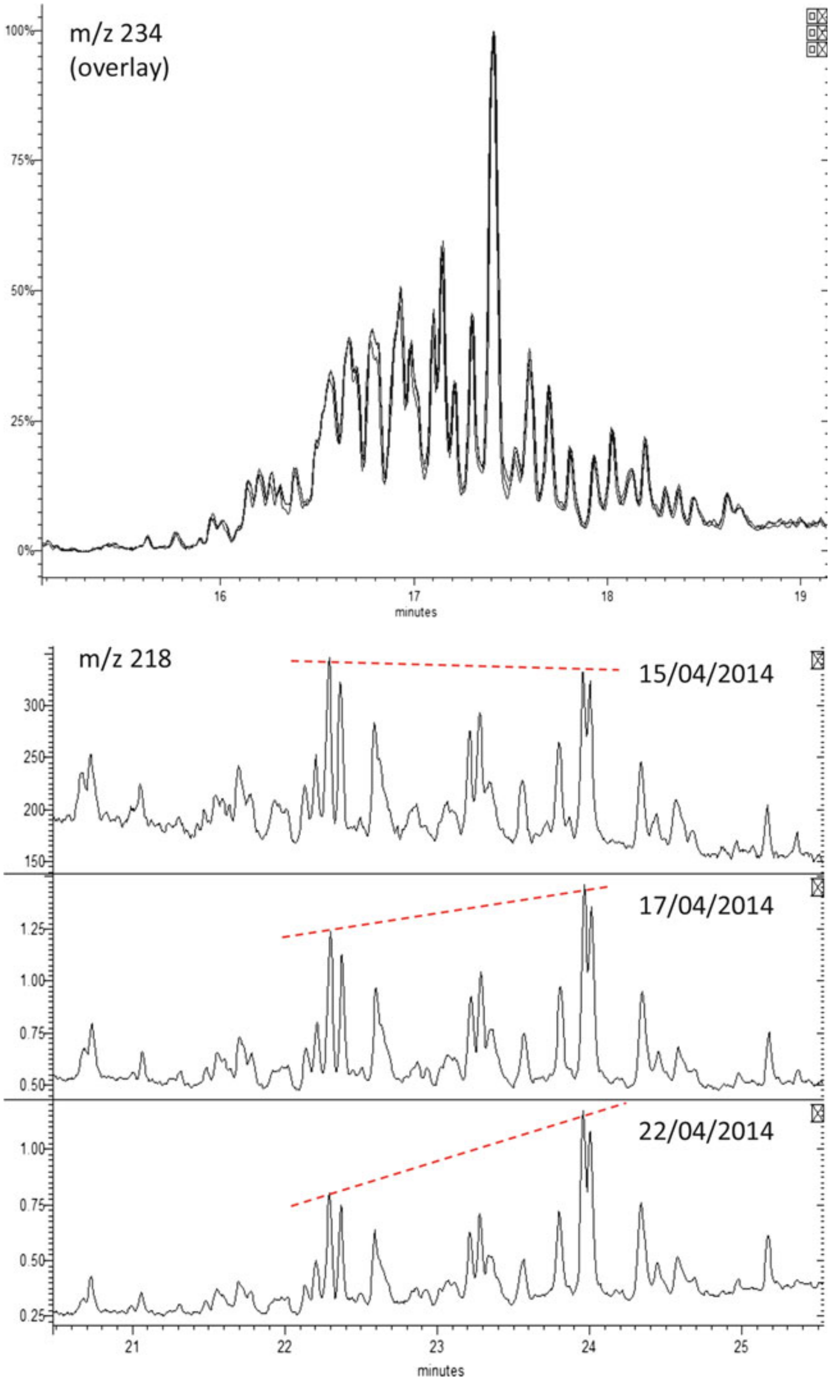


Fig. 15 Ion chromatograms of C4-methylphenanthrenes (m/z 234) and ββ-steranes (m/z 218) of *Oleg Naydenov* samples collected during April 2014

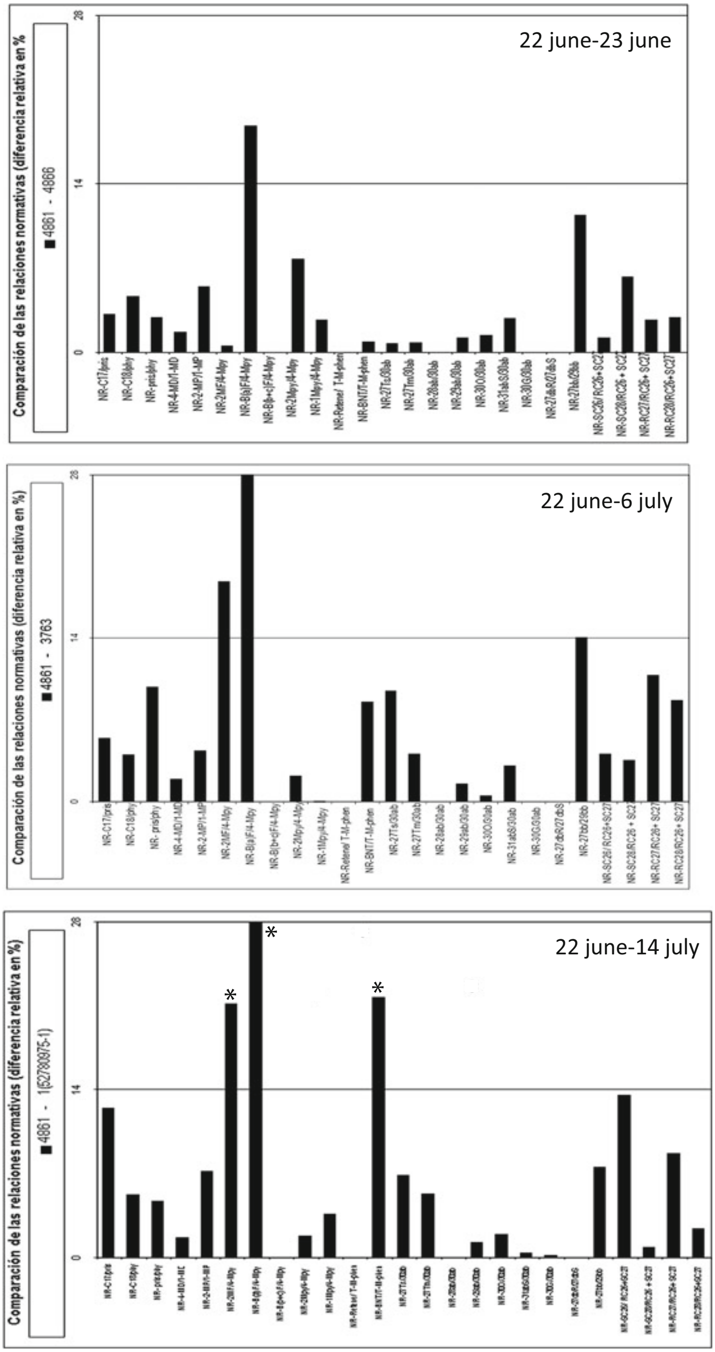
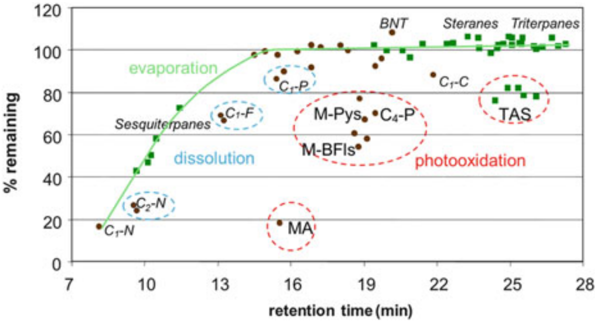


Fig. 16 Comparison of diagnostic ratios of the reference sample with those collected on the coast. *Ratios affected by photo-oxidation [34]

Fig. 17 Percentage of PAHs (*circles*) and biomarkers (*squares*) of the *Prestige* sample after simulated photo-oxidation in the laboratory [34]



100%. The loss of certain compound by weathering will be reflected by a decrease in the plot.

A summary of the effect of different environmental processes on the oil comparison is shown in Fig. 17, which reveals a significant depletion of compounds with low retention times (volatile) due to evaporation. At the same time, the effect of other processes, such as i.e. dissolution, may explain the loss of C1- and C2-naphthalenes (C1-N) and fluorenes (C1-F). Finally, the significant reduction of MA (80%), M-BFls (40%) and M-Pys (20–40%), C4-Ps (30%) and TAS (20%) can be attributed to photo-oxidation, as it has recently been demonstrated through laboratory and field tests [35].

When the effects of weathering on a spilled oil are understood, any affected ratio can be eliminated or cautiously considered when comparing a weathered spill sample with an unweathered source sample.

6 Conclusion

Throughout history, large incidents have allowed countries to move forward on oil spill preparedness and response. This happened to Spain in 2002 when the Maritime Authority had to face the *Prestige* spill. At that moment, a national system for oil pollution was being set up, but of course it was not enough to cope with such a major accident. Lessons were learnt at a national and international level. Due to the *Prestige* incident, important investments were made in Spain, greatly increasing its resources. Oil spill response equipment was acquired; and multipurpose vessels and fixed-wing aircrafts became new units in the Spanish fleet. But also scientific and technical research was supported, providing interesting results. All these resources, developments and innovations have been integrated into the national system.

Today, Spain has a solid system for oil pollution prevention and response. Policies have been established to implement the international and European regulation, to ensure coordination and cooperation at a national and international level and to make an efficient use of the resources. The regulatory framework includes a National Maritime Plan and a Coastline Protection Plan as well as the coordination mechanisms between them. The operative plans established with neighbouring coastal states are also part of the system. Through investment action plans, the pollution strategies have been defined covering preparedness, prevention and response. Aerial and satellite surveillance together with oil forecasting and sampling are strengths of this system, providing a reliable monitoring of the Spanish waters. These monitoring tools are key in the enforcement processes to prove the pollution offences in case of illegal discharges. But they are also essential to provide an effective response in oil spill incident's management.

Although a large incident has not occurred since 2002, Spanish authorities have dealt with medium and small oil spills, in which the whole system has been tested. Learning from these past incidents and keeping updated with international experiences and developments is crucial. Also, measures have been taken to enhance maritime safety in order to reduce the shipping accidents, with a special interest in being at the forefront of technology. And never forgetting preparedness, prevention and response for hazardous and noxious substance incidents, a major challenge in which a great effort needs to be done perhaps with a European coordinated approach.

Acknowledgement This chapter is built on the work of the whole human team of the Spanish Maritime Safety and Rescue Agency (SASEMAR). Jesús Uribe, the Operations Director for many years, guided many of us throughout the pollution preparedness, prevention and response knowledge. Gracia Alburquerque and Mónica Mulero's enthusiasm and commitment are responsible for the bottom line of this chapter. The Aerial Inspection Unit, Néstor Perales and Berta Blanco, has greatly supported the outcome of this chapter providing data and maps (Figs. 1, 6, 7 and 9), as well as the Operational Oceanographic Unit (Ana Rietz) with its thoughtful advice. Eugenia Sillero, the Technical Secretary, has made this happen supporting SASEMAR's participation.

References

1. Real Decreto 1695/2012. Boletín Oficial del Estado, No. 13, January 15, 2013, p 1793
2. Sardá R (2013) Ecosystem services in the Mediterranean sea: the need for an economic and business oriented approach. In: Hughes TB (ed) Mediterranean sea. Ecosystems, economic importance and environmental threats. Nova Science Publishers, New York, pp. 1–35
3. Barragán JM (2003) Coastal zone management in Spain (1975-2000). J Coastal Res 19:314–325
4. Integrated coastal zone management in Spain (2010) Report by Spain in fulfilment of the requirements of Chapter VI of the Recommendation of the European Parliament and of the Council concerning implementation of Integrated Coastal Zone Management in Europe. http://ec.europa.eu/ourcoast/download.cfm?fileID=1323
5. Garcia-Ayllon S (2016) Geographic information system (GIS) analysis of impacts in the tourism area life cycle (TALC) of a Mediterranean resort. Int J Tourism Res 18:186–196
6. Ariza E, Sarda R, Jiménez JA, Mora J, Ávila C (2008) Beyond performance assessment measurements for beach management: application to Spanish Mediterranean beaches. Coast Manage 36:47–66
7. Vázquez V (1998) The future for fisheries-dependent communities: The fisheries-dependent region of Galicia. J Northw Atl Fish Sci 23:175–184

8. Kai W, Wirtz KW, Xin Liu X (2006) Integrating economy, ecology and uncertainty in an oil-spill DSS: The *Prestige* accident in Spain, 2002. Estuar Coast Shelf Sci 70:525–532
9. Ecosystems and Human Well-being Synthesis (2005) Millennium Ecosystem Assessment (MEA). Island Press, Washington, DC http://www.millenniumassessment.org/en/Framework.html
10. SASEMAR (2014) Annual reports. http://www.salvamentomaritimo.es/sm/que-hacemos/informe-anual/
11. Albaigés J, Bernabeu A, Castanedo S, Jimenez N, Morales- Caselles C, Puente A, Viñas L (2015) The prestige oil spill. In: Fingas M (ed) Handbook of oil spill science and technology. John Wiley & Sons, Hoboken, NJ, USA, pp. 515–546
12. Cedre (2013) Classement alphabétique des accidents. http://www.cedre.fr/fr/accident/classement-alphabetique.php
13. Puertos del Estado, Anuario estadístico (2014) Madrid, Spain. http://www.puertos.es/es-es/estadisticas/RestoEstad%C3%ADsticas/anuariosestadisticos/Paginas/2014.aspx
14. Sicre MA, Fernandes MB, Pont D (2009) Poly-aromatic hydrocarbon (PAH) inputs from the Rhône River to the Mediterranean sea in relation with the hydrological cycle: impact of floods. Mar Pollut Bull 56:1935–1942
15. UNEP/MAP/MEDPOL/WHO (2004) Municipal wastewater treatment plants in Mediterranean coastal cities (II). MAP Technical Report Series No. 157. UNEP/MAP, Athens
16. Pon J, Albaigés J (2011) Oil pollution in the Mediterranean. In: Stambler N (ed) Life in the Mediterranean sea: a look at habitat changes. Nova Science Publishers, New York, pp. 681–717
17. Real Decreto Legislativo 2/2011. Boletín Oficial del Estado, No. 253, October 20, 2011, p 109456
18. Ley 14/2014. Boletín Oficial del Estado, No. 180, July 25, 2014, p 59193
19. Orden FOM/1793/2014. Num. 241, October 4, 2014, p 79031
20. Orden AAA/702/2014. Boletín Oficial del Estado, No. 107, May 2, 2014, p 34450
21. Real Decreto 1593/2010, Boletín Oficial del Estado, No. 289, November 30, 2010, p 99368
22. Orden FOM/1634/2013. Boletín Oficial del Estado No 219, September 12, 2013, p 67128
23. Plan Nacional de Seguridad y Salvamento Marítimo 2010–2018. http://www.salvamentomaritimo.es/wp-content/files_flutter/1320770125PlanNacionalSeguridad-Salvamento-Maritimo2010_2018.pdf
24. Jordi A, Ferrer MI, Vizoso G, Orfila A, Basterretxea G, Casas B, Álvarez A, Roig D, Garau B, Martínez M, Fernández V, Fornés A, Ruiz M, Fornós JJ, Balaguer P, Duarte CM, Rodríguez I, Alvarez E, Onken R, Tintoré J (2006) Scientific management of Mediterranean coastal zone: a hybrid ocean forecasting system for oil spill and search and rescue operations. Mar Pollut Bull 53:361–368
25. Castanedo S, Medina R, Losada IJ, Vidal C, Mendez FJ, Osorio A, Juanes JA, Puente A (2006) The *Prestige* oil spill in Cantabria (Bay of Biscay). Part I: operational forecasting system for quick response, risk assessment and protection of natural resources. J Coastal Res 22:1474–1489
26. Gonzalez M, Uriarte A, Pozo R, Collins M (2006) The *Prestige* crisis: operational oceanography applied to oil recovery, by the Basque fishing fleet. Mar Pollut Bull 53:369–374
27. Alvarez-Fanjul E, Losada I, Tintoré J, Menéndez J, Espino M, Parrilla G, Martinez VI, Muñizuri VP (2007) The ESEOO project: developments and perspectives for operational oceanography at Spain. Proceedings of the International Offshore and Polar Engineering Conference, p 1708
28. Garcia-Ladona E, Font J, del Rio E, Julia A, Salat J, Chic O, Orfila A, Alvarez A, Basterretxea G, Vizoso G, Piro O, Tintore J, Gil M, Herrera JL, Castanedo S (2005) The use of surface drifting floats in the monitoring of oil spills. The *Prestige* case. Proceedings of the 19 Biennial International Oil Spill Conference (IOSC), Miami, CD-ROM: 14718 A

29. Dahlmann G, Kienhuis P (2015) Oil spill sampling and the bonn-oil spill identification network: a common method for oil spill identification. In: Carpenter A (ed) Oil pollution in the north sea. Springer International Publishing, Switzerland, pp. 237–254
30. European Committee for Standardization (CEN) (2012) 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. CEN, Brussels. https://standards.cen.eu/dyn/www/f?p=204:105:0
31. Albaigés J, Kienhuis P, Dahlmann G (2015) Oil spill identification. In: Fingas M (ed) Handbook of oil spill science and technology. Wiley, Hoboken, pp. 165–204
32. Diez S, Jover E, Bayona JM, Albaigés J (2007) Prestige oil spill. III. Fate of a heavy oil in the marine environment. Environ Sci Technol 41:3075–3082
33. Bernabeu AM, Rey D, Rubio B, Vilas F, Dominguez C, Bayona JM, Albaigés J (2009) Assessment of cleanup needs of oiled sandy beaches: lessons from the *Prestige* oil spill. Environ Sci Technol 43:2470–2475
34. Bernabeu AM, Fernández-Fernández S, Bouchette F, Rey D, Arcos A, Bayona JM, Albaiges J (2013) Recurrent arrival of oil to Galician coast: the final step of the *Prestige* deep oil spill. J Hazard Mat 250–251:82–90
35. Radović JR, Aeppli C, Nelson RK, Jimenez N, Reddy CM, Bayona JM, Albaigés J (2014) Assessment of photochemical processes in marine oil spill fingerprinting. Mar Pollut Bull 79:268–277

Oil Pollution in French Waters

Michel Girin and Pierre Daniel

Abstract This chapter presents an overview of the French Mediterranean marine pollution prevention and response organization and its recent evolution in relation to the threat and consequences of tankers accidents and operational spills in the maritime areas under French jurisdiction. Accidental shipping spills statistics for the whole Mediterranean from 1977 to 2010, gathered and exploited by Girin in Part I (The International Context) of this book, were compared with existing data for water areas under French jurisdiction. During the period surveyed, there was no accidental spill above 10 tons in those waters. However, in 1991, waves, wind and current carried, to the famous "Côte d'Azur," an estimated 10,000 tons of weathered and partially burnt oil from a 144,000 tons spill in Italian waters. As regards operational pollution, aerial surveillance reported an average 330 spills per year during the decade 2000 to 2009 in the area of the Mediterranean under French jurisdiction; down to 115 spills in 2012.

The chapter examines then the specificities of the Mediterranean waters under French jurisdiction as regards oil pollution and highlights the main areas of progress under way. This concerns mainly (1) the evolution of aerial and satellite surveillance of operational spills and the transfer of that experience to accidental spills; (2) the prosecution of offenders and the measures taken to constrain shipowners to deal with the risk of possible pollution from wrecks, at their expense; (3) the sharing of experience and response with partners from the industry and counterparts in

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neighbouring countries; (4) support to initiatives of the Regional Marine Pollution Response Centre for the Mediterranean Sea (REMPEC) and the European Maritime Safety Agency (EMSA).

Keywords Accidental oil spill, French oil spill organization, Mediterranean Sea, Operational oil spill

Contents

1 Introduction: The Sources of Spills

This chapter intends to provide a brief overview of the responsibility area of France as regards oil spills in the Mediterranean Sea, the oil spills it has faced, its response organization and its level of preparedness.

The overall oil pollution in the Mediterranean waters is the sum of four different sources, namely:

1. Accidental spills inland, from storage tanks, road/rail/pipeline accidents, acts of war or vandalism, with the oil being carried to the sea by rivers. There are no statistics at national level of those spills, which are generally very small. There is, however, occasional mention in local newspapers of accidental spills by trucks or train accidents, voluntary or accidental damage to pipelines, with oil finding its way into the hydrographic network to the sea. A

typical example in France is that of the southern Mediterranean trans-European pipeline in the vicinity of Marseilles airport, suffering a more or less important accidental rupture about every other year. One would have to check local journals, over the last decades, to quantify the amount of oil released inland and reaching the Mediterranean Sea. Hence, that source will not be further considered here.
2. Ships and coastal storage accidents or acts of war, releasing without warning a large quantity of oil in a particular place. These are quite rare: less than one per decade on average for those over 10 tons (smaller ones are hardly documented in national statistics accessible from abroad). Such incidents make the headlines in the media, with always the same question: “will the Mediterranean survive yet another spill?”
3. Operational spills by shipping: these take place weekly as an overall average and are estimated as being up to daily on some heavy traffic routes, where they are concentrated. They are voluntary and individually small (a very few such spills contain 10 m^3 of oil or more). However, their frequency in some areas makes them a concern for the Authorities.
4. Natural seeps on the sea bed: there is some evidence to suggest that natural spills occur in some places, indicative of the presence of fossilized oil and gas seeping from underground reservoirs. Oil companies are suspected to know about it, but they usually deny it. Although there exist estimates of such natural seeps worldwide [1] and at regional [2] level, we did not find any evidence of such spills in the northern half of the western Mediterranean basin. Hence, natural spills will not be further considered here.

As a whole, the French Mediterranean coastline has never been faced, up to the current time, with a major oil spill from a supertanker producing swathes of heavy black waves loaded with oil, drifting toward the coastline, like those impacting the Atlantic coast after the stranding of the *Amoco Cadiz* or from the wrecks of the *Erika* and *Prestige*.

2 The French Oil Spill Prevention and Response Organization

France has no Coastguard established as a specific public service. Hence, the prevention of, and the response to, accidental oil spills are shared between different public services and institutions with a public service mission. This is known to the French as the “organisation Polmar Marine pollution organization,” “Polmar plan” or just “Polmar.”

2.1 The Polmar Rules

The Polmar organization is governed by two “Instructions[1]”:

1. That of 4 March 2002 “*relative à la lutte contre la pollution du milieu marin*” [3], and
2. That of 13 January 2006 “*portant adaptation de la réglementation relative à la pollution du milieu marin*[2]” [4].

Those instructions incorporate two sectorial rules published in 1991, namely:

1. The 19 April 1991 law “*sur les déballastages*” (law on operational spills), establishing a co-responsibility of the captain and shipowner in case of illegal spill and increasing their liability to €1.2–4 million, depending of the size of the ship (€200,000–€600,000).
2. The 12 April 1991 instruction on the “accidents maritimes majeurs” (major maritime incidents), putting Polmar at the same level as the plan of assistance to castaways, both being specialized plans under the umbrella of the “plan d’organisation des secours – ORSEC” (organization of assistance) applying to all forms of major emergencies (earthquakes, floods, fires, tsunamis, etc.).

We shall, in the rest of this chapter, refer to the French Marine Pollution Organization so established as Polmar.

2.2 The Polmar Leaders

Polmar establishes response leaders, giving them powers to mobilize all services and institutions mentioned in the instructions, for the tasks they are expected to implement. Those leaders are:

- At sea, the Maritime prefects, representing, in their areas of responsibility, the Prime Minister. There are three maritime Prefectures for mainland France, that of the Mediterranean, that of the Atlantic and that of the Channel and North Sea. The Maritime Prefects are admirals from the Navy.
- On the coastline, the mayor for a pollution incident limited to one “commune” (NUTS 4), the prefect of “département” for a pollution incident impacting several communes in a “département” (NUTS 3) and the region prefect for a pollution incident impacting several “départements” (NUTS 3) within a region (NUTS 2).[3]

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[1] An instruction is a text that lists public service entities and describes the actions they should implement in an emergency.

[2] Instruction related with response to pollution of the sea/Instruction related with the adaptation of rules related with response to pollution of the sea.

[3] NUTS = An EU statistical tool to facilitate comparisons between areas under different levels of authority.

Those response leaders have access to the advisory services of a unique expert, the Cedre ("Centre de documentation, de recherche et d'expérimentations sur la pollution accidentelle des eaux") which they can mobilize with the sole commitment that they will claim the payment of its services from those liable for the pollution.

Polmar insists on the importance of joint training, to make sure that leaders and partners can communicate efficiently between themselves, have identical technical approaches to a common problem, and inform the media each in his field of competence. For that reason, each "Préfecture maritime" organizes every year a vast exercise with a response at sea (Polmar-sea), in partnership with one or several "préfectures de département" leading the response on the coastline (Polmar-land). There exists, for mainland France, 3 Polmar-sea and 25 Polmar-land manuals, and a full set with more than 100 pages of information and recommendations. They are updated every 4–6 years, and a full set is immediately accessible in the emergency response room of Cedre.

2.3 The Polmar Partners

In addition to the role of the response leaders discussed above, key Polmar partners have the following duties:

- The Ministry in charge of the Environment represents France, together with the Ministry in charge of the budget, at the International Oil Pollution Compensation Funds (IOPC Funds) and it is endowed with the responsibility to quantify the environmental impact of the pollution, with the scientific support of the French Institute for the Exploitation of the Sea (Ifremer);
- The Ministry responsible for Equipment is in charge of the Polmar-land equipment stockpiles and the provision of manpower for oil recovery on land;
- The Ministry in charge of fisheries and aquaculture installs the necessary fishing bans, aquaculture products sales bans and possible destruction orders, and resumes the bans;
- The Ministry of budget operates the Polmar specialized planes, through the Customs service and it is empowered to claim the Polmar response expenses from the shipowner and
- MeteoFrance is responsible for the slick drift prediction modelling used, a service of paramount importance for the Maritime Prefects, who have among their duties that of informing the land authorities of the predictable movements of the oil slicks at sea and the expected time and place of their landing.

All the Polmar partners, save one, have other concerns than oil pollution. Between two accidents, they retain only a skeleton staff in their Polmar unit and re-staff it when a new incident arises. The exception is Cedre, the expert in the mitigation of accidental water pollution and the memory of the lessons learnt in past incidents. For that reason, Cedre provides training courses to the staff earmarked to join a Polmar command centre when needed. And it is expected to send, when a pollution occurs, a technical adviser to each of the activated command centres.

3 Accidental Oil Spills

An accident is by definition a sudden, unpredictable event. It may, however, have been slowly developing unnoticed (mismanagement, inadequate training, control delayed, etc.) or unaccounted for over a long time (where a deficiency is known but not addressed). On the principle that there is always some responsibility somewhere, an incident always leads to one or several procedures in front of various courts.

3.1 The Sources

The overall oil pollution in the French Mediterranean waters is the sum of four different sources, two of which only were sufficiently documented to be discussed here, namely:

1. Ships and coastal storage accidents or acts of war, releasing without warning a large quantity of oil in a particular place. They are quite rare: less than one per decade on average for those over 10 tons (smaller ones are hardly documented in national statistics accessible from abroad). Such incidents make the headlines of the media, with always the same question: "will the Mediterranean survive yet another spill?"
2. Operational spills by shipping: these take place weekly as an overall average and are estimated as close to daily on some heavy traffic routes, where they are concentrated. They are voluntary and individually small (a very few such spills contain 20 m^3 of oil or more). However, their frequency in some areas makes them a concern for the Authorities.

The other two sources are accidents inland and natural seeps. As regards accidents inland there is occasional mention in local newspapers of accidental spills by trucks or train accidents, voluntary or accidental damage to pipelines, some quite far inland, that have found their way into the hydrographic network and have reached the sea. A typical example in France is that of the southern Mediterranean trans-European, pipeline in the vicinity of the Marseilles airport, suffering a more or less important accidental rupture about every other year (Cedre, personal communication).

One would have to regularly check local journals, over the last 40–50 years, to quantify the amount of oil released into the environment from inland spills and reaching the Mediterranean Sea.

Table 1 Oil spills over 10 tons by ship accidents and an act of war in the Mediterranean Sea, 1970–2015

Year	Ship/plant name	Location of incident	Nature of ship and circumstances of spill	Type of oil spilled	Tons spilled
1977	*Al Rawdatain*	Off Genoa port, Italy	Tanker. Inadequate manoeuver at unloading	Crude oil	1,160
1978	*Pavlos V*	Off Sicily, Italy	Tanker. Fire on board, sinking while on tow	Fuel oil	1,500
1979	*Grey hunter*	Gibraltar straits	Tanker	Non-volatile oil	770
1980	*Juan A. Lavalle*	Arzew harbour, Algeria bay	Tanker	Non-volatile oil	37,000
1980	*Irenes Serenade*	Navarin Bay, Greece	Tanker. Explosion at anchor, sinking	Crude oil and heavy fuel	20,000
1981	*Cayo Cambanos*	Off Tarragona, Spain	Tanker	Diesel	18,000
1985	*Patmos*	Messina Strait, Italy	Tanker. Collision with other ship	Crude oil	700
1990	*Vasilios V*	Greece	Spill in ship to ship transfer	Diesel	1,000
1991	*Agip Abruzzo*	Off Livorno port, Italy	Tanker. Collision with ferry boat	Crude oil	2,000
1991	*Haven* (The whole cargo of the ship was spilled in waters under Italian jurisdiction, save a few hundred tons that remained trapped in the wreck)	Off port of Genoa, Italy	Tanker. Explosion at anchor, fire, partly towed, sank in three parts	Crude oil	144,000
1991	*Erato*	Off Algeria	Sinks in storm with 25,000 tons phosphate and 500 tons bunkers	Heavy fuel	500
1991	*Svangen*	En route by Almeria, Spain	Tanker. Sinks in a storm	Fuel	180
1992	*Geroi Chernomic*	Off Skiros island	Tanker	Non-volatile oil	1,500
1993	*Iliad*	Port of Pylos, Greece	Tanker. Stranded on rocky shore by storm	Crude oil	200

(continued)

Table 1 (continued)

Year	Ship/plant name	Location of incident	Nature of ship and circumstances of spill	Type of oil spilled	Tons spilled
1996	*Kriti Sea*	Port of Agiou Theodori, Greece	Tanker. Wrong manoeuver at unloading	Crude oil	50
1999	*Enalios Thetis*	Sarroch port, Sardinia, Italy	Wrong manoeuver at loading	Fuel oil	56
2000	*Castor*	Off Nador, Morocco	Structural failure in a storm	Gasoline	9,900
2005	*MSC Al Amine*	Gulf of Tunis, Tunisia	Container carrier. Mechanical failure in a storm	Heavy fuel	150
2006	Jiyeh power plant	Lebanon, south of Beirut	Oil storage tanks bombed by Israeli air force	Intermediate fuel oil	15,000
2007	*New Flame*	Gibraltar strait, UK	Dry cargo vessel. Collision with other ship	Heavy fuel	1,800
2010	*CGM Strauss*	Off Genoa-Voltri port, Italy	Container carrier. Collision with other ship	Heavy fuel	180
Grand Total 258,070 Total from tankers incidents 178,460 Total in waters under French jurisdiction 10,000					

Author elaboration from data in Cedre website [5, 6] and REMPEC database on accidents

As a whole, the French Mediterranean coastline has never been faced, up to the current time, with a major oil spill from a supertanker producing swathes of heavy black waves loaded with oil, drifting toward the coastline, like those impacting the Atlantic coast after the stranding of the *Amoco Cadiz* or from the sinking of the *Erika* and *Prestige* (see Table 1).

3.2 The Accidents

Table 1 shows that, from 1971 to early 2016, 18 accidental oil spills over 10 tons and one act of war occurred across the whole Mediterranean, totalling close to 260,000 tons of oil released. Only one of those spills involved France: the “Côte d’Azur” was impacted by part of the 144,000 tons of crude oil released by the wreck of the *Haven*, in 1991. The exact amount of unburnt or partially burnt oil which the French had to fight against in the *Haven* incident, carried into their waters and coastline by the Ligurian Current, will never be precisely known as a large and unknown part of the ship cargo burnt. From our knowledge of the depollution plan of the wreck and the surrounding sea bottom, we have estimated here that around 10,000 tons drifted into waters under French jurisdiction.

Another important feature shown by Table 1 is that, since 1991, accidental sources of oil spills were no longer solely tankers, but also dry cargo vessels and container carriers (see *Erato* sinking). The increase in the size of those ships means that their bunkers can now be sources of accidental oil spills over 10 tons.

As a whole, the *Haven* incident was the only accidental oil spill from shipping that affected the French Mediterranean coastline during the last 45 years. This is a highly positive record when compared with the seven incidents totalling close to 150,000 tons of oil spilled that affected Italy or the five incidents totalling a little over 22,000 tons of oil spilled that affected Greece.

3.3 The Response Strategy

This positive situation does not mean that the French strategy as regards response to accidental oil spills, as well as the national response capacity, remained unchanged over the period covered in this chapter. Yearly exchanges of experience between the three maritime prefectures drastically changed the attitude of the French negotiators as regards those liable for the pollution.

Before 1996, it was considered that, when a ship would sink in waters under French jurisdiction, the Maritime Prefect concerned would undertake to mitigate any pollution and risk of future pollution at France Public cost. The ministry in charge of finance would then hand over the corresponding invoice to the shipowner for payment. That was presented by the Authorities to the Public as an application of the principle “Polluter pays”: France responded (immediately), on the basis of its own rules, and polluters paid (later), on the basis of the international agreements France was party to. However, few polluters were willing to pay and those that were willing objected to many of the works undertaken and to the expenses incurred, whether as regards unit prices, considered as excessive, or flatly not needed. Unit prices were a particular source of disagreement as the Polmar organization gave priority to the use of means in the hands of its partners when the Protection and Indemnity Clubs, based themselves on available best prices, insisting on competitive pricing.

Since 2000, and with the experience of the three incidents set out in Box 1, the French attitude as regards shipowners changed to the more pragmatic: “Polluter deals with the risk of future pollution from the wreck, France deals with the rest and gets repaid through a bank guarantee subscribed by the shipowner to have his ship released.” On that basis Maritime Prefects now systematically order shipowners to pump and recover high toxicity pollutants trapped in a wreck, and release in controlled conditions low toxicity ones, at their expense. Recovery is always the chosen option for crude oil and heavy fuel.

The tools and manpower to combat a spill have also changed. After the 1978 *Amoco Cadiz* spill, in which responders dramatically lacked training and adequate confinement and recovery tools, the Ministry in charge bought a large amount of shovels, booms and recovery barges and organized with Cedre training sessions for its personnel, copying its strategy to combat pollution at sea on that in force for floods or snow.

In 1999, the *Erika* spill showed that the model did not fit. Recovery barges and booms for use in shallow waters were of no use in high seas. Equipment purchased 20 years earlier, despite whatever care had been taken to maintain it, was in poor condition and at times obsolete. The availability of trained personnel was much too short for a response that extended over some 3 months. The general public did not understand that the polluter would stand still as an observer while public services would be submerged under conflicting priorities. Believing that many hands were needed, volunteers crowded on the coastline, adding the problems of providing them with food, lodging, equipment and emergency training.

Box 1 Three Incidents That Changed the Maritime Prefects Strategy [5]

On 25 September 1996, the dry cargo vessel *Fenes* ran aground on one of the Lavezzi islands with a cargo of 2,560 tons of edible wheat and bunkers of light fuel. The Lavezzi are a marine reserve, the rules of which specify that anyone who would dump waste in it would be ordered to remove it at his expense. With the support of the scientific committee, establishing that rotting wheat is a waste, the Maritime Prefect for the Mediterranean obtained from the shipowner agreement that he would pump the rotting wheat and disperse it in deep water, remove the ship debris and pump the bunkers.

On 13 December 1999, while on tow south of Sein Island, the tanker *Erika* broke into two and sank at a depth by 100 m, with a cargo of 31,000 tons of heavy fuel. After several weeks of strong public pressure, at the request of the Maritime Prefect of the Atlantic, the French oil company Total, owner of the cargo, accepted to manage and finance the recovery of the oil.

On 31 October 2000, the chemical tanker *Levoli Sun* sank in the English Channel, while on tow, at a depth close to 100 m, in waters under French jurisdiction with a cargo of 6,000 tons of Styrene, Methyl-ethyl-ketone and Isopropanol, plus 200 tons of bunkers. Through tense negotiations, the Maritime Prefect for the Channel and North Sea obtained agreement that the shipowner would organize, implement and finance the recovery of the Styrene and bunkers and the controlled release of the alcohol and keton.

The tools and manpower sectors have now dramatically changed. It is accepted that stockpiles would not be an exclusivity of the central administration, would each be minimal and supplied with recent tools, it being established that each central administration stockpile would have a back-up by another or other ones, private, regional or foreign. The capacity to respond in high seas has been increased not by purchasing new recovery vessels, but by chartering them for a limited time, the charterer being at times the supra-national European Maritime Safety Agency – EMSA (see activities of EMSA relating to preparedness and response in this volume [7]). Training sessions have been extended to staff of local administrations and members of environmental associations.

4 Operational Oil Spills

An operational spill is by definition a spill being part of the normal operation of a ship, whether it is caused by a human hand opening a valve, overflowing of a bilge water storage tank or a by-pass installed on the water circulation system of the ship. However, all masters of ships caught operationally spilling is the result of an exceptional human or mechanical failure. In court, the master will most generally consider it to be a most unfortunate accident.

4.1 Legal and Illegal Spills

The operation of a motorboat unavoidably generates oily waste in the form of oil bilge waters and used lubrication oil. Those wastes are stored in special tanks, from which they are either pumped to a storage tank at a harbour, or released at sea. The lack of adequate reception facilities in many ports and the price charged by ports offering reception facilities have made so that many shipowners expect their captains to release oily wastes in the open sea, at times through the same piping used for discharging water carrying organic waste. Because the quantity of oil in a particular release is small (a few hundred litres to a few cubic metres), sailors do not see themselves as polluting the oceans by this practice.

Unlike accidental spills, operational oil spills are not reported in m^3 or tons of oil, but in length and at times in surface affected, it being accepted that an oily water sheen becomes visible when over 15 ppm. The Bonn Agreement for the protection of the North Sea has produced a colour code indicative of concentration that helps when comparing two sheens. However, there is presently no tool to estimate properly either the total volume of an operational spill of oil in a sheen, or the oil part of it. From our experience, a “guestimate” could be 20% oil as a global average, with a possible range between 10 and 40%.

Such operational spills can be voluntary or not, resulting from a human decision, a human error or a technical failure. They are legal if made in high seas, outside of areas recognized as “special zones” by the International Maritime Organization (IMO)[4] and

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[4] The Channel, most of the North Sea and all the Mediterranean Sea are special zones under MARPOL. See: http://www.imo.org/en/OurWork/Environment/SpecialAreasUnderMARPOL/Pages/Default.aspx.

within an accepted limit of 15 parts of oil per million. They are illegal anywhere over the 15 ppm limit and below it in the special zones.

4.2 The Experience of the Erika

Until the sinking of the tanker *Erika*, in late 1999, south of the tip of Brittany, the French authorities satisfied themselves with knowing that the two specifically equipped Polmar planes undertook routine marine pollution surveillance flights, each about 120 mornings per year, for 3–4 h, with two sworn customs officers on board. One of the two planes was regularly based in the Toulon-Hyères airport, from where it would fly over the main ship routes of the Gulf of Lion, reporting through reports of pollution in a set EU format (known as Polreps) one or two noticeable slicks from most flights. When a slick was seen with a ship at one end, the ships master was contacted and a report was produced for the prosecutor, as a basis for a fine, the amount of which ranged between €10,000 and €100,000.

In 1999, an increase of oily slicks in the area around the seeping wreck of the ill-fated tanker *Erika* attracted attention from the authorities. The French Public discovered that form of pollution, together with the astounding fact that nobody in the French administration could present proper proof that any fine had ever been paid. Over a few months, the attitude of the French administration changed drastically. Vessels seen polluting in the special zones under French jurisdiction were ordered by the Maritime Prefects to call at the closest French harbour, from which they were released only after deposit of a bank guarantee in a range of €100,000 to 1 million.

The 19 April 2001 law on operational spills:

- Officialized the constraint powers of the Maritime Prefects on passing ships,
- Multiplied by 10 the possible amounts of the fines and
- Established three courts, two on the Atlantic side (Brest and Le Havre) and one on the Mediterranean side (Marseilles) specializing in the legal aspects of operational pollution from shipping.

At the same time, the Secretariat General for the Sea endowed Cedre with the charge of collecting information available from different sources to produce a yearly report on operational spills in waters under French responsibility. From 2000, the annual report of Cedre included a page on operational spills, with a table of Polreps, an annotated map and information on the follow-up actions against offenders.

The first year considered by Cedre in its reporting was expected to be 1990. However, it quickly became evident that the statistics available for the 1990–1999 decade were dramatically incomplete and could not be compared with those of the 2000–2009 decade. The start of the reporting was therefore shifted to 2000.

4.3 *Frequency and Distribution of Operational Spills*

Table 2 shows the operational spills recorded from French Polrep reports along years 2000–2015 in the Atlantic and Mediterranean waters under French jurisdiction and those categorized as oil spills. This table is simplified from the original Cedre data which include in the identified pollutants a column for chemicals. Interested readers will find that information in Ref. [8].

It appears that 2/3 (67%) of the spills in waters under French jurisdiction were oil and only about a tenth of the confirmed operational spills could be clearly connected to their source [9]. There was unfortunately no breakdown until 2010 between spills in the Atlantic and in the Mediterranean Sea. The breakdown, when it comes shows that the Mediterranean Polrep represent between two thirds and four fifths of the total Polreps. We could not obtain any precise information on the reasons for that dominance of the Mediterranean. But a full set of hypotheses are considered to have played a part in the resulting situation:

1. More flight time spent over the Mediterranean.
2. Meteorological situation in the Mediterranean particularly favourable to observation of oil sheens.
3. Low intercalibration between observers.
4. Environmental care more limited in the Mediterranean.

Figure 1 shows that, while spills on the Atlantic side mark out the main east-west route through the Channel, the image they form in the part of the Mediterranean under French jurisdiction is more complex, with two hotspots: one is the approaches to the great port complex of Marseilles and Fos sur mer, the other is the areas along the East and North coasts of Corsica, showing the access routes to the approaches of the Italian ports of Genoa and Livorno.[5]

One would anticipate, because the Mediterranean was more affected, that the French Authorities in charge of that region would be the first to make use of the powers given to them by the new French law on operational discharge at sea entered into force on April 15, 2001. But it was not before 2003 that the Mediterranean maritime prefecture started arresting ships suspected of illegal pollution and prosecuting them with success, when the Atlantic prefecture was doing it since late 1991. A table of the ships prosecuted and condemned for illegal operational spills from 2003 to 2007 is given on the website of Cedre. It totals 39 ships, with two record years:

- 2000 as the record year for starting procedures against illegal spillers (44); and
- 2004 as the record year for total distributed fines (€7,100,000).

Half way through the 2011–2019 decade, the number of started procedures tended to stabilize at 20 per year and the total distributed fines at €2 million.

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[5] There would be evident merits in the Italian Guardia Costiera publishing a similar map and the two maps being merged.

Table 2 Polreps for the 2000–2015 period in the French areas of responsibility in the Atlantic and Mediterranean

Year	Confirmed Polreps Mediterranean + Atlantic (1)	Confirmed Polreps Mediterranean	Spill identified as oil (2) (The original data included a column for a handful of chemical spills (see more on such spills in [8]))	Oil Polreps/ total Polreps (2)/(1) (%)	Spill source identified (3)	Spill source identified/total Polreps (3)/(1) (%)
2000	281		147	52	39	14
2001	325		120	37	39	12
2002	296		122	41	27	9
2003	372		144	39	19	5
2004	396		189	59	32	8
2005	335		199	59	22	7
2006	409		261	59	20	7
2007	351		242	69	21	6
2008	360		253	70	31	9
2009	288		254	53	30	10
2010	163	137	102		24	
2011	141	107	82		11	
2012	113	73	79		20	
2013	118	64	81		34	
2014	96	46	66		34	
2015	90	48	61		24	
Total	4,213		2,347		428	
Average	263		471	52.7		8.7

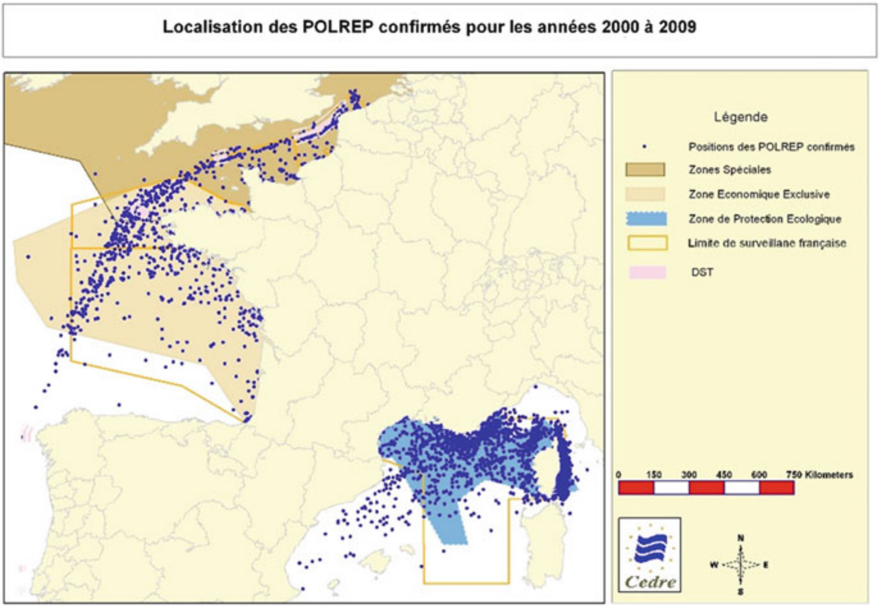

Fig. 1 Confirmed Polreps in waters under French jurisdiction, years 2000–2009 (Courtesy Cedre, copied from web pages on annual survey of operational spills) [9]

It seems that the new French law entering into force on 15 April 2001 caught many shipowners unprepared and that, after a most costly year 2004, they instructed their shipmasters to get rid of their slops before entering into waters under French jurisdiction. In addition, some shipowners contracted the assistance of highly experienced maritime lawyers, to make use of the prevalence of international rules on national ones. An example is the United Nations Convention on the Law of the Sea, stating that, would the flag state initiate a procedure against a ship caught polluting the waters of another country, the affected country should abandon its procedure (see Box 2).

Box 2 An Example of Abandoned Procedure

Source: regional press and pers. comm. from office of the Brest prosecutor

The Lithuanian general cargo vessel *Wytautas* was spotted on 6 June 2007, with a 37 km long oily sheen in its wake, in the Iroise Sea. Taken to Brest, it was released against a €400,000 bank guarantee and, in January 2009, a €700,000 fine was imposed upon it.

A few months later, however, the French court received, through the diplomatic pouch, notification that the ship had been prosecuted by a Lithuanian court, for the same offence, and that court imposed a fine of €23,000. The French court was forced to abandon the case.

4.4 Volumes of Oil Spilled

Aerial patrols looking for offenders generally concentrate their search on the areas known to be most affected. As a consequence, the Polreps omit more spills in little affected areas than in highly affected ones: planes may return daily to heavily affected areas, where they may leave an interval of several weeks before returning to a moderately affected area, missing slicks that had time to dilute between two passes.

Satellites are superior to planes from the point of view of statistical representativity [10]. However, satellites do not actually "see" oil sheens. They report only decreased roughness of the sea surface, generated by oil and a number of other factors.

We made our own estimate in the box entitled "an estimate among others" (see Box 3). The result, some 63,000 tons of oil per year, is consistently lower than the estimate of 100,000 tons made in 1992 by the European Common Research Centre (see [10]), Fund as reported by the World Wildlife Fund (WWF) website [11].

Box 3 An Estimate Among Others

Cedre reports on its website [9] that 34 Mediterranean Polreps of the year 2011 were submitted in 2012 to oil volume assessments on the basis of the colour code of the Bonn Agreement for response to oil and chemical pollution in the English Channel and North Sea. Those assessments led to estimate that the average slick expanded, when reported, over 3 km^2 (against five a decade before) and contained 1–12 cubic metres of oil, with an average by 6 cubic metres.

In a flight day, a pollution monitoring plane can fly for up to 8 h, overlooking half of the 115,000 km^2 area under French jurisdiction. As an average, summer leave, bad weather and plane maintenance mean that there is an eye in the sky only an average 4 h per 24 h, i.e. one sixth of the time. Surveillance requiring daylight, the ratio can be set at 2 h per 24 h as a slick spotted 1 day will rarely be seen the day after. The 40 slicks confirmed as oil reported for 2012 would then be the visible part of an "iceberg" of $40 \times 12 = 480$ oil spills in the 115,000 km^2 area under French jurisdiction. Should that be representative of the situation over the whole 2.5 million km^2 of the Mediterranean Sea (i.e. 22 times the French jurisdiction area), this would lead to an estimated $480 \times 22 = 10{,}560$ spills in a year.

Where the estimate of an average 6 tons of oil per spill be close to the reality, this would give: $10{,}560 \times 6 = 63{,}360$ tons of oil.

Low as it may seem, our estimate of yearly operational spills over the whole Mediterranean represents more than three times the average yearly amount of oil released into the sea by accidental spills over the 10 years 2000 to 2009.

5 Improved and New Tools and Procedures

Because the Mediterranean waters under French jurisdiction have been spared up to now the impacts from a major spill, the main national level R&D programmes and the national technical adviser on pollution prevention and response are based on the Atlantic coast of France in the westernmost metropolitan area, Brest metropole. Liaison with the Mediterranean needs are dealt with through the existence in Cedre of a Mediterranean correspondent, the participation of French Mediterranean representatives in training courses and exchanges of experience at the yearly regional Maritime conferences organized by the maritime prefects.

The French Mediterranean public is particularly sensitive about three points:

1. That the authorities in charge would now and for ever, put an end to ships deballasting at sea,
2. That maritime prefectures would be prepared, when a large accidental spill will occur, to deliver in real time accurate information on where and when the oil slicks will land, what will be the toxicity of weathered oil and what damage it will cause and
3. That they would not be left alone in front of the incoming plague.

5.1 Putting an End to Ships Deballasting at Sea

Putting an end to ships deballasting at sea is a task beyond the capacity of the sole French Mediterranean pollution response authorities. In fact, France appears now as dangerously isolated, ahead of the majority of the other Mediterranean countries, in the fight against operational spills. It is far too easy for a shipowner sailing under a flag of convenience, to step into the competent court of his flag country, offering to be fined what he will call a “reasonable” sum, compared to the French fine, which he will qualify of “unreasonable,” knowing well that the same spill in US waters would qualify him to pay five times more at least.

In that situation, the French authorities with jurisdiction for marine pollution in the Mediterranean are the logical gatherers and leaders of a group of countries determined to make things change. Attempting to disqualify the flag country from its right to prosecute the offender would imply a long and dubious battle. But the coastal country could as a starter prosecute in its own way and present its own bill to the ship, when it would call in a port of the group. It explains why the 2007

International Seminar of the European Project Mediterranean network of law enforcement officials relating to MARPOL (MEDEXPOL) could only take place in Marseilles with a keynote address by the prosecutor of the Marseilles instance court [12].

A tool of particular interest for the prosecution of offenders is satellite imagery combined with ships automatic positioning, a service provided by EMSA under its *CleanSeaNet* operational task to monitor for pollution, in conclusion with vessel tracking undertaken via its *SafeSeaNet* operational task ([13]; and see also [7]). In the near future, staff of the Marine Response Coordination Centres (MRCC) will not have to call a passing ship to know its identity; that information will appear automatically on the screens of their computers. The same information could be relayed to satellites passing by, meaning that a ship in the act of spilling illegally would no longer be an anonymous dot, but would be automatically identified.

5.2 Delivering Full, Objective and Timely Information

Being prepared for a massive accidental spill implies a need for both some judiciously selected communication tools and procedures. Like it or not, the time is past when one public body could be the sole informant to the media, through formal press conferences, and monitor what journalists said and wrote.

Sea-linked recreation weighs in economic terms more in the Mediterranean than in any other EU maritime areas, particularly since the hotspots for tourism in the northern part of the Mediterranean basin are getting close to saturation, inducing tourists without family links in the northern hotspots to look for holidays in southern countries, choosing between them on the basis of price, infrastructure, safety and clean sea. As the media always report the worst, because the worst sells better, it is of paramount importance to show the reality, on an objective, scientific basis, in a form accessible to the general public. The actual battle at sea and on the coastline against the oil will always be won by man at the end. But it may look lost on the Internet.

For that purpose, all partners in pollution response should be allowed to speak to the media, but only within the strict limits of their responsibilities per Polmar. They should be instructed on how to communicate on the web with a layer of information they would be responsible of. Prefects would deal with the response. Biologists would do the same for flora and fauna. Chemists would deal with toxicity. Economists would deal with losses. And so on, making so that the lead authority would be rid of specialized matters.

Baseline data should be acquired before the spill, the way to the impact evaluation as an essential contribution to pollution response of scientific institutions, the mobilization of which is now planned in the French response plans. An example is given by the permanent monitoring program for the coastal habitat along the French coast called REBENT (=benthic network) [14], established after the *Erika* spill in the Atlantic and used for the monitoring of the *Prestige* spill [9]. Most unfortunately, REBENT is not operational around the Mediterranean coastline. Plans to develop a Mediterranean REBENT do exist, but not the financing to implement it, at least as long as no major spill will hit the "Côte d'Azur."

As soon as a spill occurs, activation of the response plan automatically mobilizes at-sea slicks detection, using satellites, observation planes, drones and industry/public warning networks. This is immediately followed by slick drift modelling to inform those due to protect coastal activities, a task attributed in the at-sea response plans to a slick drift prediction committee meeting daily at Cedre, with access to a prediction model designed by MeteoFrance, using the calculation capacity of its Toulouse research and education Centre, for the production of a prediction map distributed by the maritime prefect.

Early decisions have to be taken on the high risk areas designated by the plan to be protected in priority and orientation of the impact targeted response. Decisions should be permanently refined on the basis of new information coming in. For that purpose, operational data management teams are installed in the Command centres, in the form of a pollution response advisory team, establishing connections to various useful datasets to be soon enriched by the monitoring activity. In parallel, targeted biological reference indicators and reference species are collected for analysis and levels of pollutant are measured at suitable time intervals.

Finally, all the information collected along the pollution response phase should, on the one hand, be exploited in real time by the Polmar communication team, to inform the Public in an objective way and, on the other hand, be passed to the pollution damage assessment team, operating on behalf of the ministry in charge of the environment, working in close collaboration with similar teams in neighbouring countries.

5.3 Strengthening International Cooperation

In the Mediterranean, as well as in the Atlantic and in the waters surrounding its overseas territories, France has used major pollution incidents as a driver to improve and refine its pollution response organization and stockpiles. Through this learning process, it has now moved a long way from the idea which prevailed at the time of the *Amoco Cadiz* spill that public services could and should have stockpiles of equipment sufficient to fight the largest foreseeable spill. The basic idea prevailing now is that, pollution by shipping being an international menace, response to such pollutions should be an inter sectorial and, if needed, international endeavour. For that reason, the French institutions concerned by different aspects of pollution generated by shipping actively cooperate with their national counterparts in the oil and shipping businesses.

Examples among others are:

- The Mediterranean private pollution response team and stockpile created by Total S.A. with participation of the sailors firemen of Marseilles is registered as a possible contributor to the response;
- The Polmar surveillance planes and their crews regularly participate in joint exercises, through bilateral agreements or the Barcelona Convention;
- The French Maritime prefects regularly invite their Spanish and Italian counterparts to their yearly return of experience maritime conferences;
- The French Secretariat General for the Sea and Cedre coordinate the French participation in the activities of the European Maritime Safety Agency (EMSA) [13];
- The French maritime prefect for the Mediterranean, the Directorate of water in the Ministry in charge of the Environment and Cedre regularly send delegates to the focal points meetings of REMPEC [15] and
- Cedre maintains a Mediterranean database of ship prosecution for “accidental” pollution [16].

6 Conclusions

France had the chance up to now to be spared a major ship accident such as those suffered on its Atlantic side. But the French authorities are conscious that a major spill can happen anytime and all the lessons learnt from the major spills on the Atlantic side are communicated to the Mediterranean side. Among those lessons, two major ones are public information on the Web, each member of Polmar being prepared to communicate in its field of responsibility and impact assessment implemented from a good knowledge of the baseline situation before the spill.

Active surveillance by planes alone did not reduce the flow of operational spills. But active surveillance and determined prosecution did it. One has to admit that deballasting at sea is an easy, tempting solution for shipmasters. In the same way as the fear of radars are the main way to deter drivers from driving above speed limits, the fear of a deterrent fine in response to illegal pollution could be the main way for shipmasters to respect the POLMAR endeavour.

As a whole, France is by far the country in the Mediterranean region with the largest experience of spills at sea and the most sophisticated response organization. For that reason, France is a major player in the regional cooperation programmes [7, 12, 13, 15].

References

1. Newman O, Foster A (1993) European environmental statistics handbook. Gale Research International Ltd, London
2. MacIntyre AD (1998) Pollution of the North Sea from oil related industry: an overview. In: Newman PJ, Aag AR (eds) Environmental protection of the North Sea. Heineman, Oxford
3. French Prime Minister (2002) "Dispositions of the instruction of 4 March 2002" relative à la lutte contre la pollution du milieu marin (documentation nationale Polmar). French Official J 79:5877–5894
4. French Prime Minister (2006) "Dispositions of the instruction of 13 January 2006" portant adaptation de la réglementation relative à la pollution du milieu marin (Polmar). French Official J 11:4 p
5. Girin M, Mamaca E (2011) Mieux combattre les marées noires. Quae Edit 188 p
6. Cedre (2015) Database on accidental oil spills at sea. http://wwz.cedre.fr/Nos-ressources/accidents. Accessed Aug 2016
7. Carpenter A (2016) European Maritime Safety Agency Activities in the Mediterranean Sea. In: Carpenter A, Kostianoy AG (ed) Oil pollution in the mediterranean sea: part I – the international context, Hdb Env Chem, Springer International Publishing Switzerland 2016. Doi: 10.1007/698_2016_18
8. Cedre (2015) Database on chemical spills at sea. http://wwz.cedre.fr/Nos-ressources/pour-les-jeunes/mieux-comprendre-les--pollutions chimiques-maritimes/. Accessed Aug 2016
9. Cedre (2015) Database on deballasting at sea. http://wwz.cedre.fr/Nos-ressources/déversements opérationnels/. Accessed Aug 2016
10. Ferraro G, Bernardini A, David M, Meyer-Roux S, Muellenhof H, Petrovic M, Tarchi D, Topouzelis K (2006) Towards an operational use of space imagery for oil pollution monitoring in the Mediterranean basin. Mar Poll Bull 54(2007)
11. World Wide Fund for Nature (WWF). Mediterranean states commit to stop sea pollution. http://wwf.panda.org/wwf_news/?2413/. Accessed Aug 2016
12. REMPEC (2015) Mediterranean network of law enforcement officials relating to Marpol (MEDEXPOL) Working document WG 38/7, 17 p
13. EMSA (2016) CleanSeaNet and SafeSeaNet services. http://www.emsa.europa/search. Accessed Aug 2016
14. Ifremer (2016) REBENT, le réseau benthique, ce qu'il est, ce qu'il fait. www.rbent.org. Accessed Aug 2016
15. REMPEC (2015) Rejets illicites/Projets AESOP et MARCOAST. http://www.rempec.org/rempec.fr. Accessed Aug 2016
16. CEDRE (2016) Prosecution of offenders. http://wwz.cedre.fr/Nos-ressources/Rejets-en-mer/Rejets-d-hydrocarbures/Condamnations/Tableau-des-jugements-depuis-le-Prestige. Accessed Aug 2016

Oil Spill Monitoring in the Italian Waters: COSMO-SkyMed Role and Contribution

Francesco Nirchio, Giuseppe Grieco, Maurizio Migliaccio, and Paola D. M. Nicolosi

Abstract The Mediterranean Sea, rich in biodiversity and with a large number of endemic species, provides sustenance for millions of people living along its coasts. Due to its position it also represents the natural route between major oil production areas and oil consumers. Its preservation passes also through satellite technologies which are ever and ever playing an increasing role in environmental monitoring. Italy, recognizing its contribution, has decided to invest in this sector with the satellite Mission COSMO-SkyMed. Its frequent revisiting time, day and night and all weather acquisition capability, makes it an essential part together with aerial and naval component of the National Contingency Plan (United Nations Conference on Trade and Development, Review in Maritime Transport. Available at http://unctad.org/en/PublicationsLibrary/rmt2015_en.pdf) to contrast marine oil pollution.

Keywords COSMO-SkyMed, Oil, Oil spill response, Pollution, Satellite monitoring

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1 Introduction

Italy, located in the southern part of Europe, is a country surrounded by the Adriatic Sea in the east, the Ionian Sea in the southeast, the Tyrrhenian Sea in the southwest, and the Ligurian Sea in the northwest. Italy covers a total area of 301,340 sq. km. It is situated between the latitudes of 47°5′0″ and 35°29′0″ North and the longitudes of 6°37′0″E and 18°31′0″E, with a total land borders length of 1,932 km and a coastline of 7,600 km.

Italy, with its 49 UNESCO's World Heritage Sites and natural treasures, is one of the most visited countries in the world, but it is also one of the European countries at greatest risk from natural and man-made disasters such as earthquakes, volcanos, soil instability, fire, and floods. In addition, it is exposed to sea oil pollution with nearly 25% of the world's sea-transported oil transiting or directed to Mediterranean ports [1, 2].

The environmental sensitivity of the Mediterranean Sea to maritime oil transport is due to its limited water exchange. Furthermore, about 30% Italian population lives in the 646 coastal towns on 13% of the national territory.

In order to provide the Country with a tool to support risk management in all its phases – prevention, crises, and remediation – the Italian Parliament in August 1996 approved an initial founding for the COSMO-SkyMed (COnstellation of small Satellites for the Mediterranean basin Observation) mission, a space-borne program for the observation, remote sensing, and data exploitation for Risk Management, Coastal Zone monitoring, and Sea Pollution. The system has been conceived by the Italian Space Agency (ASI) and funded by Italian Ministry of Research and Italian Ministry of Defense. It is intended for both military and civilian use. The space segment of the system is composed of four identical medium-sized satellites, each equipped with a Synthetic Aperture Radar (SAR) sensor in X-band. The system can acquire data worldwide in all-weather conditions, day and night. Its main features are the frequent revisiting time and high resolution imagery.

With the aim of exploiting COSMO-SkyMed (CSK) data and support its operational use, the Italian Space Agency has started nine Pilot Projects devoted to risk management to develop demonstrative services based mainly on data gathered by space-borne sensors. Among these the Pilot Project “PRIMI” addressed the oil spill risk. It has fruitfully tested the synergic use of satellite and maritime resources to contrast marine pollution. This chapter first presents the Italian national organization to combat marine pollution, then discusses the main features of CSK mission. Subsequently it describes the key scientific results on the use of SAR data for oil spill monitoring and finally there are reported some operational experiences of oil spill detection services in the Mediterranean Sea provided with SAR data.

2 Italian Energy Production and Imports

Italy, according to Eurostat data, in 2013 has produced about 36.9 million tonnes of oil equivalent. 0.1% of that quantity comes from solid fuel, 17.5% from natural gas, 15.9% from oil, and the remaining fraction from renewable energy. 125 million tonnes of oil equivalent has been imported. Crude oil arrives in Italy essentially transported by tankers from Middle East countries and Russia, but that is not the total quantity transported through the Mediterranean Sea, as reported in Table 1; about 25% of all oil transported in the world passes through it.

Tanker trades represents about 60% trade among littoral Mediterranean States. The principal loading places are Sidi Kerir in Egypt with 74 MT, Arzew in Algeria with 40 Mt, Ras Lanuf in Libya with 14 MT, while the principal discharges ports are Trieste (Italy) and Fos (France) with about 35 MT each, followed by Augusta (Italy) and Genoa (Italy) with, respectively, 20 MT and 15 MT; five of the top ten discharge ports are located in Italy.

Although the oil pollution risk is high, the number of large incidents (releases of oil above 5,000 tonnes) during the last 25 years has been small. Nevertheless, between 1st August 1977 and 31st December 2010, approximately 310,000 tonnes of oil entered into the Mediterranean Sea as a result of accidents; the largest accident happened in April 1991 when 144,000 tonnes of crude oil was spilled due to the explosion and fire on board *MT “HAVEN”* off Genoa.

Table 1 Flux of oil and refined products within the Mediterranean in 2006 [2]

Quantity (million tonnes)	Transportation
421	Total amount transported
220	Loaded at Mediterranean ports
255	Discharged at Mediterranean ports
72	Transits between non-Mediterranean ports

3 Pollution Response Authorities and Their Roles

The first Italian law to contrast marine pollution dates back to 1921. It ruled the discharge of public and industrial waste waters into sea. Presently the law no. 979 approved on 31st December 1982 [3] and its following integration and modifications regulate the subject.

The Italian Response system is organized on three levels: the strategic direction, which is in charge of the Ministry of Environment; the operational responsibility, both at national and local level, which is assigned to the Coast Guard a branch of the Italian Navy; and in case of large and catastrophic events the direction of the operation is assumed by the Civil Protection department directly depending by the Prime Minister.

Two different conditions of emergency are identified:

- The local emergency: it can be usually contrasted with the resources of the Ministry of Environment.
- The National emergency: it is declared by the Prime Minister on request of the Minister of Environment when he considers the resources of the Ministry alone are not sufficient to contrast the pollution.

From an operational point of view three different levels are considered:

- level 1: the pollutant quantity is small and far from the coast or from protected areas
- level 2: the oil spill is of small or medium size but it treats coasts or protected areas
- level 3: the oil spill is large and requires the intervention resources in additional of those available to the Ministry of Environment.

According to the Guidelines for Co-operation in Combating Oil Pollution (adopted in 1987 and updated in 2013 [3]) level 2 and 3 oil spill are reported to the Regional Centre, at least all spillages or discharges of oil in excess of 100 cubic meters.

The Ministry of Environment, to enforce the law, has defined a patrol and remediation service since December 1998. That service is provided by the naval and aerial resources of the Coast Guard, additional resources have been acquired through a contract signed on 1998 and updated during the last years.

The Italian Coast Guard is equipped with about 600 vessels distributed in more than 100 harbors devoted to: Search And Rescue; harbors governance; fishing protection and environmental protection, while the contracting company (Castalia Consorzio Stabile S.C.p.A.) operates in stand-by mode with the staff available 24 h a day. At the beginning the contracting company had 62 vessels and they were involved in patrolling along pre-defined routes and participated in clean-up activities. Subsequently in 2000, the number of vessels increased to 71, while in 2002 there were 58 of them and the experimental usage of the satellite and aerial data was used to complement the monitoring performed by vessels. The present convention [4] foresees 36 vessels being used in total (9 high sea vessels and 27 coasters).

With reference to the aerial component of the service, the Harbour Corps constitutes the operational arm of the Ministry of Environment. In the event of pollution or of the imminent threat of pollution of marine waters, they are responsible for taking all necessary measures to prevent or mitigate the harmful consequences of such pollution. The Italian Coast Guard operates according to the Ministry's directives, relying, where necessary, on specialized vessel and equipment to respond to sea pollution. Thanks to ad hoc funding by the Ministry for the Environment, the Coast Guard aircraft are equipped with sensors for the detection of pollution at sea and for the detection of environmental parameters useful for controlling waters. The Italian Coast Guard works in cooperation with the Marine Environmental Department of the Coast Guard Corps (Reparto Ambientale Marino del Corpo delle Capitanerie di Porto – R.A.M.), at functional dependencies of the Ministry of Environment, to achieve a more rapid and effective support in carrying out institutional tasks in environmental matters.

To accomplish their institutional activities, the Italian Coast Guard is equipped with: airborne P180 Avanti II, ATR 42-MP (see Fig. 1), P166DL3SEM (see Fig. 2), and helicopters AW139 and AW139 GC.

The ATR 42-MP has an active sensor, the Side Looking Airborne Radar (SLAR), which allows the detection of oil pollution and other oily substances into the sea. The aircraft is also equipped with a passive sensor multispectral channels 12 Daedalus/Sensytech 1268 Enhanced, which operates in the bands of visible and infrared electromagnetic radiation.

In addition, a hyperspectral CASI system 1500 has been recently introduced on to the Piaggio P166 aircraft. On-board equipment allows operators to carry out, even at night, pollution control and castaway searches with first aid being provided by launching, via a special trap door located on the floor of the aircraft, self-inflating rafts.

Fig. 1 ATR 42-MP of Italian Coast Guard (*Courtesy of Italian Coast Guard*)

Fig. 2 P166DL3SEM of Italian Coast Guard (*Courtesy of Italian Coast Guard*)

Table 2 Miles cruised by the vessels of the contracting company in the period 2005–2007

2005	2006	2007
343,948	350,476	342,118

Table 3 Interventions performed by the contracting company per year

	2005	2006	2007
Oil spill	138	144	96
Garbage collection	21	19	
Rescue	6		3
Drill		25	13
Support to mammal and turtle	19	14	9
Other	2	3	12
Total	189	205	133

Table 4 Italian Coast Guard interventions per year

	2005	2006	2007
Large – medium oil spill	75	379	89
Small oil spill	471	482	476
Anti-pollution actions	460	452	173
Inspections	60,871	65,854	79,831
Legal actions	325	359	415

Table 5 Collected wastes in m^3 per year

	2005	2006	2007
Oil mixtures	668	667	495
Plastic	574		
Wood	638		
Other	358	23	
Total	2,238	690	495

In Tables 2, 3, 4, 5, and 6 some data are reported concerning the service provided by the Italian Coast Guard and the contracting company both in the period 2005–2007 [5] and more recently.

Table 6 Pollution events and intervention between 2013 and 2014

	2013	2014	2015
Pollution events	96	149	157
Events that required intervention of Castalia vessels	18	14	12
Coast Guard intervention	78	70	145

The Italian Oil Pollution Monitoring Practice is also based on satellite imagery. Part of that monitoring capability is provided by COSMO-SkyMed data processed by e-GEOS, an ASI-Telespazio Company, part by EMSA through the project Clean Sea Net.

4 The COSMO-SkyMed Mission

Italy has been involved in some of the early scientific and pre-operational remote sensing programs such as the ESA projects ERS and ENVISAT or the NASA-DLR-ASI SIR-C/SAR-X mission. The potential of satellite environmental monitoring was evident but it was also manifest that there was a gap between some of more frequent national user needs and its operational capabilities. The COSMO-SkyMed System was conceived as a step forward in the effective use of satellite data, because of two key parameters – frequent revisiting time and high resolution. These are considered essential in several applications, and are among its main features.

COSMO-SkyMed represents the largest Italian investment in space systems for Earth Observation. COSMO-SkyMed has been designed to mainly provide data in the following fields of Risk Management: floods, droughts, landslides, volcanic/seismic, forest fire, industrial hazards, and water pollution. It is a civil and defense system providing data also for applications such as surveillance, intelligence, mapping, damage assessment, vulnerability assessment, and target detection/localization.

The overall system architecture is composed of a space segment, a constellation of four SAR satellites, an online ground segment for system command and control, and an offline ground segment dedicated to data archive and user services. COSMO-SkyMed provides data at privileged condition both to national institutional users, such as Civil Protection Department and international institutional users which have signed a memorandum with Italy. COSMO-SkyMed data are also available to commercial users through e-GEOS, the appointed distributor.

The system general performance characteristics are the following [6]:

- Full global observation coverage with all weather, day/night acquisition capability
- Collection capability of large areas within a single pass

- High image quality, to allow a robust image interpretability at the requested scale of analysis (data sets are characterized by adequate spatial resolution suitable to perform analyses at different scales of detail)
- Ground track repeatability: the satellites of the SAR constellation shall have a ground track repeatability better than 1 km
- Fast response times (from the data/service user request up to the data/service delivery to that requiring user).

The four satellites are in sun-synchronous polar orbits with a 97.9° inclination at a nominal altitude of 619 km and an orbital period of 97.2 min. Each satellite repeats the same ground track every 16 days, and all of the satellites follow the same ground track. They cross the equator at 06:00 and 18:00 local-time each day. The satellites are phased in the same orbital plane, with COSMO-SkyMed's 1, 2, and 4 at 90° to each other and COSMO-SkyMed 3 at 67.5° from COSMO-SkyMed 2. This configuration allows to perform interferometric acquisitions (to repass over the same ground track in the same configuration at least after 1 day). The sampling interval can be arranged between 1 and 15 days.

The first satellite was launched on 8 June 2007 while the constellation was completed on November 5, 2010 with the launch of the last satellite. The expected operating life of each satellite is estimated to be 5 years, although the present life is well beyond this figure.

Each satellite is equipped with an SAR instrument operating in X-band (9.6 GHz with a wavelength of 3.1 cm).

Three basic types of imagery can be provided:

- Spotlight, a high resolution mode collected over areas of 10 Km × 10 Km with 1 m of resolution.
- Stripmap, a medium resolution mode collected over long continuous swaths up to 1,000 km and 40 km wide with a resolution between 3 and 15 m. The system can collect dual-polarization data at 15 m resolution over a swath of 30 km (Pingpong mode). The dual-polarization data can consist of any two polarizations (HH, VV, VH, and HV), and it is non-coherent, as it is collected in "pulse groups" that alternate from one polarization to the other.
- ScanSAR, a low-resolution mode which provides 30 m resolution data over a swath of 100 km, and 100 m resolution data over a swath of 200 km.

The system can acquire up to 450 images per satellite per day. If user requests do not exploit the total daily COSMO-SkyMed acquisition capability, the system acquires data according to a background mission, which is intended to guarantee the availability of reference datasets for future mapping projects, emergency mapping, and change detection applications.

5 On the Physical Basics of SAR Oil Spill Monitoring

Marine monitoring is a very demanding task since there are only a few ground reference data and the associated sea dynamics call for high revisit time. Hence, a non-cooperative satellite monitoring system such as the CSK constellation is of primary interest in the field. Nevertheless, the processing chain that is able to extract the physical information of interest must be reliable enough to limit the need of extra information and/or ground reference data.

The problem of unambiguously detect oil spills in SAR images is a complex problem that entangles different expertise and is more intriguing than one may naively expect [7, 8].

Generally speaking, physical interpretation of SAR measurements is a challenging task since the SAR imaging process is not straightforward and is, furthermore, affected by noise. Such a noise can be additive, generally uninformative, or multiplicative, possibly uninformative, and partly due to uncertainties in the model itself.

The fundamental problem that must be considered before designing the inversion procedure is related to the concept of identifiability. As reported in [9] "Identifiability is an important concept central to estimation theory. It indicates whether or not an estimation procedure will yield a unique and consistent estimate of the desired parameters from the available measurements." The interested reader is referred to [9] and references therein reported for all mathematical. The key points to be considered are:

- Among the possible solutions the true one is present;
- The selection of true solution can be made with or without external information to the measurement set.

Let us consider first the popular case of single-polarimetric SAR images where large swath and fine full-resolution are at disposal. The damping of oil pollutant, generally a very thin slick compared to the microwave carrier wavelength (i.e., about 3 cm in the CSK case), is heavy to dampen the small sea ripples connected to the Bragg scattering and decrease the friction velocity with effect also on long waves [10]. Hence, dark areas or better saying low-scattering areas are generated over the SAR images. However, not all low-scattering areas are associated with oil slicks. Two main classes of dark areas can be meant, the first is associated with "heavy damping phenomena" and the second one to "light damping ones." Note that this classification is useful for the purposes of this chapter but not all dark areas are due to the presence of surfactants. Oil spills belong to the first class (except very seldom cases that are not at the core of this chapter) and surely they are to be monitored by surveillance marine services. The most challenging look-alike, i.e., a dark area not due to the presence of an oil at sea, belonging to such a class is related to low wind areas. While the most challenging look-alike belonging to the low damping class is due to biogenic surfactants.

The reference and standard single-polarimetric SAR oil spill processing chain first calls to detect dark areas and then to sort out the ones associated with oil spills (see Fig. 3). Unfortunately, in order to mitigate the presence of speckle (the multiplicative noise), spatial resolution is degraded to about 100 × 100 m.

That choice has impacts both on service goals and on SAR interpretation capability. The marine surveillance service should be aware that most illegal oil spills are the so-called micro oil spills that are usually lost if SAR spatial resolution is degraded. This has an important side effect, since all nowadays operation services are put in service on such a way that the official oil spill statistics are necessary underestimated. Some experts state that micro oil spills have a limited effect on the

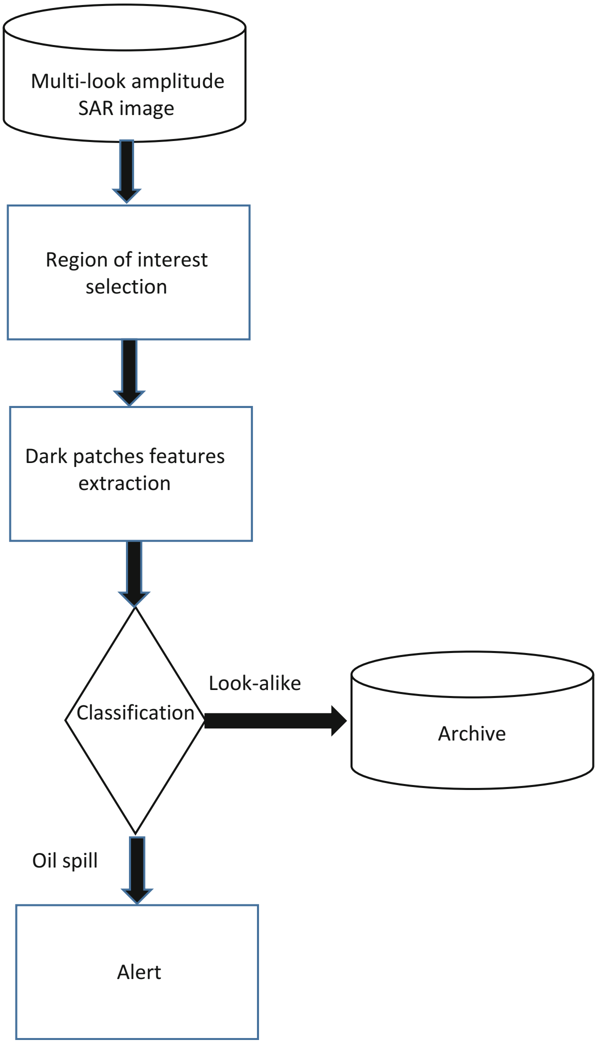

Fig. 3 Block diagram of the reference standard SAR single-polarimetric processing chain

marine environments but more and more are aware of their cumulative effect is not negligible at all. On the other side, speckle is not at all necessarily uninformative and can be exploited to detect dark areas in full-resolution, i.e., speckled SAR images. A possible guideline along this concept is illustrated in [11, 12].

Once that dark areas are all selected then look-alikes should be taken out. The standard reference procedure calls for estimating a set of features that assist the human expert (Fig. 3), i.e., a supervised classification scheme is in place, to classify the ones associated with sea oil spills.

The interested reader can find all necessary details in [7] and references therein but for the purposes of this chapter is useful to remind that adding more and more features does not provide at all better classification results. Conversely, one experiences the well-known pattern recognition problem known as "curse of dimensionality" that hampers the classification. Hence only a limited and "powerful" set of features must be considered. Analyzing the relevant literature [7], it arises that discrimination between oil spill and look-alike became difficult without external information. In particular, low wind scattering areas can be taken out only with extra wind information. The mathematical and experimental analysis demonstrates also that the one-class classification problem better performs than the standard reference two-class classification approach. In fact, the so-called look-alike class is not at all a homogeneous class as even previously described. One question naturally arises: apart from low wind areas, is it possible to distinguish oil spills from light damping dark areas? First attempts along this line were made using scattering approaches (see, for example, [10, 13]) and have been recently focused on CSK X-band also [14]. However, on the operational perspective the most relevant result was first presented in [10] and further extended and validated at L- and X-bands in [15, 16].

These studies are fundamental in modern SAR oil spill monitoring and deserve some special attention. Hence the main results are hereafter summarized. The background and relevant studies on SAR oil spill monitoring date back to the SIR-C/X-SAR mission and are summarized in [17]. That experiment stated that was no real benefit of SAR polarimetric measurements and SAR oil spill monitoring was possible at C-band only. One must say that the SIR-C mission was hampered by several technical problems at L-band and in fact even in [15] the new polarimetric SAR approach resulted not effective at L-band. However, it was not at a physical intrinsic problem, as demonstrated in [18] but related to data quality. Even more important and not at all straightforward was the result achieved at X-band with TerraSAR-X data [16].

From the marine service point-of-view these results demonstrate on one side that SAR polarimetry is beneficial to sort out heavy damping oil spills from light damping look-alikes and that L-, C-, and X-bands can be effectively used. Last but not least, it must be noted that even if standard polarimetric SAR modes [8] reduce the swath and the spatial resolution if compared to the single-polarimetric mode, one may think of a virtual constellation, not necessarily all satellite operated, where large swath associated with single-polarimetric mode are interleaved with smaller swath associated with polarimetric mode, hence coupling the time and classification effectiveness of the polarimetric mode approaches [4] with the large swath benefit of the single-polarimetric mode. This is actually the forthcoming CSK constellation asset that couples the four CSK first generation satellites, with no coherent polarimetric mode, and the new two CSK second generation satellites with coherent polarimetric modes. Alternatively, one can conceive virtual constellations combining L-, C-, and X-band SAR measurements ensuring an even denser and reliable SAR oil spill monitoring.

5.1 Wind Speed Retrieval for Oil Spill Detection Purpose

Wind speed is a fundamental external information in the process of oil spill detection. Moreover, SAR cannot detect oil spill if wind conditions are outside the range 2–14 m/s [19, 20]. Oil films cause the damping of the surface capillary waves generated by wind. Therefore, oil contaminated areas could be confused with no wind areas if the wind speed is less than 2–3 m/s. On the other hand, this damping effect strongly decreases when wind speed is higher than 13–14 m/s [20], because of wave breaking. Therefore, the detection of oil slicks is difficult under such wind regimes. In addition, the sea weather (wind and sea state conditions) affects the persistence, shape, and structure of oil slicks.

For all the above considerations, a correct estimation of the sea state and wind field is fundamental for oil spill detection and evolution forecast. That information is provided every 6 h at large scale (25 km by 25 km) by meteorological offices but it is generally very different from local actual conditions. Synthetic Aperture Radar (SAR) although has not been designed to operationally monitor the sea surface wind field, it has been soon recognized a suitable candidate for this purpose. Indeed, the SAR can achieve a spatial resolution up to 1 m and has demonstrated to be used to monitor sub-kilometer ocean phenomena and wind structures both in open and coastal areas.

SAR, as any other Radar, measures the target Radar Cross Section (RCS), which on sea depends on waves whose wavelength is comparable to radar wavelength (Bragg resonant interval is 1.8–4.5 cm in X-Band for incidence angles between 20° and 60°). This range of wavelength is the first to be generated by wind. The stronger the wind the bigger the wave amplitude and consequently the stronger the RCS [21]. The wind field estimation from SAR RCS is an underdetermined problem. Indeed, the SAR acquires only one RCS measurement versus two unknowns: the wind speed and its direction.

In order to deal with this problem, different strategies have been tested and are here briefly cited.

The most commonly used strategy, the so-called scatterometric method, consists of retrieving the wind speed by inverting an ad hoc semi-empirical geophysical model function (GMF) applied to the SAR RCS, provided the wind direction is from external sources [22]. In unstable atmospheric conditions, linear wind row signatures caused by ascending and descending atmospheric currents are clearly visible from SAR images. These rows are parallel to the wind direction with a good approximation [23], even if the 180° ambiguity remains. Otherwise, the wind direction can be directly provided by model forecast. A simultaneous retrieval of the wind speed and direction can be achieved by merging the a-priori wind forecast information with the SAR RCS measurement through a Bayesian approach [24]. A Bayesian approach has also been used by [25] to merge the RCS measurement with the Doppler Centroid estimation from the SAR image. The latter parameter is highly sensible to the wind direction.

The wind speed can be retrieved with a precision of 1 m/s in the range 2–25 m/s with a sub-kilometer spatial resolution.

An alternative to the scatterometric method is the so-called spectral method. This method takes advantage of an empirical linear relation between the significant wave height and the azimuth wavelength cut-off [26]. In case of fully developed sea state, the linear relation holds also with the sea surface wind speed [27].

The azimuth wavelength cut-off is a measure of the effective SAR azimuth resolution that is reduced mainly because of the velocity bunching mechanism [27, 28]. The azimuth cut-off strictly depends on the acquisition geometry of the platform.

This method does not need a calibrated radar cross section as a scatterometric one does, therefore, a GMF developed for a specific SAR could in principle be used for any other SAR, given that a correction for the acquisition geometry is applied to the SAR data. The significant wave height can be retrieved with an expected precision of 0.5 m while the expected precision on the wind speed is around 1.5 m/s.

All the retrieval methodologies described above have been developed and tested mostly for C-band SARs. The recent launch of the X-band satellite SAR missions COSMO-SkyMed (2007), TerraSAR-X (2007), and KOMPSAT-5 (2013) has given an important impulse to research on the retrieval of the sea surface wind field from X-band SAR images.

TerraSAR-X data have been used to develop and test a GMF relating the RCS to the wind vector (XMOD) [29], while the same has been done for COSMO-SkyMed data [30].

An investigation of the possibility of estimating the wind vector from COSMO-SkyMed data through the XMOD developed for TerraSAR-X data and vice versa was undertaken [31] comparing the results. They found that the retrieved wind vectors are equivalent with a root mean square difference of about 1.5 m/s with the buoy measurements of the National Data Buoy Centre (NDBC), as expected. Anyway, one should take care when inverting SAR cross-wind scenes acquired in low wind regimes. Finally, as expected and already verified for the C-band cases, the sensitivity of the retrieval to the wind direction is very important, especially for cross-winds.

6 From Pilot Projects Towards an Operational Use of Satellite Imagery

Satellite-based geo-information products are nowadays used in the maritime domain for environmental monitoring as well as security and safety applications.

Building upon more than 10 years of specific Research & Development activities in the Maritime field, thanks to Italian and European contributions (ASI, ESA, and EU), oil spill and vessel detection technologies evolved during those years, resulting nowadays in valid algorithms and certified satellite-derived products, together with tailored processing capabilities, which allow Ministries, Agencies, and private customers to be operationally supported with these kind of services.

Also incidents and crisis events which occurred during last 15 years, like the oil spill in Galicia in 2002 caused by the sinking of the oil tanker *MV Prestige*, or the more recent event in 2010 in the Gulf of Mexico of the Deepwater Horizon oil spill, have increased the awareness of rapid response for recovery actions and support to decision systems.

Pilot projects such as **MARISS** (European Maritime Security Services, funded by ESA, 2005–2013); **MarCoast** (Marine & Coastal Environment Information Services, funded by ESA, 2005–2008), **PRIMI** (PRogetto pilota Inquinamento Marino da Idrocarburi, funded by ASI, 2007–2010), and **DOLPHIN** (Development of Pre-Operational Services for Highly Innovative Maritime Surveillance Capabilities, co-funded by EC, 2011–2013) have marked the roadmap towards operational services in the Maritime field.

Thanks to the above mentioned projects, both at Italian and European level, industries built up their own processing capabilities, resulting, at European level, in fully operational services that European Maritime Safety Agency (EMSA), the Agency at the forefront in oil spill and vessel detection, which provides support to European Member States within the framework of the *CleanSeaNet* services, and at Italian level, in the fully operational services provided by e-GEOS to Italian Ministry of Environment and Italian Coast Guard.

According to the pilot projects' results, beside the most advanced optical sensors, Synthetic Aperture Radar (SAR) systems have been identified in the forefront of Earth Observation technology, improving the detection capabilities and the exploitation of information. Operational use of SAR satellite data in maritime applications allows monitoring sea waters:

- irrespective of the day time and weather conditions,
- out and inside the range of coastal surveillance systems, and
- irrespective of the vessel cooperating behavior.

The COSMO-SkyMed satellite constellation provides SAR unmatched performances and represents the reference in terms of revisit time, image resolution, rapid coverage of huge territories, and number of scenes acquisition. It provides synoptic information, day and night and at all weather conditions, from remote survey support, allowing operational service.

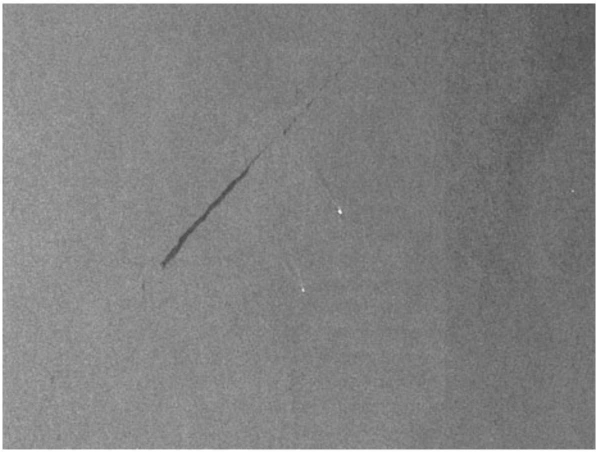

Fig. 4 Oil spill generated by illegal dumping at sea. Image acquired by CSK4 on 2nd July 2013, about 100 km off the South-East coast of Malta

The pilot project brought to applications and solutions hereinafter summarized:

- Acting *against Oil Pollution* at Sea
  Routinely oil spill detection monitoring of a sea basin has a deterrent action against those vessel owners who operate tankers' illegal washing (see Fig. 4).
- *Identifying Offenders*
  If identification systems data are available, a cross check of the routes followed by the vessels sailing the area affected by the oil spill is done. Suspected vessels are required for a Port State Control Inspection at the destination port. If the inspection highlights irregularities, the vessel is detained and/or a sanction is assigned.
- *Oil Rigs and off-shore pipelines* monitoring
  Routinely oil spill detection and monitoring of off-shore oil rigs and pipelines are required to prevent coastal environment pollution and support recovery actions (see Fig. 5).
- *Natural Seepages* detection
  Routinely oil spill detection and monitoring of sea areas can also be exploited to spot natural seepages due to their repeating leakages with similar features.
- *Prompt Response in case of accident*
  Prompt response services to support involved entities in decision-making processes can have provided.
- *Fishing ships control within marine protected areas*
  Satellite remote sensing technologies allow competent authorities to analyze the presence of the vessels in a given area (without the cooperation of the vessels) and at a given date and time and assess the overall conditions under which the fishing activity was performed, thus filling the gaps that neither patrols nor ground-based systems can fill. On the contrary, the simultaneous combination of the ground positioning systems (*Vessel Monitoring System* [VMS] and *automatic identification system* [AIS]) with the remote sensing observation systems,

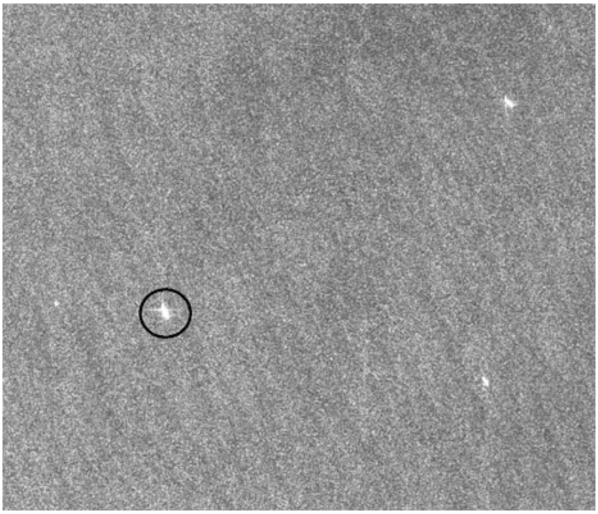

Fig. 5 Image acquired by CSK4 on 10 December 2015 in the Adriatic Sea. The *white spot* inside the *dark circle* is an oil platform

especially radar, leads to the optimization of the benefits in a complementary manner, thus ensuring optimal support to the activity of addressing, managing, and controlling the sector at both national and international levels.

In particular, exploiting the non-cooperative characteristics of the space imaging sensors, it is possible to detect:

- vessel with failed or malfunctioning GPS and/or transmitting equipment;
- vessel that deliberately "turns off" the System so as to avoid detection;
- vessel that, because of its smaller size, is not under the obligation of having an on-board positioning system (which in the Mediterranean Sea are the majority), as well as sport fishing vessels.

- *Locate a lost vessel*

  The *search and rescue* operations are extremely difficult when the on-board ship reporting systems is turned off (due, for example, to Piracy attack) or failed and when the search area is remote and wide.

Space-borne SAR imagery, thanks to its coverage capacity (wide area in short time), represents a valid asset to support the localization of lost vessels. Starting from the last known position and speed (if available) of the vessel, the position of the vessel at the time of availability of satellite images is estimated and used to program the acquisitions of medium resolution satellite. When the vessel has been located and detected on the programmed images, high and very high resolution images are programmed in order to better classify the vessel and to provide information related to the area around the vessel itself.

As an example, in Fig. 6 shows an oil spill detected and verified during the validation campaign of the PRIMI Pilot Project on August 2009, while Fig. 7 is a detail of that spill [32].

Fig. 6 Example of a long oil spill detected off the southern coast of Sicily (35°18.143′N, 16°27.091′E) during the August 2009 campaign of the Pilot Project PRIMI

Fig. 7 A detail of the spill in Fig. 6

6.1 *Off-Shore Platforms Monitoring Service: The Italian Integrated System Over Italian National Sea Waters*

Along the Italian coasts there are 139 off-shore installations, 119 of them are production platforms, 8 are support platforms, and 9 are non-production ones. 123 of those installations are platforms while 13 are subsea wellheads. 93 are located within the 12 nautical miles from coasts and from protected areas, 43 beyond that limit [33]. Italian national organization for the prevention of and fight against marine pollution has been significantly enhanced with an integrated surveillance system, which provides constant monitoring of those off-shore

Fig. 8 Off-shore platforms location. *White boxes* represent the satellite image footprint, *green drop* the platforms location

platforms over national territorial waters, devoted to extraction of hydrocarbon products.

The map in Fig. 8 illustrates the areas where oil rigs are located and that are monitored.

The monitoring system is based on a three-component monitoring: satellite, aerial, and naval, with the aim to daily monitor the four groups of rigs and target immediate detection of potential oil spills, in order to minimize the risk of pollution of Italian coasts. Vessels crossing the Italian waters are monitored too by satellite and those potentially linked to oil slicks are identified and reported to the Ministry.

With particular reference to the satellite component, the service consists of 24 h/7 day operational monitoring of off-shore rigs and also any vessels crossing the sea. The service is based on the COSMO-SkyMed Italian constellation and the satellite sensor mode used is the ScanSAR Wide image (100 × 100 km swath and 30 m of resolution).

An ad hoc agreement between Italian Space Agency and Ministry of Environment has been put into place, for COSMO-SkyMed imagery provision. In the framework of this agreement, images are daily downlinked and processed at the Matera Remote Sensing Centre of e-GEOS, in Near Real Time, within 30 min from satellite sensing, for detecting the potential presence of any oil substance on the sea surface. During the first year of monitoring (2015), 950 COSMO-SkyMed images were processed and delivered to the Italian Ministry of Environment and Cost Guard.

Over those areas where, on certain days, satellite images are not available, special flight missions by the Coast Guard aircraft are programmed, based on an agreement made ad hoc between the Italian Ministry of Environment and the Italian Coast Guard itself.

This satellite-based oil spill and vessel detection monitoring allows maximum continuity with no overlap among the satellite and aerial flight components and with low operating costs. It is completed with daily patrols activities, carried out by the anti-pollution means of naval fleet, in areas where oil rigs are located. Such ships are equipped with a tracking system that allows to view on line position, course, and speed, in order to control the activity constantly.

In order to avoid covering the same area at the same time, the satellite-based component of the off-shore platforms monitoring service is also harmonized with images acquired over Italian waters in the framework of the *CleanSeaNet* service, operated by EMSA on a European scale and delivered to Member States [34], for the early detection of pollution by oily substances at sea and the identification of merchant ships responsible for oil spills.

Once the satellite image is downlinked at Matera Remote Sensing Centre, it is processed by an e-GEOS proprietary platform which is multi-source (ingests data from different kinds of platforms, i.e., satellites, EO turrets) and multi-mission (processes both SAR and optical satellites data); it integrates ancillary data (such as vessels ID data and met-ocean) and open source data, with particular attention to sea state conditions, which are essential for assessing the feasibility of the oil spill detection and reducing at maximum the false alarm; for this reason all available ancillary information are considered during the oil spill detection process.

In case of presence of potential oil spill, an alert is immediately sent to Ministry of Environment and Coast Guard in parallel, via e-mail followed by a phone call, within 30 min from satellite pass. Thus, competent authority can take the proper measures in case of identification of vessel responsible of pollution and, where necessary, coordinate the operational measures for the answer or the mitigation of the effects of pollution.

Oil and vessel detection products are uploaded on a webGIS platform for information filtering, browsing, and visualization (see Fig. 9).

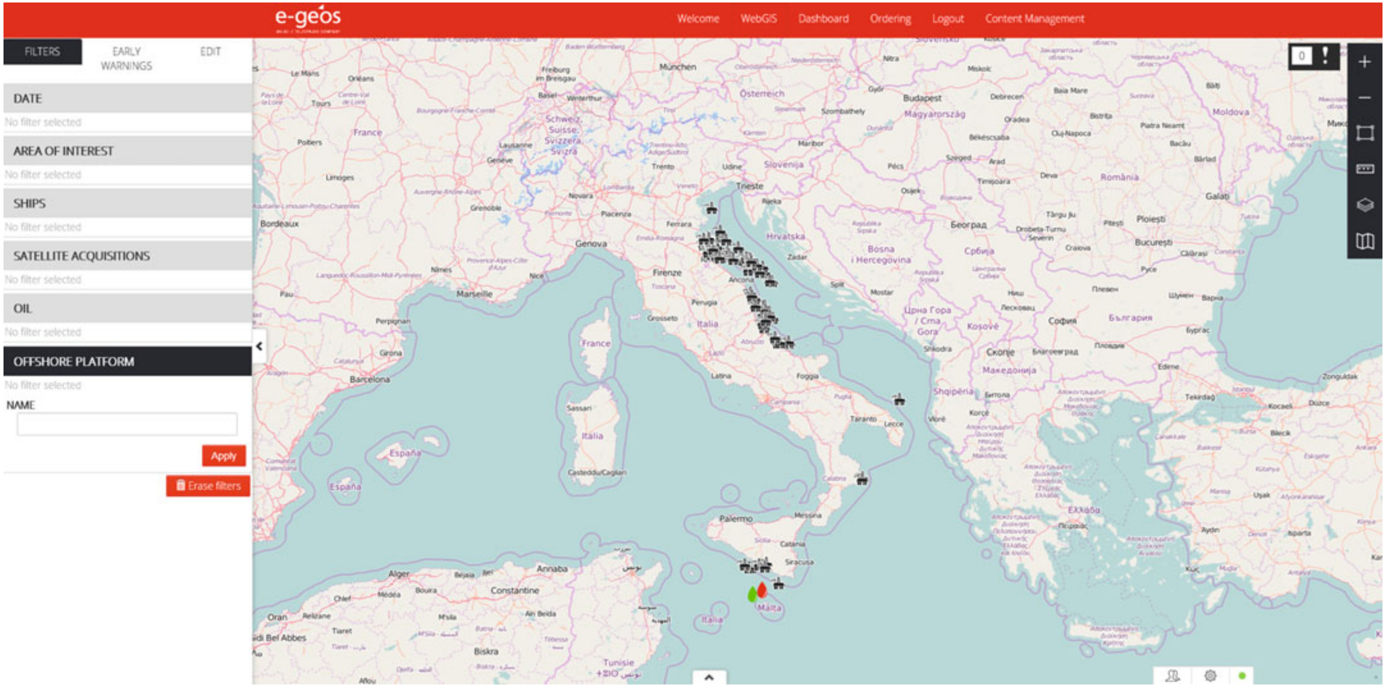

Fig. 9 e-GEOS web-GIS platform

7 Conclusions

The Mediterranean Sea represents from the ecological, historical, social, and economic point of view a reality to defend and preserve. The present anthropic pressure on it is large and is foreseen to increase in the future. Italy with its position in the Mediterranean Sea is highly interested in contributing in its preservation. Italian National Contingency plan has been changed during the last years keeping in mind both pollution risk reduction and emerging of new technologies like the satellites ones. This approach should discourage the operational oil spills that represent nowadays the major source of pollution.

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References

1. United Nations Conference on Trade and Development, Review in Maritime Transport. Available at http://unctad.org/en/PublicationsLibrary/rmt2015_en.pdf
2. Study of Maritime Traffic Flows in the Mediterranean Sea: EU project "Euromed co-operation on Maritime Safety and Prevention of Pollution from Ships – SAFEMED". Available at http://safemedproject.rempec.org/documents/safemed-1-documents/2.3-maritime-traffic-flows-study/view
3. Piano operativo di pronto intervento per la difesa del mare e delle zone costiere dagli inquinamenti accidentali da idrocarburi e da altre sostanze nocive. Available at http://www.minambiente.it/notizie/ecco-il-piano-difendere-dal-petrolio-il-mare-e-le-coste
4. Contratto tra Ministero dell'Ambiente e della Tutela del Territorio e del Mare e CASTALIA Consorzio Stabile S.C.p.A Repertorio 212 23/06/2015., CIG:6090681CF3, CUP: F49D15000000001
5. Liberati R, Tabbita R, Gestione del servizio di protezione dell'ambiente marino e di lotta all'inquinamento del mare. Available at http://www.corteconti.it/
6. Covello F, Battazza F, Coletta A, Lopinto E, Florentino C, Pietranera L, Valentini G, Zoffoli S (2010) CSK an existing opportunity for observing the Earth. J Geodyn 49:171–180
7. Gambardella A, Giacinto G, Migliaccio M, Montali A (2010) One-class classification for oil spill detection. Pattern Anal Appl J 13(3):349–366. doi:10.1007/s10044-009-0164-z
8. Migliaccio M, Nunziata F, Buono A (2015) A review on SAR polarimetry for sea oil slick observation. Int J Remote Sens 36(11–12):3243–3273
9. Long DG, Mendel JM (1991) Identifiability in wind estimation from scatterometer measurements. IEEE Trans Geosci Remote Sens 29(2):268–276
10. Nunziata F, Sobieski P, Migliaccio M (2009) The two-scale BPM scattering model for sea biogenic slicks contrast. IEEE Trans Geosci Remote Sens 47(7):1949–1956

11. Migliaccio M, Ferrara G, Gambardella A, Nunziata F, Sorrentino A (2007) A physically consistent speckle model for marine SLC SAR images. IEEE J Ocean Eng 32(4):839–847
12. Migliaccio M, Ferrara G, Gambardella A, Nunziata F (2007) A new stochastic model for oil spill observation by means of single-look SAR data. Environ Res Eng Manag 39(1):24–29
13. Migliaccio M, Tranfaglia M, Ermakov SA (2005) A physical approach for the observation of oil spills in SAR images. IEEE J Ocean Eng 30(3):496–507
14. Montuori A, Nunziata F, Migliaccio M, Sobieski P (2016) X-band two-scale sea surface scattering model to predict the contrast due to an oil slick. IEEE J Sel Top Appl Earth Obs Remote Sens 9(11):4970–4978
15. Migliaccio M, Nunziata F, Gambardella A (2007/2009) On the co-polarized phase difference for oil spill observation. Int J Remote Sens 30(6):1587–1602
16. Velotto D, Migliaccio M, Nunziata F, Lehner S (2011) Dual-polarized TerraSAR-X data for oil-spill observation. IEEE Trans Geosci Remote Sens 49(12):4751–4762
17. Migliaccio M, Gambardella A, Tranfaglia M (2007) SAR polarimetry to observe oil spills. IEEE Trans Geosci Remote Sens 45(2):506–511
18. Migliaccio M, Gambardella A, Nunziata F, Shimada M, Isoguchi O (2009) The PALSAR polarimetric mode for sea oil slick observation. IEEE Trans Geosci Remote Sens 47(12): 4032–4041
19. Demin BT, Ermakov SA, Pelinovskii EN, Talipova TG, Sheremet'eva AI (1985) Study of the elastic properties of surface-active sea films. Atmos Oceanic Phys 21(4):410–416. ISSN: 00023515
20. Espedal HA, Whal T (1999) Satellite SAR oil spill detection using wind history information. Int J Remote Sens 20(1):49–65
21. Wright J (1966) Backscattering from capillary waves with application to sea clutter. IEEE Trans Antennas Propag 14(6):749–754. doi:10.1109/TAP.1966.1138799
22. Hersbach H, Stoffelen A, de Haan S (2007) An improved C-band scatterometer ocean geophysical model function: CMOD5. J Geophys Res 112(C3):C03006. 10.1029/2006JC003743
23. Gerling TW (1986) Structure of the surface wind field from the Seasat SAR. J Geophys Res 91(C2):2308–2320. doi:10.1029/JC091iC02p02308
24. Portabella M, Stoffelen A, Johannessen JA (2002) Toward an optimal inversion method for synthetic aperture radar wind retrieval. J Geophys Res 107(C8):3086. doi:10.1029/2001JC000925
25. Mouche AA, Collard F, Chapron B, Dagestad KF, Guitton G, Johannessen JA, Kerbaol V, Hansen MW (2012) On the use of doppler shift for sea surface wind retrieval from SAR. IEEE Trans Geosci Remote Sens 50(7):2901–2909
26. Beal RC, Tilley DG, Monaldo FM (1983) Large-and small-scale spatial evolution of digitally processed ocean wave spectra from SEASAT synthetic aperture radar. J Geophys Res 88(C3):1761–1778. doi:10.1029/JC088iC03p01761
27. Hui L, Qing X, Quanan Z (2008) An overview on SAR measurements of sea surface wind. Prog Nat Sci 18:913–919
28. Grieco G, Lin W, Migliaccio M, Nirchio F, Portabella M (2016) Dependency of the Sentinel-1 azimuth wavelength cut-off on significant wave height and wind speed. Int J Remote Sens 37(21):5086–5104
29. Li X, Lehner S (2014) Algorithm for sea surface wind retrieval from TerraSAR-X and TanDEM-X data. IEEE Trans Geosci Remote Sens 52(5):2928–2939. doi:10.1109/TGRS.2013.2267780
30. Nirchio F, Venafra S (2013) XMOD2 - an improved geophysical model function to retrieve sea surface wind fields from COSMO-Skymed X-band data. Eur J Remote Sens 46:583–595. doi:10.5721/EuJRS20134634
31. Grieco G, Nirchio F, Migliaccio M (2015) Application of state-of-the-art SAR X-band geophysical model functions (GMFs) for sea surface wind (SSW) speed retrieval to a dataset of the Italian satellite mission COSMO-SkyMed. Int J Remote Sens 36(9):2296–2312

32. Nirchio F et al. (2010) Contribution of COSMO/SkyMed data into PRIMI: a pilot project on marine oil pollution. Results after one year of operations. In: IEEE international geoscience and remote sensing symposium, IGARSS, 2010, At Honolulu, Hawaii, USA
33. http://unmig.mise.gov.it/unmig/strutturemarine/elenco.asp
34. Carpenter A (2016) European Maritime Safety Agency activities in the Mediterranean Sea. In: Carpenter A, Kostianoy AG (ed) Oil pollution in the Mediterranean Sea: Part I – The international context. Handbook of Environmental Chemistry. Springer International Publishing Switzerland. doi:10.1007/698_2016_18

Oil Spills in the Adriatic Sea

Marko Perkovic, Rick Harsch, and Guido Ferraro

Abstract Despite the northwest-southeast orientation of the Adriatic Sea, commercially it is virtually a north–south sea, as it penetrates deep into the European continent, nearly to the foot of the Alps. Large vessel traffic is dense, and accordingly there is a great deal of operational pollution along with the constant threat of accidents and incidents. Researchers have developed the means to detect much of the pollution in the Adriatic, to estimate its extent, and even the means, through satellite images and the process of backtracking, to identify polluters. These techniques promise that the increasing volume of traffic in the Adriatic may coincide with a reduction of pollution from commercial vessels. However, many other sources of oil pollution are of concern, including offshore industry, fishing, natural seeps, extraction of natural gases and oil from beneath the seabed and the corroding wrecks from as long as 70 years ago. There is also concern that legislation is not strict enough in the cases of platforms and chemical tankers. Further issues and complications derive from the nature of the sea, which is shallow and is fed by a high number of streams and rivers. The Adriatic, as is actually the case for the entire Mediterranean, is classified as a Special Area (according to MARPOL Annex I), which limits the amount of legal discharging of oily wastes, for instance. In addition, since few years the possibility to extend to the Adriatic the status of Particularly Sensitive Sea Area (PSSA) is under discussion. Yet the likelihood that traffic will increase and the causes of pollution detailed here will persist suggests that the need for continued scientific intervention and further legislation will also increase if the Adriatic is to maintain a semblance of a healthy environment.

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Contents

1 Introduction

The Adriatic Sea was once the most important waterway for European trade; its narrow entrance allowed Venice to control access from Corfu, and virtually the entire coastal area, the notable exception being Ragusa (Dubrovnik), which generally thrived before the sixteenth century but never rivalled Venice. Of particular further importance was the virtually north–south orientation of the sea that allowed for goods to be brought deep into Europe, northern Italy becoming one of the most important marketplaces of the continent. Now again the same qualities are making the Adriatic a temptation for shipping oriented towards central and much of eastern Europe. The proliferation of nation states bordering the sea provides only the illusion of disunity, for the ship traffic still drives predominantly north deep into the continent, near to the foot of the Alps, to ports close to such major cities as Munich, Prague, Vienna and Bratislava, not to mention the Balkan capitols. In addition, the Adriatic has for millennia been a sea of fishermen, who in their thousands of vessels and boats continue to ply their trade. Last but not least, in the past we have seen the Adriatic also as the highway for Balkan migrants (especially from Albania). We cannot exclude that the Adriatic could become soon again a major route for migrants.

As a result of its intense traffic, the sea is unfortunately subject to illicit operational discharges and dumping from ships, a well-documented problem throughout the Mediterranean Sea, and upon close examination even the legal releases, which often enough show up alarmingly on satellite images yet turn out to be within the boundaries of the law. In view of the fact that accidental pollution rarely occurs in the Adriatic Sea, operational discharges have progressively been identified as the main source of pollution from ships, with various studies [1–7] demonstrating that the Adriatic Sea is significantly affected by this phenomenon.

The environmental threat to such a semi-enclosed sea basin as the Adriatic Sea, with its relatively low activity of sea currents and waves, is a concern for the whole neighbouring community, for pollution due to an accident or larger operational discharge could cause irreversible environmental damage and enormous economic losses. At the same time commercial shipping and offshore industry, though significant, may be rivalled as a source of anthropogenic marine pollution by land-based discharges, including industrial effluents, urban and river run-off, sewage and atmospheric pollution from land industry sources. Further, various studies [8, 9] are now suggesting that globally the largest source of oil released into the sea is by nature itself. Natural seeps are present all over the world and the Adriatic is no exception; this active tectonic area is rich in the hydrocarbons from where seeps are expected, but at the same time, extensive research in the Adriatic does not comport with global studies.

Nevertheless, to minimise the contribution of ship-generated marine pollution by oil (and chemicals), the strict enforcement of existing regulations via the control, monitoring and surveillance of maritime traffic is required. Using aerial and space surveillance systems, one can see that illegal discharging and dumping by commercial ships is still commonplace.

Figure 1 illustrates the shipping intensity (traffic density obtained from AIS for the period of 90 days, June–September 2011) in the northern Adriatic, indicating how the main environmental aspects arise from normal operations.

2 Adriatic Sea Topography, Oceanography and Meteorology Related to SAR Performance

Topography and oceanography have a determinate bearing on all pollutants. The Adriatic Sea is the northernmost arm of the Mediterranean, semi-enclosed by the Apennine and Balkan Peninsulas, linked with the Mediterranean through the narrow Strait of Otranto. The Adriatic is a rectangular basin, oriented in a NW-SE direction 800 km long [10], more or less a north–south sea in commercial terms, yet at an advantageous angle that made the sea a near perfect waterway connecting the Venetians to the Levant. The deviation of trading routes from the shortest path – through the Suez and thence the Adriatic – owes their establishment to practices demanded by the sea powers of their time, as opposed to the most rational courses available, but the global nature of trade along with the sheer numbers of international corporations has succeeded in supplanting the rationales

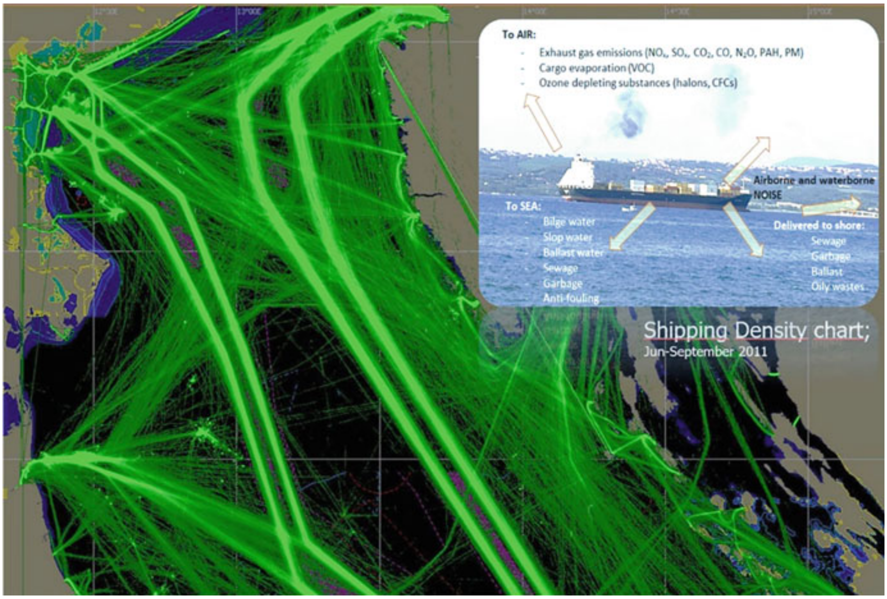


Fig. 1 Main environmental aspects arising from normal shipping operations. Density chart generated with Tran Viewer software of Transas. Photo taken at the Port of Koper anchorage

that caused the dramatic decline of shipping in the Adriatic, and now the prevailing driver of business, the profit motive, dictates that ships ply the most direct courses available (all other factors being equal).

The northern half of the Adriatic can be divided into two sub-basins: a northernmost shallow basin, the seafloor sloping gradually to the south, reaching its greatest depth at 100 m and then dropping somewhat abruptly to 200 m just south of Ancona and three pits (the central or middle part of Adriatic) located along the transversal line of the Italian city of Pescara, one of which is known as the Jabuka Pit. The southern half of the Adriatic consists largely of a basin called the South Adriatic Pit, characterised by approximately circular isobaths, with a maximum depth of about 1,200 m, separated from the middle basin by the Palagruza Sill.

The seafloor rises towards the relatively shallow Strait of Otranto, which is a mere 75 km at its narrowest. The western coast of the Adriatic Sea is regular, with isobaths running parallel to the shoreline, the depth increasing uniformly seawards. The rocky eastern coast is composed of many islands and headlands rising abruptly from the deep coastal water, most notably the extensive Dinaric Alpine stretch. The hinterlands on the opposite sides of the sea are entirely different. For the most part, the Apennine Peninsula, both north and south of the narrow eponymous mountain range, has a mild climate affected by the Mediterranean on both sides, the Alps mainly a geographic/climatic barrier, while on the Balkan side, the Mediterranean climate generally does not extend far from the sea; the land rises abruptly, and inland the climate is similar to that of Europe north of the Alps, with high karst, forest, low mountains and generally a continental climate.

The Adriatic Sea circulation and the distribution of its water masses strongly depend on the characteristics of air-sea fluxes [11]. Modelling the atmospheric forcing is quite complicated in the region of the Adriatic; surrounding mountains and valleys create a funnelling effect that significantly affects surface circulation [12]. Through the Strait of Otranto, the water generally flows into the Adriatic along the eastern and out along the western coast (however, within the sea there are several gyres that complicate the scenario). The inflowing water is usually more saline and warmer. Surface currents are responsible for the transport of an important amount of marine pollutants and freshwater dispersion. The circulation regime varies seasonally and interannually and is also driven with wind. During fall to late spring, the Adriatic Sea is dominated by two main winds, the *bora* and the *sirocco*, although Adriatic seawater circulation is also influenced by the *maestrale*, a northwesterly wind typical in the summer season in the Adriatic. The *bora* is a dry and cold katabatic wind blowing in an offshore direction from the eastern coast. The *sirocco* blows along the longitudinal axis of the basin (from the SE) bringing humid and relatively warm air into the region.

Cyclonic circulation (Fig. 2) of the marine currents in the Adriatic Sea is broken into three recirculation cells in the northern, central and southern sub-basins, being

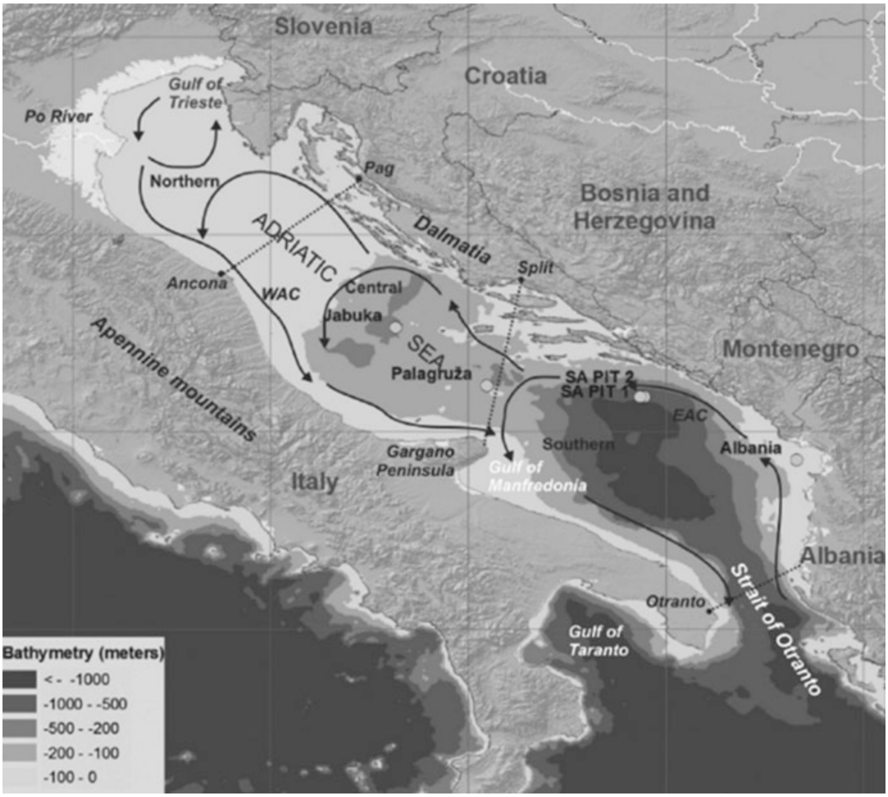


Fig. 2 Map of Adriatic Sea bathymetry and cyclonic circulation. *Source*: [10]

controlled by the bathymetry of the Mid-Adriatic Depression and South Adriatic Pit [13].

When relying on a satellite surveillance system (SAR (Synthetic Aperture Radar)), it is important to understand that the intensity of the images' backscatter is correlated to wind conditions at sea. Either conditions of little or no wind (*bonaca*) or strong wind (*bora*, *sirocco, tramontana*) will reduce the detection performance of the SAR sensor. *Bora* winds are manifested in SAR imagery as jet-like structures exhibiting intense roughness along the eastern coast. *Sirocco* winds produce more uniform roughness signatures and extend over the southern Adriatic [12].

Unfortunately, oil or chemical slicks are not the only phenomenon which can be remotely detected using a SAR sensor. Freshwater slicks, calm areas (wind slicks), ship's wakes, wave shadows behind land or structures, internal waves, currents, algae blooms and even vegetation or weed beds can calm the water just above them. This is particularly exacerbated in low wind conditions where natural surfactants can easily be taken to be spills. In practice it can be difficult to distinguish among various causes of backscattering [14].

3 Adriatic Sea Traffic

The amount of crude oil, products and liquid chemical cargos transported via the Adriatic Sea currently amounts to some 70–80 million tons per year and is increasing.

In particular, large container vessel, ro-ro and tanker traffic has been increasing throughout the last decade, each of which brings with them their specific hazards. Currently, the most important direction for oil and chemical transport in the Adriatic Sea is the import route, arriving through the Strait of Otranto and transiting the entire basin to northern Adriatic terminals. In 2015 more than 520 large tankers were called at Trieste, where 41 million tons of crude oil was discharged. Venice imported around 10 million tons, Omišalj 7–9 million tons and the port of Koper more than 3 million tons [15, 16].

There are also several other important oil and chemical ports in the Adriatic Sea, such as Ravenna, Falconara Marittima, Brindisi and Duress, but as Fig. 3 illustrates, the significance of this traffic is that almost all of it traverses the length of the Adriatic (the data for Montenegro and Albania are unreliable, so not included, but at any rate the amount is less than 2% of the total).

Figure 4 (upper part) shows daily traffic on weekdays, when intensive fishing activities are performed to the middle and western side of the Adriatic Sea, while the lower part of the image shows daily traffic at the end of the week (large intensive fishing vessels are idle on weekends).

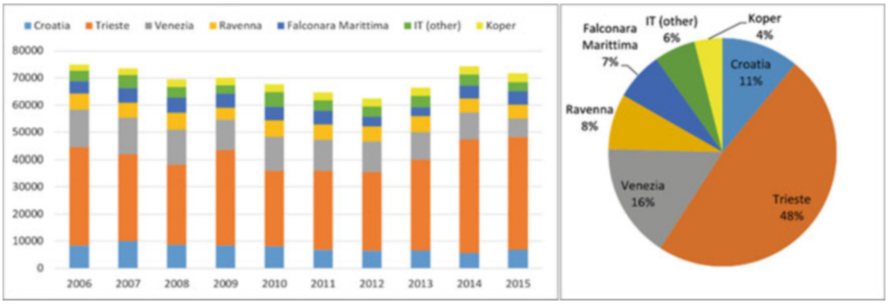


Fig. 3 Liquid bulk cargo transported through the Adriatic. *Source*: Authors adopted from [15, 16]

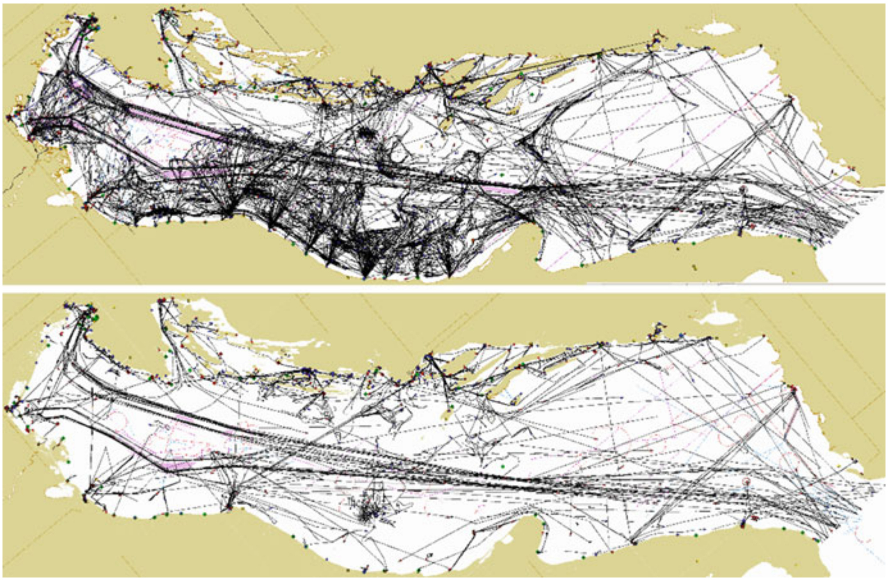
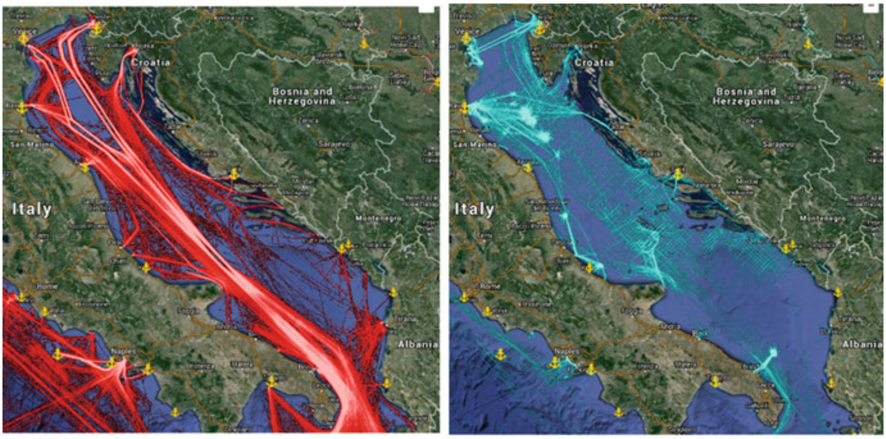


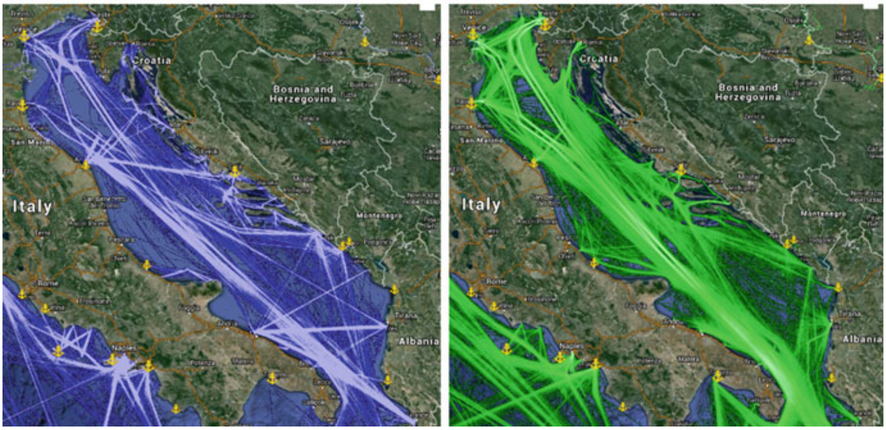
Fig. 4 Daily shipping activities in the Adriatic on weekdays (up to 1,400 vessels) and on weekends (up to 950 vessels). Trajectories generated with Tran Viewer software of Transas

Though the traffic density indicated by vessel type illustrates some differences between the four shown with Fig. 5 [17], such as the extreme south-north orientation of tankers compared to various cargo vessels, and of course the service vessels that are limited to their areas of exploration (note the grid pattern extending from the eastern shore all the way from Istria to Montenegro, which we hope is not an indication of pollution we can expect in years to come) and maintenance, it is not much of an exaggeration to say that the overall density is high, particularly for an enclosed sea.



a) Tankers

b) Service vessels



c) Cruisers and Ferries

d) Cargo vessel

Fig. 5 Shipping activities in the Adriatic Sea; density charts classified according to AIS. Charts generated online at Marine Traffic

4 Accidental Pollution

A larger accidental spill could have disastrous effects on the vulnerable environment, the natural resources of the Adriatic Sea as well as on its important uses such as for tourism and local fisheries.

A brief assessment of the overall accident exposure in the Adriatic Sea has recently been undertaken by Det Norske Veritas, which found that accident frequency is more than five times higher than the world average. Between 1995 and 2005, a total of 174 accidents have occurred in the Adriatic [18]. Actual pollution caused by accidents so far has not been as serious as the frequency of accidents

Table 1 Accidental pollution exceeding 10 m^3

Date	Location	Vessel name	Quantity of oil	Type of oil
17.07.1984		*MT Tharleos*	70 m^3	Sludge
1986	Urinj	*MT Batis*	35 m^3	Crude oil
1986	Urinj	*MT Melina One*	15 m^3	HFO
1987	Trogir	*MT Hestia*	Na	
1987	Bar	*MV Jordan Nikolov*	30 m^3	HFO
25.01.1989	Bakar	*MT Rumaila*	76 m^3	HFO
25.02.1989	Bakar	*MT Baba Gurgur*	100 m^3	HFO
22.03.2010	Split	*MT Tin Ujevic*	35 m^3	DO

could suggest [18]. There have been no incidents causing a major oil spill in the Adriatic Sea; so far the worst cases involved chemicals: in 1974 a collision in the Strait of Otranto led to the sinking of the *M/V Cavtat* with 120 t of tetraethyl and 150 t of tetramethyl lead; 10 years later, the *Brigitta Montanari* accident occurred, in which that tanker sank near a national park having on board 1,300 t of monomer vinyl chloride carcinogenic cargo – categorised as Y class by MARPOL. The *Alessandro Primo* sank outside Molfetta to a depth of 108 m with 3,013 t of dichloroethane and 549 t of acrylonitrile, both classified as MARPOL category Y, on board. About 90% of that cargo was successfully recovered. The list of accidental pollution events causing more than 10 m^3 to be spilled is presented in Table 1 [19, 20].

5 Operational Pollution

Operational pollution by marine vessels includes various types of discharges of oil and oily mixtures, including chemical, as a result of daily routine operations. Some of these, such as tank washing residues, involve only tankers. When old tankers offloaded cargo and prepared to travel empty, they had to take on large quantities of ballast water. When the ballast water was discharged, oil residues were released as well. This practice has almost disappeared because new tankers are obliged to have separated tanks for the oil cargo and for the ballast water. However, all tankers when switching cargoes must wash and remove residues from hull walls. The remaining residue from tank washing should be stored in specific tanks (slops) and can be discharged only following strict regulations. This rule is, unfortunately, often violated.

At any rate, all types of ships can discharge pollution into the sea: oil from engine room wastes, bilge waters and, in rare cases, used oil. Due to the low quality of ship fuel, only part of it is effective for propulsion. Before being burnt, some fuel must be centrifuged, generating residues which are stored in a specific sludge tank. The sludge should be delivered into harbour facilities. Bilge water, following strict

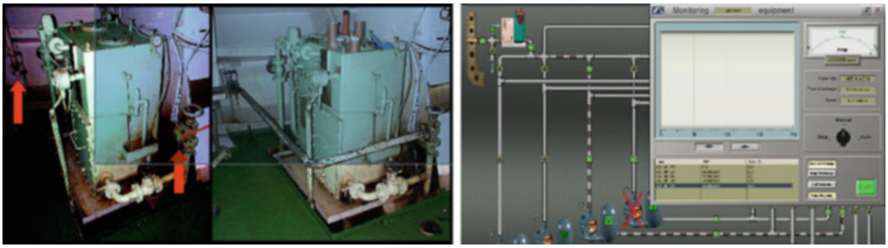


Fig. 6 Direct discharge; bypassing the oily water separator system. *Source*: [21, 22]

parameters, can be legally discharged. However, in practice, ships do not always unload residues in ports, rather the unrecorded discharges are accomplished through the use of a 'magic pipe' [21, 22] that connects the ship's purifier sludge tank with the ship's bilge holding tank, the contents of which are then pumped overboard without first being processed through required pollution prevention control equipment like the oil discharge monitor (ODM), implemented to detect and prevent discharges containing more than 15 ppm oil. Figure 6 demonstrates such real illegal acts on board the ship using a magic pipe/bypass (left part of the figure) or simulating such an event using either a liquid cargo handling simulator or engine room simulator.

The International Convention for the Prevention of Pollution from Ships, 1973, as amended by the Protocol of 1978 thereto (MARPOL 73/78) is aimed at minimising and eliminating pollution from ships. MARPOL is divided into annexes according to various categories of pollutants. Special Areas with strict controls on operational discharges are included in most annexes.

Annex I of MARPOL covers two main subjects; the special construction and equipment rules for the prevention of oil accidental pollution and the circumstances in which oil discharges into the sea are authorised [23]. Compliance with the regulations will prevent discharges exceeding legal limits. It follows that any illegal discharge will be the result of an equipment failure (and as such 'clear grounds' for thorough inspection in the next port of call) or a deliberate act. Any discharge or failure of the 'oil discharge monitoring and control system' should be entered in the 'Oil Record Book', which must be carried on board the ship. The oil discharge regulations in the convention apply differently depending on whether or not the sea area has been designated a 'Special Area': *all* of the Mediterranean is a Special Area according to Annex I. Oil residues which cannot be discharged into the sea in compliance with the regulations have to be retained on board or discharged to reception facilities. The 15 ppm oil in water concentration limit is the key parameter for identifying legal discharges from engine rooms in Special Areas (and in rare cases, ballast) [4]. Requirements for legally discharging from cargo tanks outside Special Areas are less strict, allowing discharges above the 15 ppm limit. Following a detailed study (North Sea Directorate 1992), the International Maritime Organization (IMO) recognised that it is not possible to actually *see* oily mixtures at sea that have an oil content below 15 ppm (*Resolution MEPC.61(34) of 9 July 1993 on*

Visibility Limits of Oil Discharges). This statement was based on scientific studies which confirmed that a discharge of oily mixtures with a concentration of 15 ppm can under no circumstances be observed, neither visually nor with remote sensing equipment. In conclusion, not all visible (by eyes or by RS) oil spills are necessarily illegal. But visible and/or detectable oil discharges from ships, observed in a MARPOL Special Area, are illegal without any doubt.

So why do some shipowners and crewmembers still decide to pollute? Dumping oil saves money. As mentioned, ships must have functioning oil pollution control systems and keep a detailed and accurate oil record book. Ships must use an oily water separator to ensure that all waste water pumped overboard has an oil content of less than 15 ppm.

> A report by the Organization for Economic Cooperation and Development estimated that the average annual cost of meeting the MARPOL regulations runs from $30,000 a year for an average sized cargo ship to $55,000 for a large container vessel, and the cost be up to $150,000 per year for a very large oil tanker. *These costs represent, on average, between 3.5% and 6.5% of a ship's overall operating expenses* [24].

Unfortunately, sometimes crewmembers or shipowners try to save money or the time it takes to unload waste oil in port by breaking the law, either by use of the magic pipe or simply flushing the ODM with clean water.

It is believed that globally 5–15% of all large vessels break the law by discharging their waste oil into the ocean. For the Adriatic, that means at any given moment when there are likely 100–200 commercial vessels sailing at any particular time, and applying the lower threshold of a Special Area, where ships perhaps are less apt to intentionally pollute, an estimated 7–10 are assumed to be polluting. At the same time, 5–7% of ships plying the Adriatic at any given time are on the Paris MoU (Paris Memorandum of Understanding on Port State Control) Black List.

According to the latest findings, analysing tanker traffic more precisely, some detected pollutions are not necessarily illegal regardless of potential harmful effects. Operational pollution related to MARPOL Annex II will be examined in a case study in Sect. 6.2.

5.1 Operational Pollution in the Adriatic Sea: Long-Term Archival Analysis of Images

The initial study assessing oil spill pollution from operational ship discharges in the Mediterranean Sea was performed by the EC JRC (Joint Research Centre of the European Commission), where a set of 190 ERS-1 SAR (Synthetic Aperture Radar) images acquired during 1991–1992 were analysed [1]. In 1999 the same institute acquired and visually inspected 1,600 ERS-1 and ERS-2 images, on which at least 44% displayed potential oil signatures. All together 1,638 detected spills were plotted, the highest intensity appearing along the main maritime routes. In the

Table 2 Overview of operational pollution in the Adriatic Sea (1999–2004)

Year	Adriatic Sea area covered [deg^2]	Possible oil spills [N°]	Oil spill density [N°/deg^2]
1999	155	223	1.44
2000	323	217	0.67
2001	248	168	0.68
2002	214	210	0.98
2003	248	104	0.42
2004	331	127	0.38
Total 1999–2004	1,520	1,049	0.69

Adriatic area, 159 slicks were detected, generally of rather small size – 41% were up to 3.7 km^2, 35% up to 10 km^2 and 24% larger than 10 km^2. SAR was clearly demonstrated to have the capability of detecting oil over large areas of the sea regardless of sunlight and cloud cover and as such appeared capable of complementing the conventional airborne means, which in the Adriatic was performed only by Italy.

The study was prolonged for 5 more years – up to 2004 – and altogether 18,947 SAR images were acquired, and 9,299 possible oil spills were detected in the Mediterranean area. The correlation of the oily discharge density with traffic density was evident [1]. These studies both confirmed the capacity and identified some limits of the use of satellite imagery for the detection of ship-generated operational pollution. During the period of 1999–2004, the satellite images analysed in the Adriatic Sea covered an area of 1,520 square degrees, and 1,049 possible oil spills were detected. Table 2 shows the operational pollution over a 6-year period [3].

5.2 *The Next Step: Near Real-Time Images*

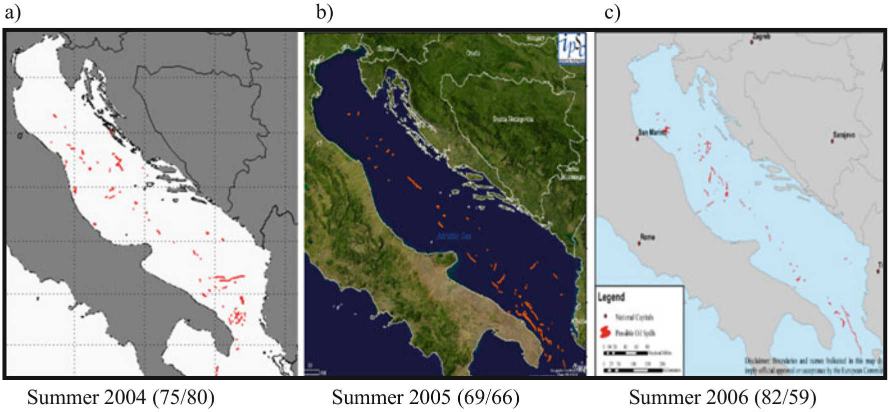
A further step towards putting the space surveillance system to practical use was made during the AESOP project in (*Aerial and Satellite surveillance of Operational Pollution in the Adriatic Sea*) in 2005 and 2006 [4]. The initiative to launch and develop AESOP was on the part of REMPEC (*Regional Marine Pollution Emergency response Centre for the Mediterranean Sea*). The other partners of AESOP were the Joint Research Centre, the Environmental Remote Sensing Regional Activity Centre, the Italian Ministry for the Environment, the Italian Coast Guard, the Central Institute for Marine Applied Research, Marche Region and the Faculty of Maritime Studies and Transport of the University of Ljubljana. AESOP aimed to test in the Adriatic the capability of providing a satellite near real-time (NRT) operation system in regard to marine oil pollution and monitoring of shipping routes. Coupling satellite imagery with the Automatic Information System (AIS) was successfully performed.

Integrating AIS with NRT service increased the possibility of detecting the actual polluting ship and prosecuting the offenders. In the summer of 2005, 69 medium resolution images from ERS-2, ENVISAT and RADARSAT were analysed, showing 66 possible spills in the Adriatic Sea. The number of detections was for the first time verified and confirmed using vessels and aerial surveillance. Additionally, during the project a significant operational release (25 August 2005) was discovered off San Cataldo Point in Puglia (southern Adriatic). A response operation to collect the oil at sea, both in small hydrocarbon agglomerates and unbroken wakes of 5–6 mm of thickness, was activated and coordinated by the Italian Coast Guard. Furthermore, on 6 September 2005 the first polluters backtracking case using hindcast simulation was demonstrated. Three slicks (out of four) were successfully correlated to potential polluters [4]: a red-handed case with a fast ferry and two partially weathered instances – one with the oceangoing vessels discharging on the way and the second involving an offshore industry, a gas rig probably discharging produced water.

During the second phase of AESOP (summer 2006), an additional 82 images were acquired, mostly concentrated on the Otranto Channel, as the results of the first phase of activities highlighted numerous cases of operational pollution in the area. Fifty-nine possible oil spills were detected.

Figure 7 shows shapes of the possibly detected (some of them also confirmed to be mineral oil) oil slicks during the summers of 2004–2006.

It must be underlined that the AESOP project was one predecessor of the *CleanSeaNet* service established on April 2007 by the European Maritime Safety Agency.



Summer 2004 (75/80)   Summer 2005 (69/66)   Summer 2006 (82/59)

Fig. 7 Possible oil spills detected in the summers of 2004, 2005 and 2006. *Source*: Authors

5.3 Surveillance and Monitoring of the Adriatic Sea

The European Maritime Safety Agency (EMSA) established a system based on the use of near real-time (NRT) space-borne imagery to support and integrate aerial surveillance in the detection of oil pollution. The platform is known as the *CleanSeaNet* (CSN) system, which uses Synthetic Aperture Radar (SAR) images. Having already acquired and analysed more than 15,000 images (since 2007), this service is confirming that oil is still illicitly pumped out across all European seas.

CSN detected (2011–2015) 593 slicks over the last 5 years in the Adriatic Sea; 250 instances or 42% were classified as probable spills and the rest as possible. Figure 8 shows the positions of the 143 potential slicks during 2015 and the results of the confirmation process.

Most of the detections that were checked are marked ‘nothing observed’. On average 3–4 h passed before what was detected could be confirmed, suggesting that likely many slicks were already completely weathered and that the discharged amounts were relatively small. The largest slick detected and confirmed during the last 5 years in European waters was in the Adriatic between Ancona and Zadar

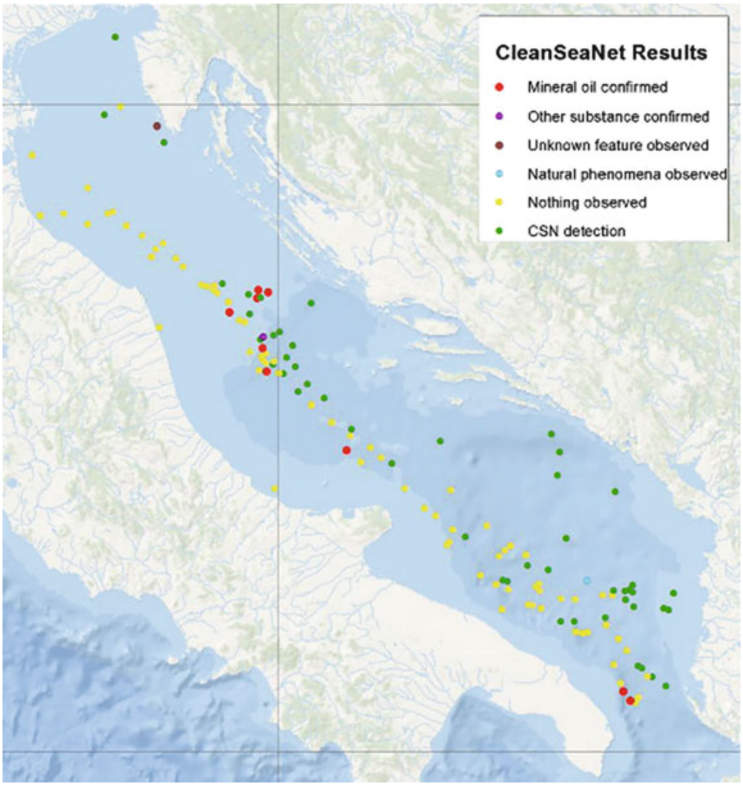


Fig. 8 *CleanSeaNet* results 2015. *Source*: [24]

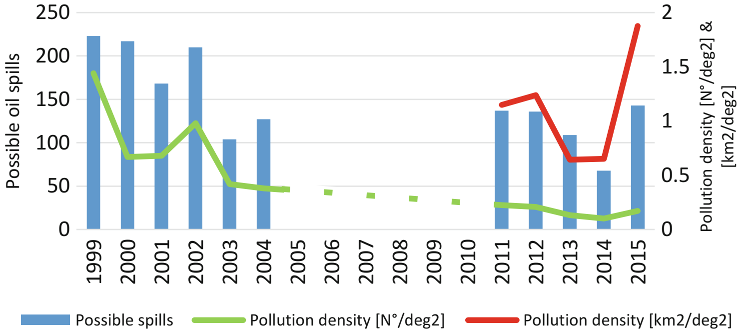


Fig. 9 Possible oil spills and detection density in the Adriatic Sea. *Source*: Authors adopted from [3, 4, 25]

[25]. A Croatian surveillance plane confirmed the spill about 3 h after detection, while an Italian surveillance vessel that arrived 1 h later could not find the slick. Though there is the possibility that the crew on the vessel were simply unable to find the slick, more likely – and here is the important point – the slick had weathered by the time they arrived, as we have come to realise that most cases of operational pollution involve small amounts in thin layers that soon disperse.

To improve our understanding of operational pollution in the Adriatic, it is necessary to go beyond counting spills and to consider the area covered by the images. In Fig. 9, the blue bars suggest that pollution is generally down from the early 2000s to the most recent 5-year period; yet once the amount of area actually covered by imagery is factored in, it is actually *much* reduced, as illustrated by the green line (pollution density: the ratio of spill number divided by covered area).

From the latest *CleanSeaNet* database, we can measure the actual area of the identified slicks. After it appeared that the size of slicks was decreasing along with the number, as one might expect, suddenly the size increased dramatically during the course of 2015 when the total area polluted was 1,550 km^2, a result that could simply reflect the quality of the new sensor, Sentinel-1. With more information, we are approaching the possibility of eventually accurately calculating the amount of oil discharged or spilled over a given period of time. From our data as it stands, we can calculate that the average size of a detected slick will be 1.11 km^2 per square degree of analysed area of sea. Multiplying this number by the size of the Adriatic Sea (about 15 square degrees), we get the average size of oil slick – 16.72 km^2. In order to determine the amount of oil discharged or spilled over the entire year, the area must be multiplied by thickness of the layer, which we presume to be rather minimal, say, 0.1 μm, which gives us an amount of 100 l/km^2, or an average slick of size 1.67 m^3. Bearing in mind that oil persistence is likely about 3 h, the total amount of oil spilled per year would be 2,920 m^3.

6 Spatial Analysis

The distribution of the pollution and some correlation towards possible identification of polluters will be discussed in case studies analysed more precisely with CSN data obtained in 2014 and 2015, when 211 slicks were identified. Figure 10 shows the spatial distribution and shapes of the detected spills. On first impression a minimum 35 of them are illegal, in that they are located within territorial waters where any discharge (from vessels) is illegal. But we cannot simply point out the most polluted area – it is again necessary to normalise detection by calculating the amount of coverage for the various segments of the sea, for satellite images were not equally distributed over the analysed period.

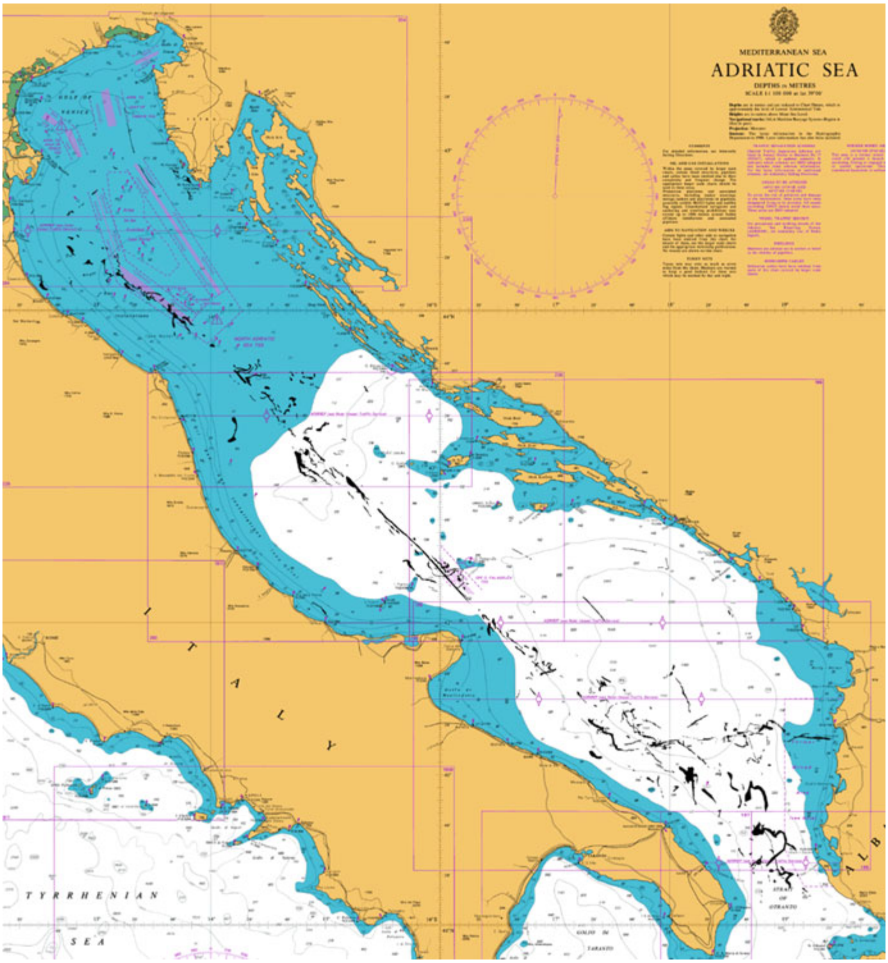


Fig. 10 Probable oil spills in the Adriatic Sea. *Source*: Authors adopted from [25]

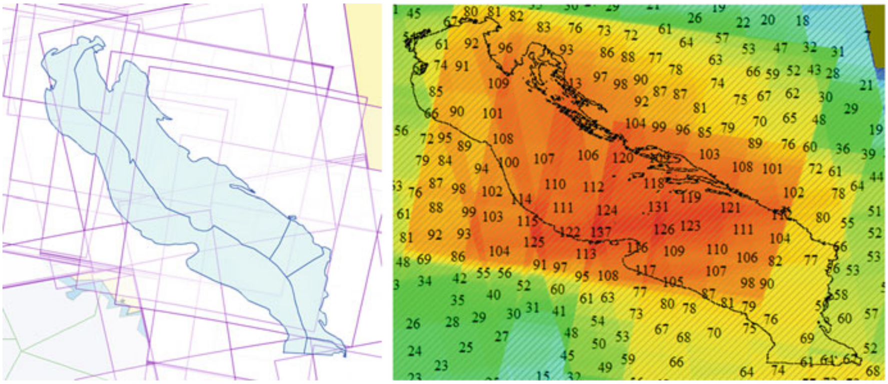


Fig. 11 EO over the Adriatic and density coverage. *Source*: Authors adopted from [25]

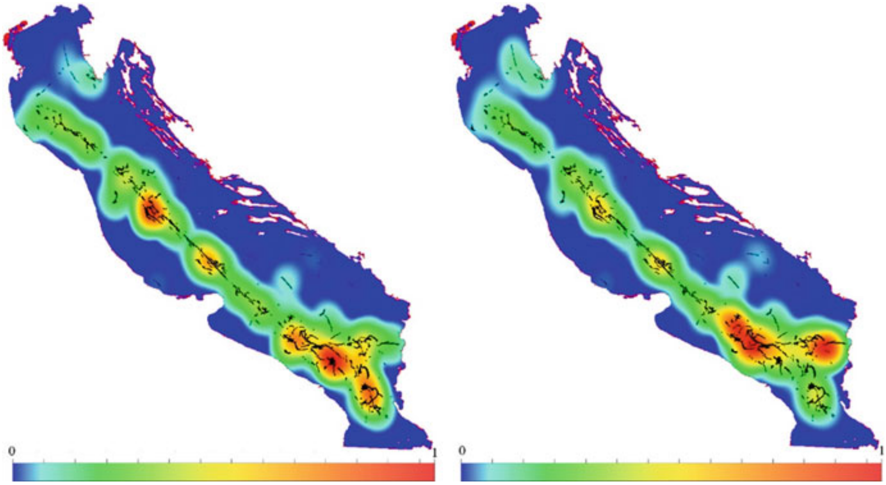


Fig. 12 Probable spills and detection density in the Adriatic Sea. *Source*: Authors adopted from [25]

The left part of Fig. 11 shows the position and size of 328 images acquired, while the right shows the density distribution. The central Adriatic is covered two times more than the extremes, the Gulf of Trieste and the Strait of Otranto. Naturally this affects how all image data is interpreted.

Figure 12 shows the distribution (relative density) of the pollution qualified on the left by area, which tends then to show where platforms are likely culprits, and on the right by perimeter, which, because it emphasises length tends to indicate fresh

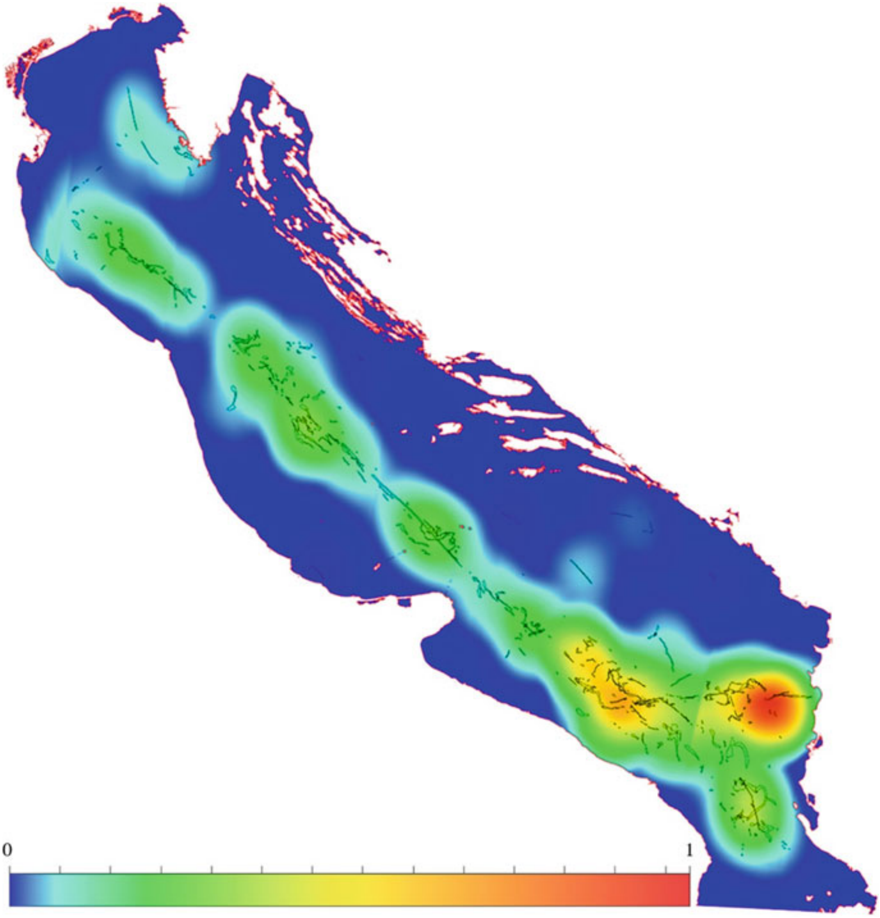


Fig. 13 Probable spills and normalised pollution density in the Adriatic Sea. *Source*: Authors adopted from [25]

slicks that are longer and thinner and those with a more frilly and irregular outline, suggesting they were caused by vessel discharges.

The circular and convex-shaped slicks are probably more related to offshore discharges or identify older, broken spills. In this figure the point is made most clearly by the difference in the south, where the ferry line between Bari and Durres makes it evident, as opposed to the map on the left, where the oil platform and accompanying Floating Production Storage Unit is somewhat isolated.

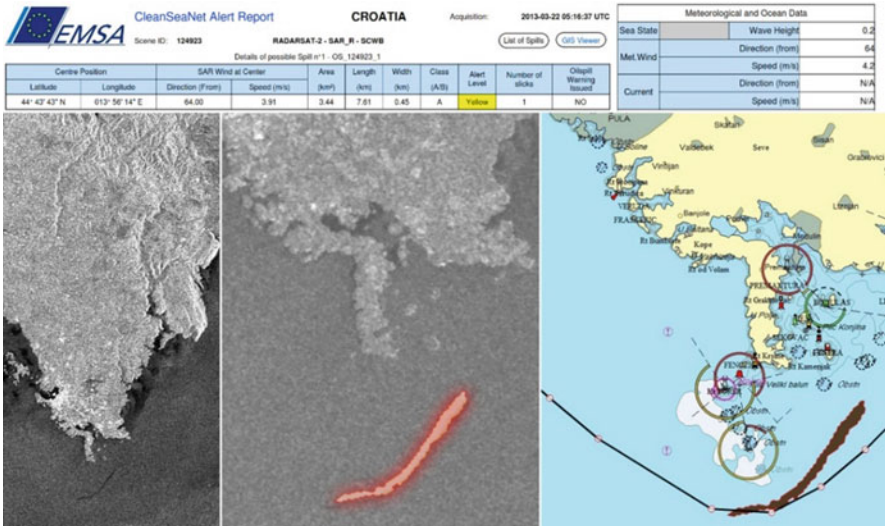
Finally Fig. 13 shows the most polluted area.

6.1 Case Study 1: Machinery Waste Discharged Along the Istrian Coast

Figure 14 shows a case of interest, a *CleanSeaNet* detection on 22 March 2013 in Croatian waters. The spill was detected approximately 5 h after the discharge. A possible source (MMSI number) was reported by the CSN service provider. The vessel track was available in an alert report based on AIS information integrated into the CSN system. As the vessel arrived in Koper, researchers upon the request of the Port State Inspector (PSI) performed hindcast modelling using an advanced oil spill simulator (PISCES 2) [26] and successfully backtracked the potential polluter. The identification was verified by the PSI and an overriding factor message in Thetis regarding a possible instance of pollution in Croatian waters was entered. Inspecting the vessel evidence was found of the discharge of oily products:

- An OWS (oily water separator) discharge line containing oil residues
- Oil spots on the starboard side hull (about 10 m^2)

The master and the company were fined 4,600 Euros. The ship was not detained.



CleanSeaNet Alert Report

CROATIA

Acquisition: 2013-03-22 05:16:37 UTC

Scene ID: 124923

RADARSAT-2 - SAR_R - SCWB

Details of possible Spill n°1 - OS_124923_1

Centre Position		SAR Wind at Center		Area	Length	Width	Class	Alert Level	Number of slicks	Oilspill Warning Issued
Latitude	Longitude	Direction (From)	Speed (m/s)	(km²)	(km)	(km)	(A/B)			
44° 43' 43" N	013° 56' 14" E	64.00	3.91	3.44	7.61	0.45	A	Yellow	1	NO

Meteorological and Ocean Data			
Sea State		Wave Height	0.2
Met.Wind		Direction (from)	64
		Speed (m/s)	4.2
Current		Direction (from)	N/A
		Speed (m/s)	N/A

Fig. 14 Oil spill detection, polluter identification and sanction. *Source*: Authors adopted from [25]

6.2 Case Study 2: Chemical Cargo Residue Discharged in the Central Adriatic Sea

This is the classical case where probably cargo residues or possibly bilge waters have been discharged. An oil/chemical tanker vessel sailed through the entire Adriatic Sea calling at four different ports (Brindisi, Ravenna, Trieste and Venice). There are different protective measures adopted to improve safety at sea and to protect the environment, such as a mandatory ship reporting system (ADRIREP), routing systems, VTMIS Directive and the declaration of the Adriatic Sea as a Special Area under MARPOL Annex I.

According to the ADRIREP, all oil tankers above 150 gross tonnage must report to the designated coastal authorities their entry into the Adriatic Sea and, further, must report at different sectors while sailing through the Adriatic Sea (Fig. 15). The particular vessel in question, while within the Adriatic, was obliged to report 17 times:

01	Entering Adriatic Region (sector 1)	First report	(Brindisi Coast Guard. ch.10)
02	Arrival Brindisi	End report	(Brindisi Coast Guard – ch.10)
03	Departure Brindisi; 16.03.2016 23:45	First report	(Brindisi Coast Guard – ch.10)
04	Crossing rep. line; 17.03.2016 04:55	Position report	(Bar MRCC – ch.12)
05	Crossing rep. line; 17.03.2016 08:20	Position report	(Rijeka MRCC – ch.10)
06	Crossing rep. line; 17.03.2016 18:00	Position report	(Ancona MRCC – ch.10)
07	Arrival Ravenna; 18.03.2016 05:15	End report	(Ancona MRCC – ch.10)
08	Departure Raven.; 20.03.2016 09:10	First report	(Ancona MRCC – ch.10)
09	Arrival Trieste; 20.03.2016 18:10	End report	(Trieste MRCC – ch.10)
10	Departure Trieste; 22.03.2016 09:30	First report	(Trieste MRCC – ch.10)
11	Arrival Venice; 22.03.2016 14.30	End report	(Venice MRCC – ch.10)
12	Departure Venice; 5.03.2016 12:40	First report	(Venice MRCC – ch.10)
13	Crossing rep. line; 25.03.2016 20:45	Position report	(Ancona MRCC – ch.10)
14	Crossing rep. line; 26.03.2016 05:00	Position report	(Rijeka MRCC – ch.10)
15	Crossing rep. line; 26.03.2016 14:00	Position report	(Bar MRCC – ch.12)
16	Crossing rep. line; 26.03.2016 17:30	Position report	(Brindisi Coast Guard. ch.10)
17	Leaving Adriatic; 26.03.2016 23:45	End report	(Brindisi Coast Guard. ch.10)

Each report received by designated authorities must subsequently be distributed to all other authorities in the Adriatic Region. Seeking to check the vessel's cargo manifest, researchers could only find two reports, both from Venice, which stated that 13,000 t of palm oil had been discharged and ballast water loaded.

It was also possible to determine the cargo classification by analysing VTS archived data. The AIS status was 'DG, HS or MP category B', meaning dangerous goods or hazardous substances or marine pollutant cargo category B, or according to the latest classification category Y of 'X, Y, Z and others' (Fig. 17).

According to the latest revision of the MARPOL Annex II (2007), a vessel is allowed to discharge dangerous goods of type Y when the ship is proceeding en route at a speed of at least 7 knots, and the total discharged amount does not exceed

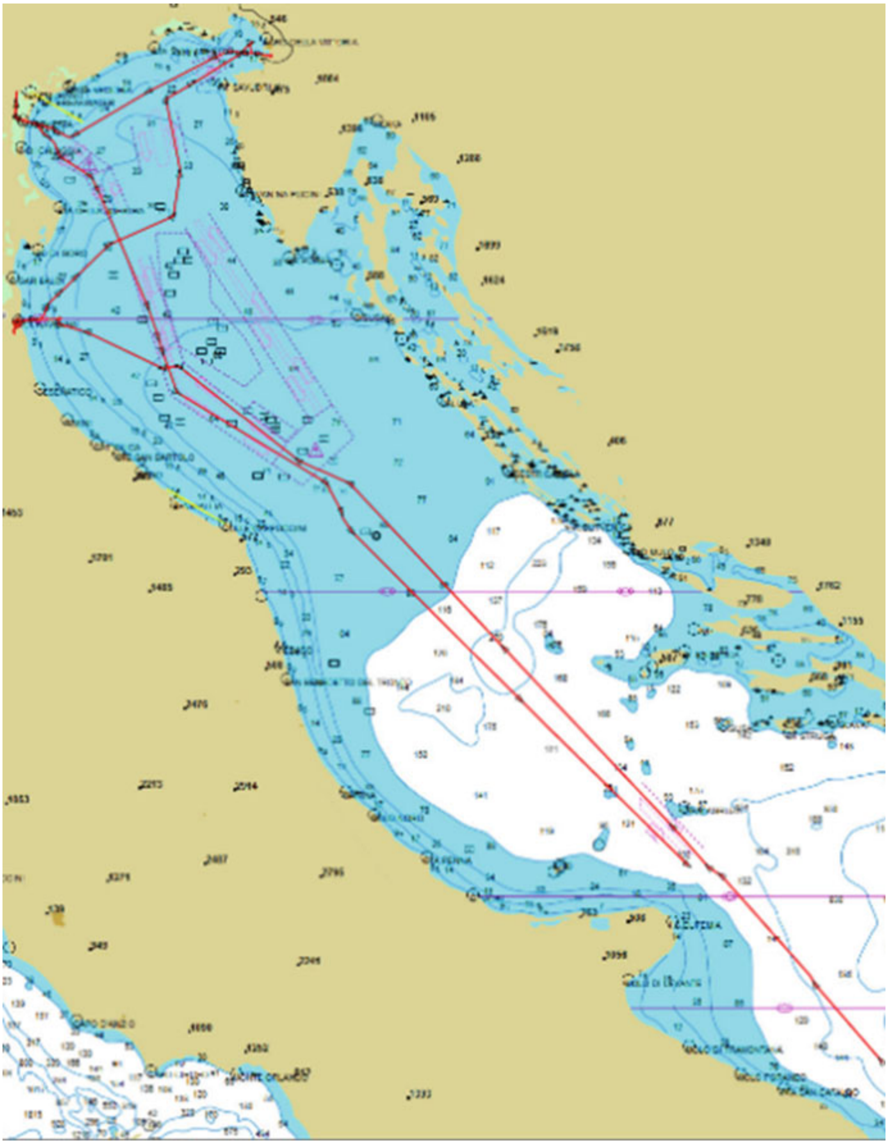


Fig. 15 Tracking the vessel of interest [17]

100 l per tank, and further discharging has to be below the waterline (‘MARPOL line’) and discharging outside territorial waters (further than 12 nm from the nearest land), where the depth of water is greater than 25 m. According to the old criteria, which took into consideration discharge concentration (maximum 1 ppm, cargo type y), despite reducing the total amount of discharge allowed, under the previous MARPOL regimen, no slick (of cargo type Y) should have been visible using SAR imagery. But in this case, a clear and long slick *was* visible (Fig. 16).

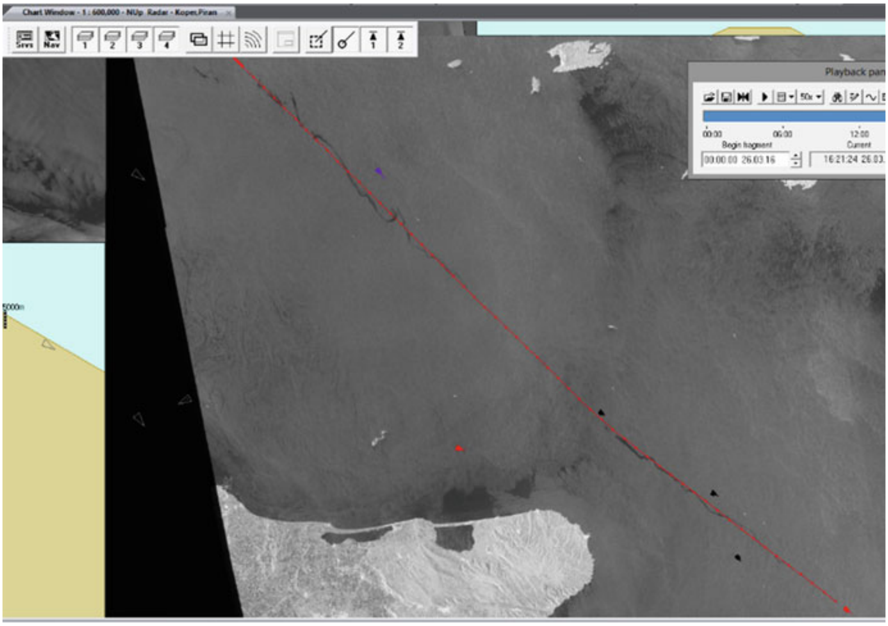
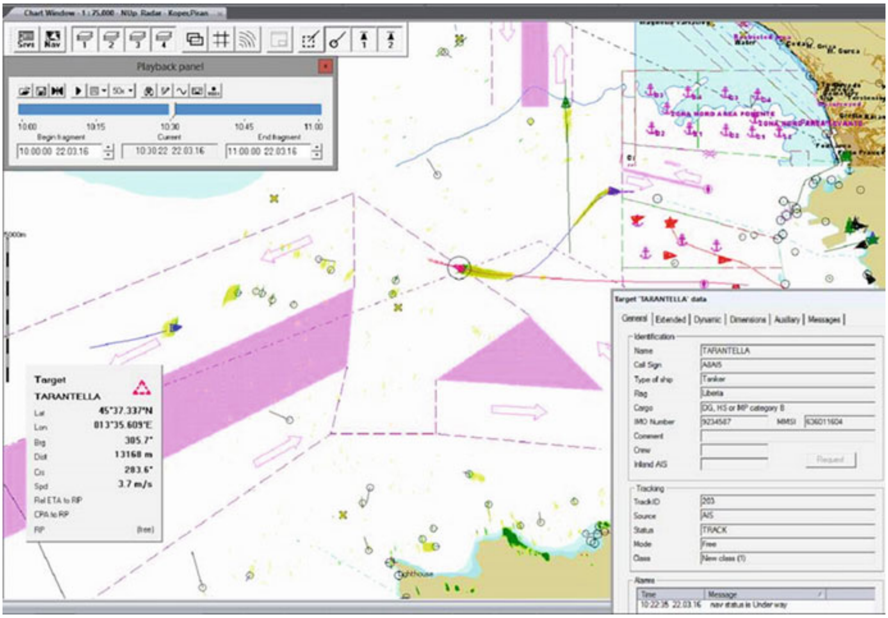


Fig. 16 Sailing track and detected instance overlaid with the sailing route. Navi-Harbour software of Transas was used to merge SAR image with the AIS history data [27]

The immediate assumption was that a case of illegal operational pollution had been detected, which likely would have been true if the contents were oil and not chemical. The vessel would have been allowed to discharge cargo residues directly into the sea – without pre-washing for cargo category Y, low viscosity – up to 100 l from each tank. The catch is that not only does the size of the spill cause concern, it is also true that the ship may use various chemical detergents to wash the chemicals that remain in the tanks and that are limited in the amount that may be discharged. It would not be an exaggeration to say that 200 or more litres of chemical detergents were used to clean each tank. To further elaborate on the problem, with palm oil a tank that has 100 l left will also have a great deal more on the walls of the tank, depending on the temperature. The amount of chemical cleaning also depends on the cargo that will be loaded after the palm oil, a cargo compatibility issue. Inevitably, many vessels will undertake to clean their tanks when close to 100 l are left, but much more is on the walls and it all will be discharged using chemical cleansers, meaning that the law is not necessarily violated, but its intended result fails (Fig. 17).



Begin fragment: 10:00:00 22.03.16
Current: 10:30:22 22.03.16
End fragment: 11:00:00 22.03.16

Target
TARANTELLA
Lat 45°37.337'N
Lon 013°35.609'E
Brg 305.7°
Dist 13168 m
Crs 283.6°
Spd 3.7 m/s
Rel ETA to RP
CPA to RP
RP (free)

Target 'TARANTELLA' data

Identification
Name: TARANTELLA
Call Sign: A8AI5
Type of ship: Tanker
Flag: Liberia
Cargo: DG, HS or MP category B
IMO Number: 9234567 MMSI: 636011604
Comment:
Crew:
Inland AIS:

Tracking
TrackID: 203
Source: AIS
Status: TRACK
Mode: Free
Class: New class (1)

Alarms
Time	Message
10:22:35 22.03.16	nav status is Under way

Fig. 17 Suspicious vessel's AIS info regarding dangerous goods on board (departing Trieste port). *Source*: Navi-Harbour software of Transas [27]

7 Offshore Industry: Gas and Oil Extraction and Exploration Activities

The Adriatic seabed, mostly in the central and northern parts, is rich in hydrocarbons. Figure 18 on the left shows offshore rig positions, while the right side presents exploration and some extraction wells. There are, all together, more than 100 rigs and 1,358 wells on the Italian side and 133 wells on the Croatian side of the sea. Additional exploration is foreseen in the Croatian waters marked with purple colour (in fact, aside from Bosnia and Slovenia, all countries bordering the Adriatic intend to begin exploratory drilling). Some pollution may occur during the drilling operation and continuous operational pollution is expected during the exploration. Effluent called produced water is normally discharged from such installations. Special regional rules are relevant for the offshore industry (offshore protocol under the Barcelona Convention). Platforms and rigs are allowed to discharge higher concentrations of oily water compared to shipping, despite the fact that, obviously, they are not mobile and so without natural means for dispersal. The monthly average concentration is limited to 40 ppm, while instance concentration may be as high as 100 ppm.

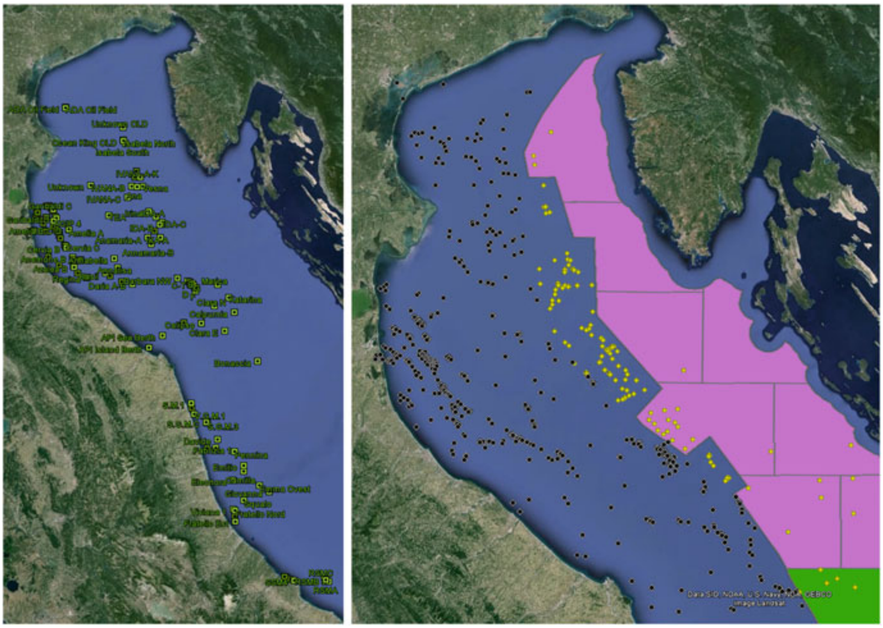


Fig. 18 *Left*: oil platforms and rigs. *Right*: bore hole drilling sites. *Source*: Navigational charts from Navi-Harbour software of Transas [27] and drilling data received from CHA-Croatian Hydrocarbon Agency

7.1 Offshore Cases

Case 1 was a confirmed release of produced water from a rig in the Adriatic, detected during the AESOP project. The figure below clearly shows the leakage from platform 'Daria A–B'. The amount and concentration was so great the image was visible even from the low-resolution optical sensor, which would be considered an overriding factor in determining that there was a violation of the law in regard to the offshore protocol agreed at the Barcelona Convention (Fig. 19).

Case 2 involves a much greater amount of likely spillage from a rig (Fig. 20). Comparing the inserts, one can see that the two images – with the surprisingly long time span of 2 days – were not correlated, the first identifying most of what seems to be one long spill, the other only lone vestiges or separated marks on the image. Likely the operators were different on the two different days, for what may appear to be a natural phenomenon on the latter day, looks far less so when it first appears, and especially when seen a second time with the first view in mind.

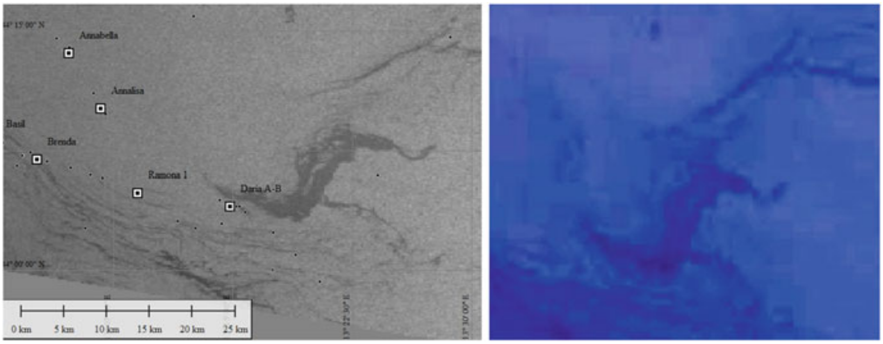


Fig. 19 Case offshore Ancona, *left* ENVISAT/ASAR (21/07/2006 – 09:26 UTC), *right* MODIS/Terra (21/07/2006 – 10:25 UTC). *Source*: [28]

8 Natural Seeps

Oil and gas seeps are natural springs where liquid and gaseous hydrocarbons leak from the ground fed by natural underground accumulations of oil and natural gas [API, page]. Natural discharges of petroleum from submarine seeps have been recorded throughout history, used as pitch, fires in religious ceremonies, for heat and even weaponry (Greek fire). The most comprehensive worldwide assessment of natural seepage is contained in a NAS (National Academy of Science from the USA) background report. According to the study, there are six crude oil seeps recorded that impact the marine environment in the Adriatic Sea [29]. Estimates of the levels of natural seepages suggest the quantities are very large. However, these estimates contain significant uncertainty. SAR systems are currently a common detection tool for these applications, since a large area can be controlled without being affected by cloud conditions, but the quantity of shows is difficult to assess. Further, pollution due to seepage can be mistakenly attached to human activity or offshore production. More precise studies of the geological nature of the Adriatic Sea and SAR monitoring in the area have been performed by oil companies in the process of hydrocarbon exploration, but most of the results of such studies are not publicly available. It *is* known, however, that the Adriatic subsea bottom is rich with hydrocarbons.

A model for the marine seeps system is presented in Fig. 21 [30, 31]. Open arrows are gas fluxes, shaded arrows oil fluxes and negative signs indicate sinks including microbial consumption (oxidation). Gas is vented at the seafloor, forming a bubble plume. Methane and other hydrocarbons diffuse out of the bubbles and into the water. Methane, dissolved in the ocean, is in turn oxidised by microbial activity. The bubbles remain intact while rising burst at the surface, releasing hydrocarbon gas and air into the atmosphere. Oil travelling upwards with the plume partly dissolves with the remainder, forming a slick at the sea surface.

Too many questions remain regarding natural seeps for any determination to be made regarding their effects, especially in the Adriatic, where it appears that

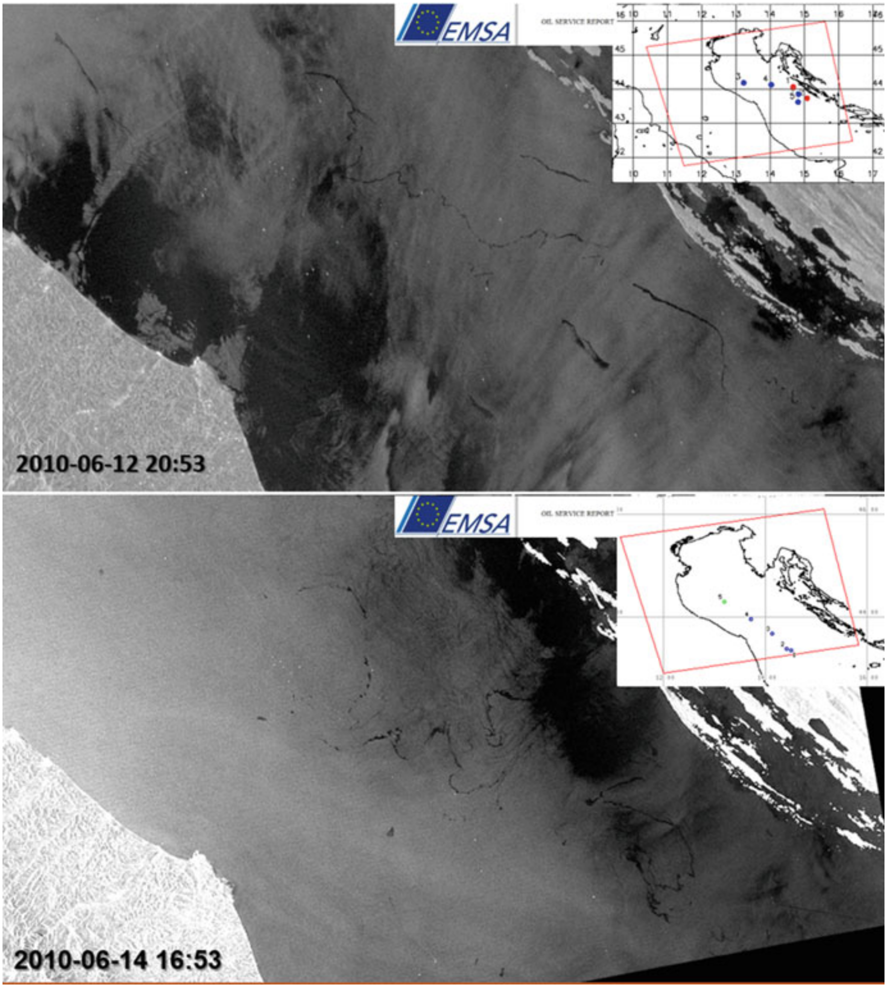


Fig. 20 Probable offshore rig leak. A large discharge remained visible for more than 2 days indicating a high concentration of oil in produced water. *Source*: EMSA [25]

methane is a great deal more prevalent than oil. At any rate, it is unknown what the effects of natural seepages of oil have.

For one thing, the oil is unprocessed and is therefore generally thicker than processed oil. Secondly, the oil tends most often to be discovered more weathered than oil that is released on the surface.

Another important factor affecting the number of oil slicks on the sea surface to be considered is a link between seepage, mud volcanism and regional seismicity [32].

In a recent study [31], the map of the gas leakages and main tectonic lineaments in the northern Adriatic region was presented (Fig. 22), while others [33] identified

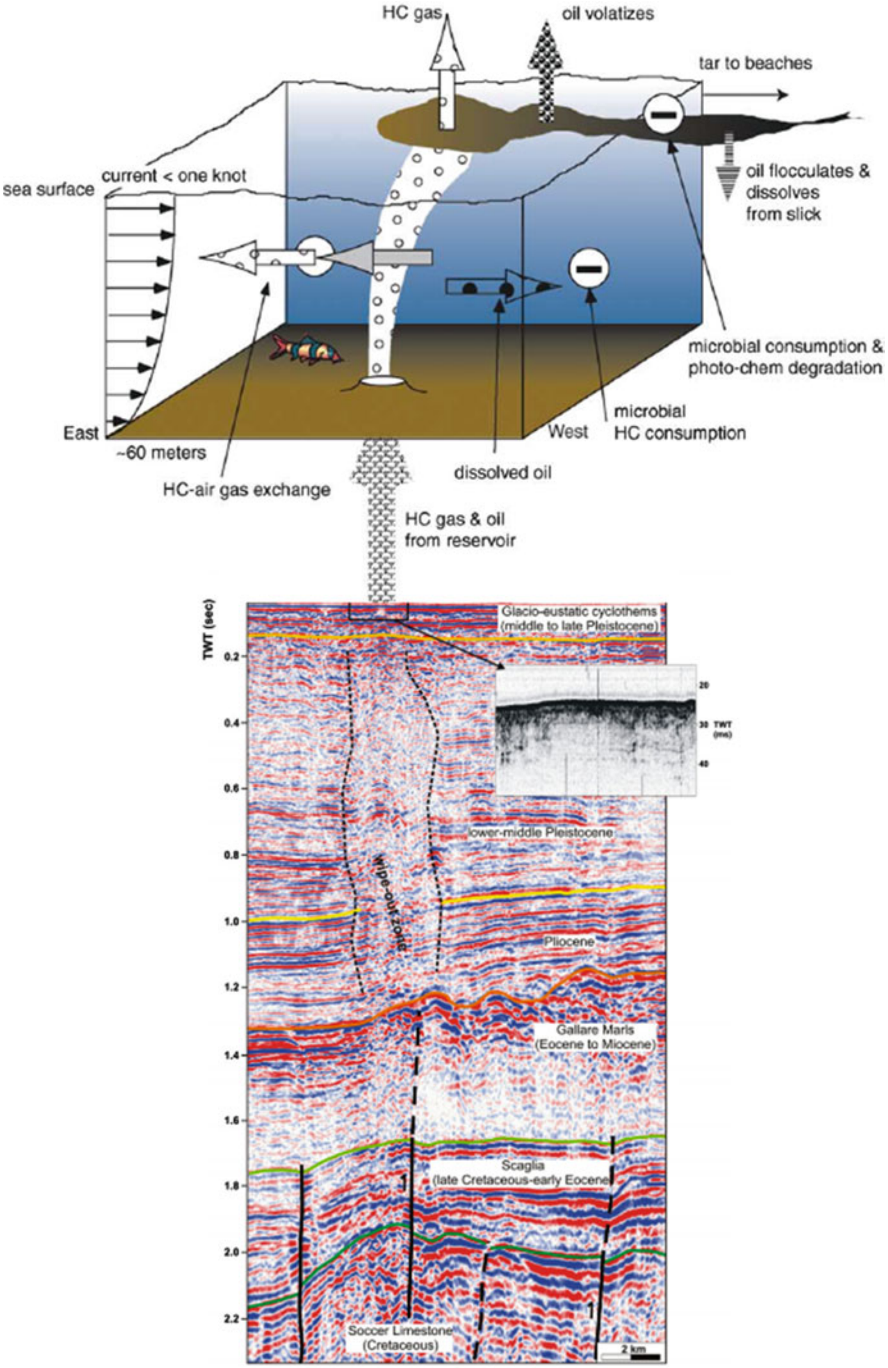


Fig. 21 Wipeout zone, gas and oil shows. *Source*: [31]

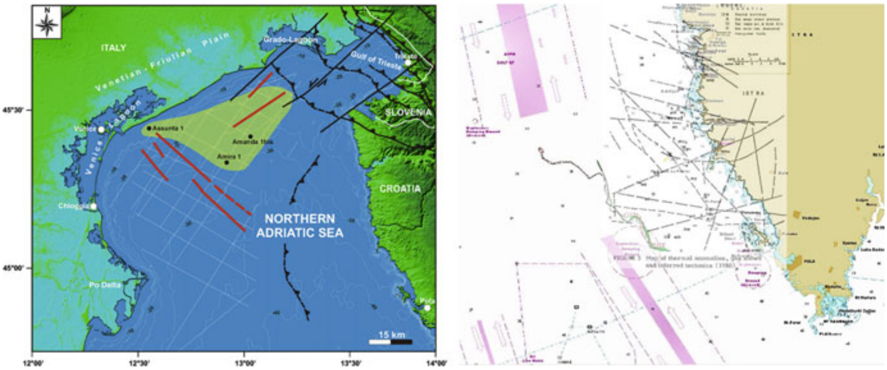


Fig. 22 Gas shows, inferred tectonics and two detected slicks originate from the same location. *Source*: [31, 34]

the link between gas seepage features such as pockmarks, mud volcanoes and mud-carbonate mounds with gas pulls present in the central Adriatic Sea.

Some seismic anomalies known as wipeout zones were discovered and interpreted as gas leakages.

The image on the right presents a map of thermal anomalies, gas shows and inferred tectonics identified with the study of [34]. Figure 22 also shows two detected slicks which originate from the same location, their origin seeming to be natural seeps.

Given the number of platforms and bore holes, not to mention the intensive commercial marine traffic, it is virtually impossible at this point to determine the extent of pollution deriving from natural seeps. One certainty, however, is that where a natural seep detected yields a great deal of natural gas or oil, there soon will be activity likely to generate pollution at some point in time.

9 Other Sources

An enclosed, variegated marine environment such as the Adriatic is vulnerable, particularly in some protected areas, to minor pollution. And some pollution is virtually impossible to quantify. Some known problematic sources are covered here.

9.1 Pollution Related to Fishing Activities

The subject of fishing in the Adriatic is particularly sensitive. Fishing is a part of the heritage of the entire Adriatic coast and in one sense is more important today than

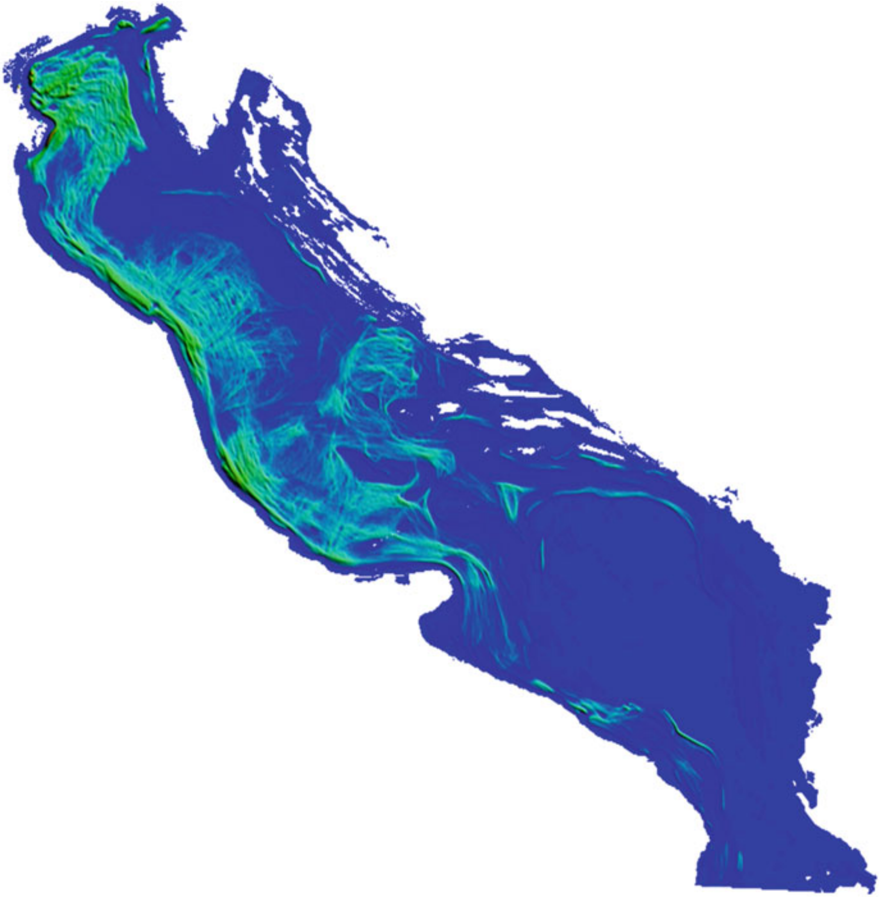


Fig. 23 Fishing vessel tracks during 2014–2015. *Source*: Authors adopted from [35]

ever, as tourism is keeping many Adriatic communities alive and could not exist without fresh seafood. On the other hand, not many would argue the fact that the Adriatic is overfished and on top of that, bottom trawlers certainly damage the seabed. An enormous number of fishing vessels, at least 10,000, are registered, over 2,000 of which are bottom trawlers. Figure 23 shows the fishing vessel tracks during 2014–2015 [35].

Regarding oil pollution, the size of the engines of the larger fishing vessels are 3–400 horsepower, which increases the likelihood of pollution to an extent impossible to determine, though wherever there is an engine, some bilge water concentrates likely end up in the sea, on top of which the hydraulic systems can easily have failures that lead to leakages. Figure 3 from Sect. 3 compares the density of traffic during the week as opposed to the weekends; if we find a correlation in detected pollution that follows the same pattern, we will have a far better idea of the effect of fishing on pollution in the Adriatic (this research is ongoing).

9.2 Wrecks

Sunken vessels could pose a potential pollution threat because of the hazardous nature of their cargoes and presence of munitions or because of bunker fuel left on board. Naturally corrosion takes place and eventually oil is likely to be released from the wrecks. The most notable case of a polluting wreck was that of the *Stella Polare* torpedo boat sunk in February 1944 in the northern Adriatic. The wreck was discovered in 1998, and oil leakage only began in 2001. Extensive response and cleaning was performed. There are more than ten wrecks threatening pollution in the northern Adriatic Sea.

9.3 Low-Level Pollution: Oil to Sea Interface System

On top of vessel pollution previously discussed, the frequent low-volume operational discharges and leaks of lubricants must be added. Such leakages and washed pollutions normally do not result in the type of response generally applied in major accidental or larger operational oil spills. Yet sometimes in perfect conditions, satellite and airborne systems have the technical capability to detect the oily patches released or drained from the water boundary propulsion systems or equipment located below waterline where mineral oils are used: stern tubes, rudder bearings, thrust bearings, controllable-pitch propellers, podded propulsion system stabilisers, thrusters, etc. (Fig. 24). Other equipment subject to immersion and ensuing oil release, such as deck gear, wire ropes, towing notch interfaces and any mechanical equipment subject to immersion such as dredges and grabs, add to the total pollution.

Almost all oceangoing ships operate with oil-lubricated stern tubes and use lubricating oils in on-deck and underwater machinery. Oil leakage from stern tubes, once considered a part of normal 'operational consumption' of oil, results in millions of litres of oil released into the water every year [37]. The amount of operational oil that leaks from a ship's propeller shaft bearings has been well

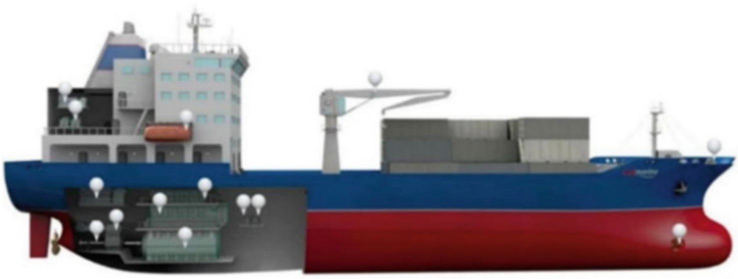


Fig. 24 Low-level pollution sources to be considered. *Source*: [36]

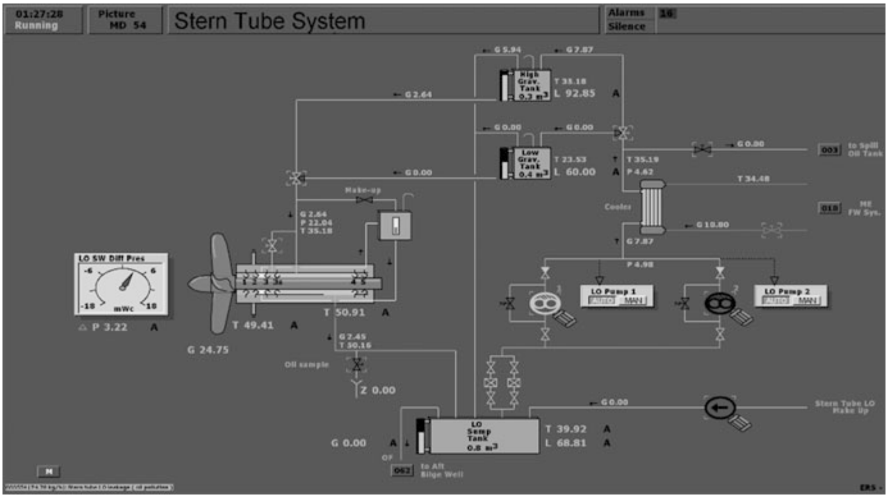


Fig. 25 Low-level pollution form damaged stern tube seal

documented. A typical stern tube system holds several hundred litres of oil. 'The leakage rate for stern tubes has been widely reported as 6 l per day for a vessel of 1,000 DWT, with higher rates for larger vessels and lower rates for smaller vessels and the average vessel' [38]. Figure 25 presents the stern tube system from the engine room simulator where a damaged stern tube seal is simulated. In normal conditions, oil pressure has to be slightly higher than static seawater pressure. In this particular case, oil pressure is higher by 3.22 mWc (metre water column), resulting in 24.75 kg/h oil pollution.

According to some research [38], several million litres of mineral oil-based lubricants are discharged into commercial harbours each year through stern tube leakage. To minimise the cumulative impact from leaking lubricants, the EPA [39] has introduced a list of environmentally acceptable lubricants[1] (EAL) which shall gradually replace existing mineral oils. Environmentally acceptable lubricants are vegetable oils, biodegradable synthetic ester, biodegradable polyalkylene glycols and water [40].[2]

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[1] Environmentally acceptable lubricants means lubricants that are 'biodegradable' and 'minimally toxic' and are not 'bioaccumulative', which have performance standards defined by the EPA.

[2] Seawater-lubricated stern tube systems have been developed recently – they use nonmetallic bearings instead of classical that require mineral-based lubricants or EALs.

9.4 Soot Blow from Inert Gas and SCR

Because ships pollute the air, seawater is used by selective catalytic reactors to clean exhaust, which is also cleaned on tankers – by scrubbers – to be converted into inert gases. All the water used in these processes is subsequently discharged directly back into the sea. A case of such pollution of some interest is presented in the chapter on Slovene maritime pollution.

10 Conclusion

Marine operational oil pollution includes various types of discharges of oil and oily mixtures as a result of ships' daily routine operations. Some of these, such as oily ballast water and tank washing residues, involve only tankers. All types of ships, however, may cause pollution through discharging oil into the sea from engine room wastes, bilge waters and, in rare cases, used oil. All international waters are legislatively protected against accidental and major operational spills of oil and chemicals under IMO's MARPOL regulations and the Adriatic has been designated a Special Area in Annex I, to which stricter controls are applied. Unfortunately, regulations do not enforce themselves and intentional/operational pollution remains problematic, as does the refusal of some shipowners to take proper care to prevent such spills as are caused by hull deficiencies, for instance. The mathematics behind the problem are quite simple: as long as polluting or failing to prevent pollution is vastly cheaper than doing everything possible to maintain a clean environment, those drawing income from control of maritime commerce will tend to behave in ways increasingly unacceptable for the environment and those who desire to maintain it at a high standard. We have described an identified polluter that was fined 4,600 €, and recently in the Adriatic, two cases of operational pollution were calculated to have cost *millions* of euros. Until the economics of prevention become a factor in European enforcement, we can expect pollution to remain at a high level and that level to become farther and farther from that which is necessary to preserve a healthy marine environment.

In the Adriatic, the process of identifying both the degree of operational pollution and the polluters themselves gained momentum when the EC JRC began examining the archives of satellite images in 1995 and again on a larger scale in 1999. Before long, researchers were studying pollution using near-real-time images and beginning to develop techniques to identify polluters through backtracking, in many cases successfully contributing to the detection and sanctioning of vessels. With improvements in SAR imagery and the establishment of *CleanSeaNet*, we are now able to actually make a rudimentary calculation of the amount of oil spilled in the Adriatic Sea.

The difficulty of reducing pollution is compounded by the further fact that the sources are not limited to accidents and incidents involving commercial vessels.

Globally, it is estimated by some that 47% of oil in the sea results from natural seeps. The Adriatic *does* have seeps, but from what can be observed, it is quite likely that the percentage of oil in the Adriatic from natural seeps is far lower. However, the seeps indicate sources of oil or gases and invite exploitation, which, of course, leads to discharges such as those described in Sect. 7. A further problem is that the rules governing discharges allow a much higher concentration of pollutants to be discharged by rigs/platforms than by ships, which at least are able to disperse their discharges through the simple act of their movements and by making use of propellers.

Another source of pollution is offshore industry – quite a few rivers and streams feed the Adriatic, and in such, a closed sea not only delivers pollutants but presents oceanographers, marine biologists and other researchers with complications that impede the process of understanding the life of the Adriatic as well as the effects of the delivered pollutants. Fishing, too, especially commercial fishing, a necessary economic component to the Adriatic communal economy, both pollutes with oil and damages the marine environment through its use of bottom trawlers.

All in all, the Adriatic is a unique marine environment with highly sensitive microenvironments and such problems as an exceptionally shallow northern gulf where two of the main ports receive a large number of tankers, ro-ro and container vessels. The number of rivers that feed the Adriatic need not be a problem, but, to name one example, one of them is the Po, which is notorious for its deleterious effect on the sea. The point is, of course, the interaction between nature and commerce, and commerce of course runs primarily on oil. Advances have been made that have led to some reduction in oil pollution, but the net oil pollution combined with the threat of greater pollution remains a threat.

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References

1. Pavlakis P, Tarchi D, Sieber A (2001) On the monitoring of illicit vessel discharges using spaceborne SAR remote sensing - a reconnaissance study in the Mediterranean Sea. Ann Télécommun 56(11–12):700–718
2. Bernardini A, Ferraro G, Meyer-Roux S, Sieber A, Tarchi, D (2006) Atlante dell'inquinamento da idrocarburi nel Mare Adriatico. European Commission. EUR 21767 IT
3. Tarchi D, Bernardini A, Ferraro G, Meyer-Roux S, Muellenhoff O, Topouzelis K (2006) Satellite monitoring of illicit discharges from vessels in the seas around Italy 1999–2004. European Commission EUR 22190 EN
4. Ferraro G, Bernardini A, David M, Meyer-Roux S, Muellenhoff O, Perkovic M, Tarchi D, Topouzelis K (2007) Towards an operational use of space imagery for oil pollution monitoring in the Mediterranean Basin: a demonstration in the Adriatic Sea. Mar Pollut Bull 54 (4):403–422
5. Ferraro G, Meyer-Roux S, Muellenhoff O, Pavliha M, Svetak J, Tarchi D, Topouzelis K (2009) Long term monitoring of oil spills in European Seas. Int J Remote Sens 30(3):627–645

6. Ferraro G, Baschek B, de Montpellier G, Njoten O, Perkovic M, Vespe M (2010) On the SAR derived alert in the detection of oil spills according to the analysis of the EGEMP. Mar Pollut Bull 60(1):91–102
7. Vespe M, Ferraro G, Posada M, Greidanus H, Perkovic M (2011) Oil spill detection using COSMO-SkyMed over the Adriatic Sea: the operational potential. In: Proceedings of the conference IEEE international geoscience and remote sensing symposium IGARSS 2011, Vancouver, 24–27 July 2011, pp 4403–4406
8. Fingas M (2011) Oil spill science and technology, prevention, response, and cleanup. Elsevier, Burlington
9. GESAMP (2007) Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection. Estimates of oil entering the marine environment from sea-based activities. GESAMP Reports and Studies 2007
10. Franic Z (2005) Estimation of the Adriatic Sea water turnover time using allout 90Sr as a radioactive tracer. J Mar Syst 57:1–12
11. Poulain PM, Raichic F (2001) Forcings. In: Benoit CR, Gacic M, Poulain PM, Artegiani A (eds) Physical oceanography of the Adriatic Sea. Springer
12. Askari F, Signell RP, Chiggiato J, Doyle J (2003) RADARSAT mapping of BORA/SIROCCO winds in the Adriatic Sea, IEEE, pp 236–238
13. Ilijanic N, Miko S, Petrinec B, Franic Z (2014) Metal deposition in deep sediments from the Central and South Adriatic Sea. Geologica Croatica 67(3):185–205
14. Müllenhoff O, Bulgarelli B, Ferraro G, Perkovic M, Topouzelis K, Sammarini V (2008) Geospatial modelling of metocean and environmental ancillary data for the oil spill probability assessment in SAR images. In: Proceedings of SPIE 7110, Remote sensing for environmental monitoring, GIS applications, and geology VIII, 71100R, Cardiff, pp R1–R10
15. Statistical Office of the European Communities EUROSTAT, http://ec.europa.eu/eurostat/statistics-explained/index.php/Main_Page
16. European Sea Ports Organisation, Annual Reports, http://www.espo.be/
17. MarineTraffic, http://www.marinetraffic.com/
18. Vidas D (2006) Particularly sensitive sea areas: the need for regional cooperation in the Adriatic Sea. In: Katarina O, Institute of Public Finance Zagreb (eds) Croatian accession to the European Union. Vol. 4, The challenges of participation. Zagreb, pp 347–380
19. Domovic D (2005) Origin and sources of marine oil pollution. In: Medexpol 2005, Regional seminar on the use of remote sensing in oil pollution control, Nicosia
20. REMPEC, Alerts and accidents database. http://www.rempec.org/tools.asp?theIDS=2_71&theName=Tools&daChk=1
21. Pasfield B, Rindfleisch E (2010) Finding the magic pipe: do seamen have constitutional rights when a U.S. Coast Guard boarding turns criminal? USF Maritime Law J 22(1):23–38
22. Perkovic M, Greidanus H, Muellenhoff O, Ferraro G, Pavlakis P, Cosoli S, Harsch R (2010) Marine polluter identification: backtracking with the aid of satellite imaging. Fresenius Environ Bull 19(10b):2426–2432
23. Ferraro G, Pavliha M (2010) The international legal framework on monitoring and response to oil pollution. J Environ Monit 12:574–580
24. Chuna T (2016) European organization for economic cooperation and development. In: ADRIASPILLCON 2016, Third Adriatic conference on spill prevention, preparedness and response, Opatija, 10–12 May 2016, p 23
25. EMSA CleanSeaNet Service, http://www.emsa.europa.eu/operations/cleanseanet.html
26. PISCES II resource management simulator, Transas, http://www.transas.com/products/simulation/navigational-simulators/Oilspillsim
27. Navi-Harbour VTMS, Transas, http://www.transas.com/products/vtms/vessel-traffic-management-system/VTS
28. Müllenhoff O (2010) Remote sensing for operational pollution monitoring, source detection and identification. Frascati, Italy 14th/15th September 2010, p 17

29. Judd A, Hovland M (2007) Seabed fluid flow – impact on geology, biology and the marine environment. Cambridge University Press, Cambridge, p 400
30. Luyendyk B, Kennett J, Clark JF (2005) Hypothesis for increased atmospheric methane input from hydrocarbon seeps on exposed continental shelves during glacial low sea level. Mar Pet Geol 22:591–596
31. Donda F, Civile D, Forlin E, Volpi V, Zecchin M, Gordini E, Merson B, De Santis L (2013) The northernmost Adriatic Sea: a potential location for CO2 geological storage? Mar Pet Geol 42:148–159
32. Zatyagalova VV, Ivanov AY, Golubov BN (2007) Application of Envisat SAR imagery for mapping and estimation of natural oil seeps in the South Caspian Sea. In: Proceedings of Envisat Symposium 2007, Montreux, Switzerland, p 6
33. Gelettin R, Del Benw A, Busettin M, Ramellan R, Volpin V (2008) Gas seeps linked to salt structures in the Central Adriatic Sea. Basin Res 20:473–487
34. Kosces B (1984) Application of remote sensing methods to petroleum exploration in Northern Adriatic. In: Proceedings of the 27th International Geological Congress, vol 18, pp 91–113
35. EC JRC (2016) Mapping fishing activities (MFA), https://bluehub.jrc.ec.europa.eu/webgis_fish/
36. Motorship (2013) US calls time on low-level pollution, mandates Enviro-lubricants, http://www.motorshipcom/news101/ships-equipment/us-calls-time-on-low-level-pollution,-mandates-enviro-lubricants
37. Schmidt-Etkin D (2011) Spill occurrence: a world overview, oil spill science and technology, prevention, response, and cleanup. Elsevier
38. Schmidt-Etkin D, Worldwide analysis of in-port vessel operational lubricant discharges and leakages
39. EPA (2011) Environmentally acceptable lubricants. United States Environmental Protection Agency Office of Wastewater Management, EPA 800-R-11-002. Washington, p 27
40. Wollenhaupt G (2014) Vessel operators make the switch to environmentally acceptable lubricants, Professional Mariner. http://www.professionalmarinercom/April-2014/environmentally-acceptable-lubricants/

Oil Pollution in Slovenian Waters: The Threat to the Slovene Coast, Possible Negative Influences of Shipping on an Environment and Its Cultural Heritage

Marko Perkovic, Uros Hribar, and Rick Harsch

Abstract Slovenian waters and the Slovenian coast are situated within and along the Gulf of Trieste at the northernmost part of the Adriatic Sea. Despite the extremely small area concerned, this seascape is rich in cultural heritage ranging from pre-Hellenic hillforts to currently operating traditional saltpans, with cities built mainly in the Venetian style, a region with protected waters and coasts that is passed by a relatively large number of commercial vessels. The absence of a historic calamity here is perhaps a mere function of probability and size. But if that's been the luck of Slovenian waters, the risk is concomitantly greater with the rapid increase of traffic including dangerous cargos in ships plying in and very near this particularly sensitive shallow sea. And the fact is, accidents *have* occurred, the fragile ecosystem and rich heritage sites avoiding damage through sheer luck; yet they are increasingly under threat, at the mercy of elements man-made and natural that need only align malignantly for a catastrophe to occur. Case studies show recent events that might well be deemed near misses. Even minor instances of operational discharge represent a determined threat to the health of Slovenian seas.

Keywords Accidents at sea, Adriatic Sea, Heritage, Marine pollution, Ports, Remote sensing, Salt pans, Sensitivity, Shipping, Slovenian waters

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Contents

1 Introduction

The slightest glaze of oil or chemical pollution in the sea is by nature repellent [1]. This is worth pointing out because the human combination of science and industry has the species trapped in a situation in which the effects of pollution are measured not by visceral means, but mathematically, financially. Yet it is instructive to consider that the very use of oil as human tool derived from a series of virtual accidents, inventions that set, for one instance, propulsion, on an arbitrary but dogged course such that it has become a product inextricably intertwined with the profit motive to become a force acting against the elemental human environment, effectively devouring the natural, including the inherent human aversion to pollution, while perpetually threatening the anathema of economic destruction [2]. Small clusters of humans cling to a millennial heritage in the face of what at times must appear an absurd and inevitable onset of ruin.

The Slovenian coast is 46.6 km long with a significantly shallow sea area of only 180 km^2, along which are two functional salt pans, mussel farms, fish farms, and protected environmental areas[1] aside from these for the protection of flora, fauna, physical formations, archaeological sites, and three historic towns of predominantly Venetian architectural style (Fig. 1).

The coast is a collage of diverse heritage, including viticulture and olive groves, classic Mediterranean tourist features of modernity, and the trappings of a twenty-first century port city. Aside from large commercial vessels, innumerable pleasure and fishing boats ply the sea. Yet the profile is not discordant as might be suggested, for the flora is remarkably rich, the architecture largely pleasing, the overall space quite green, and the climate stubbornly Mediterranean, salubrious with sun and sea breezes.

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[1] There are five protected areas in the Slovenian coastal region: the Sečovlje Salina and Strunjan Nature Parks (two nature reserves—Stjuža and Strunjan—are within the Strunjan Park), the natural monuments Debeli rtič and Rt Madona and the Škocjan Inlet Natural Reserve [3].

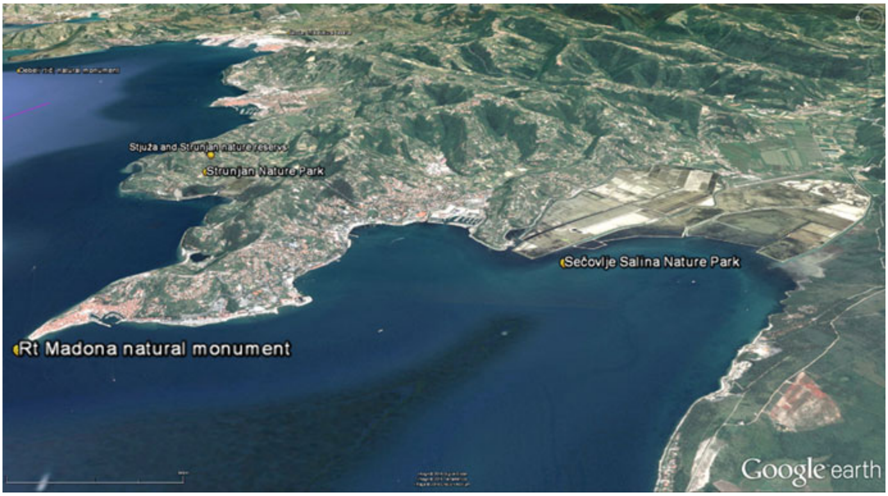

Fig. 1 Landscape of the Slovenian coastline, marine, and coastal protected areas. Map generated online at Google. Source of map data: Google, DigitalGlobe

Establishing the human context of the study of oil pollution in the Slovene waters of the northern Adriatic is necessitated by the absence of a catastrophic pollution event – we are left with the potential of pollution as our ‘measure’. Later in the chapter we will describe a pollution event off Istria in neighbouring Croatian waters (within the same Gulf of Venice wherein are all Slovene waters and the Gulf of Trieste) that had the potential to cause devastation to the largest salt pans in Slovenia.

Oil pollution anywhere on the Slovene coast would be a disaster beyond the reckoning of the costs of clean-up and economic loss, and that a likely time lag in the effect would be a psychological inevitability (for instance, tourists who would have heard of an accident affecting Slovenia would quite naturally direct themselves far from Istria). Therefore, in describing the Slovenian sea[2] and the threat of oil pollution, the ‘interaction’ between human and pollution informs the whole of the discussion.

2 Slovenian Waters and the Heritage of the Coastal Region

The Slovenian coast is irregular, with several bays and peninsulas, geo-morphologically quite diverse, with 80 m flysch cliffs of natural heritage value, to the sedimented lowlands at the heads of seven rivers and streams. The sea depth averages just 17 m, with a maximum depth of 37.5 m just off Piran

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[2] The Croatia–Slovenia sea border remains in dispute. International arbitration is ongoing.

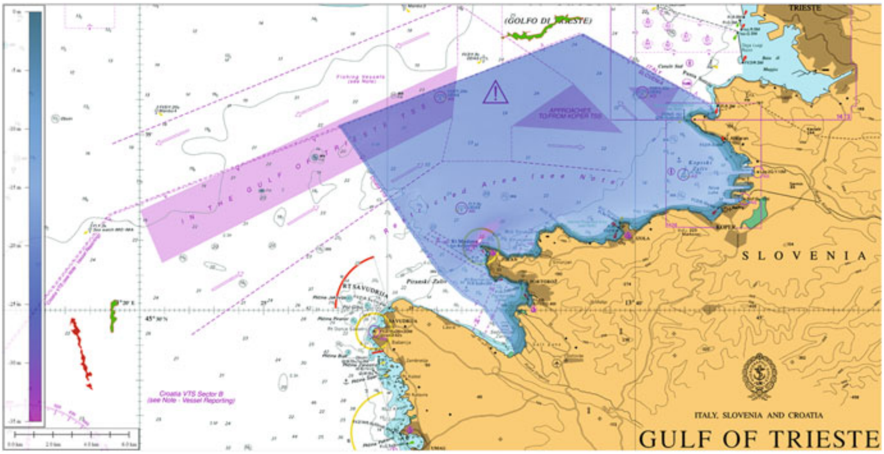


Fig. 2 Slovenian Sea (traffic lanes, depths, bottom types, etc.). Incidentally, one can see nearby three near certain oil slicks, two marked *green*, and one *red*. Source; map taken from UKHO, depth area adopted from Geodetic Institute of Slovenia, and operational pollution footprints inserted from *EMSA CSN* service

(an anomalous canyon that is, oddly, the deepest point in the Gulf of Trieste) (Fig. 2). The seabed along the entire coastline is largely sandy but for the bays, which tend to be muddy, silted, and a few steeper depressions that are rocky.

The relative isolation of the northern Adriatic – separated from the central and south by vast gyres and deep waters – compared to the rest of the Mediterranean, along with the characteristic of the proximity to the Alps and its watery headlands, has rendered it a unique and sensitive sea environment. One feature providing an example are the beds of sea grass found between Koper and Izola, the highly endangered *Posidonia oceanica* [4, 5]. Slovenian protected areas, which despite their relatively small sizes are quite unique, and where 'a plethora of ecological niches for a variety of benthic invertebrates and fishes' [4] are, given the nature of the small sea and relatively small Gulf of Trieste, effectively made smaller by the presence of two very active ports, in Koper and Trieste, that turn around a great number of large commercial vessels.

The Gulf is also subject to volatile hydro meteorological conditions. The most disturbing wind is the bora (burja), a katabatic wind predominantly from the northeast that can prevail for from a day up to weeks at a time [6, 7]. The more explosive and at times damaging wind is the tramontana, a summer storm wind that generally lasts from just a few minutes to a few hours (seldom does it last more than half an hour), but which can fell trees, spawn tornadoes, and wreak havoc on shipping. Figure 3 shows the results of a sudden – if brief – shift from a mild enough maestral (NW wind) to the near directly northern, violent tramontana. The orientation of the ships along the path of the winds changes suddenly, one ship in particular was dragged far enough she was forced to start her engine to gain control of the vessel

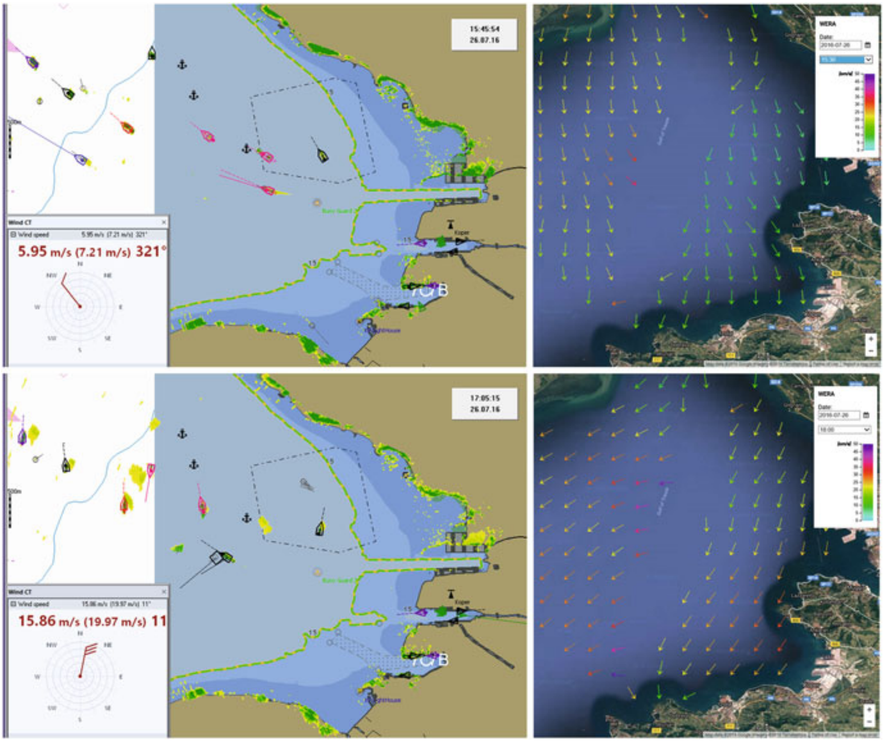


Fig. 3 Tramontana in the Gulf of Trieste on July 26, 2016. Orientation of vessels (*left*) before and after the storm; surface circulation before and after (*right*) measured by HF radar. Traffic figures taken from the Slovenian Maritime Administration; *HF Radar* data obtained from Marine Biological Station. Source of map data: Google, TeraMetrics

and reposition. The wind also changed the surface circulation as shown by the HF Radar measurements on the right sides of the figure.

Flooding in the northern Adriatic tends to occur during times of predominant southern winds and low pressure, generally from early autumn to midwinter. The jugo, or sirocco, a south-eastern wind, is most threatening when its perseverance raises the water level in the northern Adriatic up to a metre. This is complicated by the various other southerly winds, such as the libeccio, which is directed from the southwest, tends at times to be quite strong, and is, naturally, directed toward the Gulf of Trieste.

The currents in the area are generally counter-clockwise. The tides alternate in approximately 15 day periods between diurnal and semi-diurnal; strictly measured by tide, the water level varies generally by less than a metre, but can raise more at given times.

This brings us to one of the greatest concerns regarding potential oil spills. The westernmost part of the Slovene sea is just around Croatia’s Savudrija Peninsula, where in the Bay of Piran are the Secovlje Salt Pans at the alluvial plain of the

Fig. 4 Secovlje salt pans under normal conditions and while flooded. Photos taken by Sergio Gobbo (*upper*) and Uros Hribar

Drnica and Dragonja rivers. Much of the salt pans are actually below sea level. They are protected by embankments, but under a confluence of circumstances could easily be devastated: an already elevated sea, high tide, and strong winds from the southwest – all common occurrences – need only combine with an oil spill to destroy a millennia of heritage. Once oil breaks through the channels of the salt pans, the oil would be carried up to three kilometres inland. Figure 4 presents images of the Secovlje salt pans under normal conditions and while flooded.

Major oil pollution can seriously endanger maritime underwater heritage, which is already daily endangered by fishing trawlers and anchoring procedures. Currently there are 36 underwater areas with cultural remains registered at the Ministry of Culture of the Republic of Slovenia. Among them let us just point to the earliest known shipwreck, dating to the Roman period [8].

The severity of pollution is a function of the properties of the substance spilled, the quantity lost during an incident, and the consequential effects on the environment and human health. Hazard identification is necessary in order to identify all the potential or likely hazards concerning oil and/or chemical spills. Hazardous products can behave very differently under different environmental conditions and can have a variety of physical and chemical properties that yield a wide variety of scenarios [9]. Hazard analysis investigates the probability of shipping accidents and the probability of a spill. It would be expected that the number of accidents increases with the number of shipments carried out in a given area. Some coastal

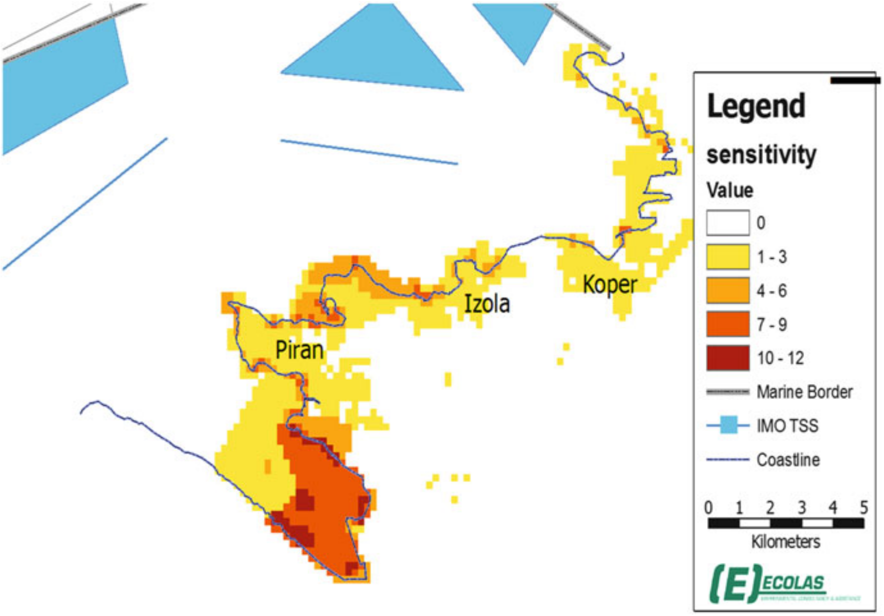


Fig. 5 Cumulative sensitivity scores of the Slovenian coastal area. Higher scores mean a higher relevance for protection [9]

areas are more sensitive to pollution incidents than others. Factors that determine the sensitivity are, for example, the type of coast, the presence of important natural resources, amenity values, or production activities. In planning the response to chemical spills, in-depth knowledge of the coastal sensitivities in the threatened area will make it possible to make optimum use of response resources. Figure 5 helps quantify the sensitivity of the Slovenian coast, which is at its most vulnerable in the Bay of Piran. This risk requires protection involving a high level of preparedness and capacity for response, both of which in turn require efficient cross-border cooperation. A successful combating operation of a marine pollution is dependent on a rapid response from the time the spill is reported to the time combating operations have been initiated [10].

A sub-regional contingency plan among Italy, Croatia, and Slovenia (Fig. 6) to address this need has been drawn up, presented to the Barcelona Convention and awaits final adoption [11]. Though Fig. 6 is rather straight-forward it is necessary to emphasise the importance of personnel training, without intensive execution the entire scheme collapses; for this reason Slovenia, for example, has established a modern simulation based oil spill crisis management centre that provides not only training but also doubles as an active centre for real emergencies (since its inception it has been used in cases from the Levant to the English Channel) [12].

In the process of cooperating toward activating the international sub-regional contingency plan, vessel traffic surveillance, metocean buoys, and high-frequency radar [13] have all been installed by stakeholders.

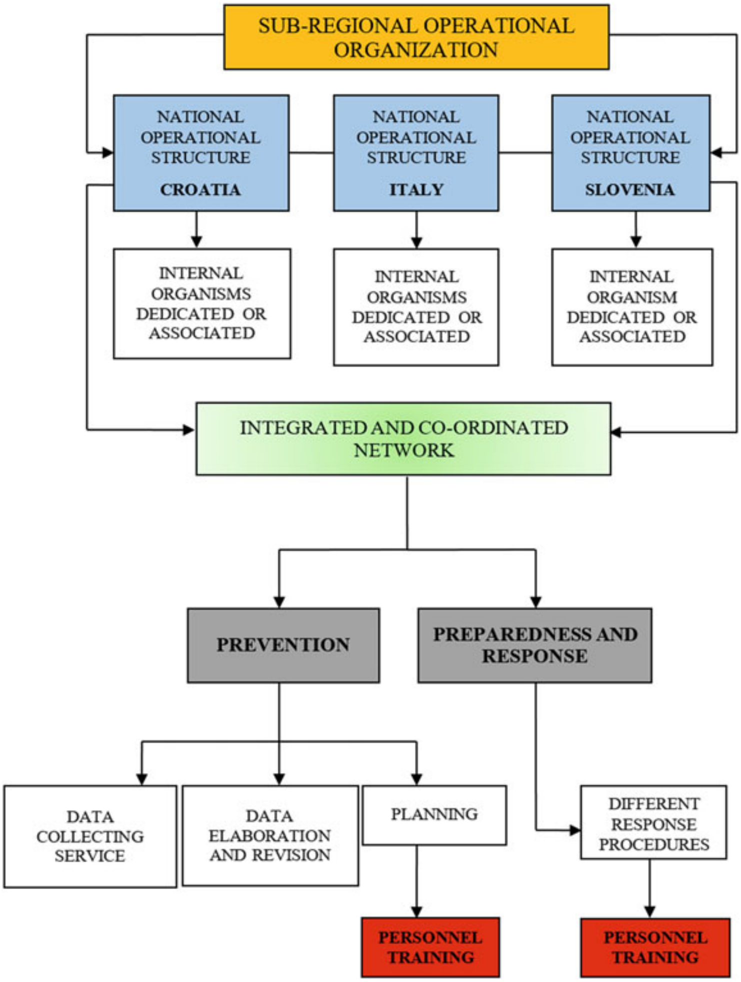


Fig. 6 Trans-border cooperation in case of prevention, preparedness, and response [11]

3 Northern Adriatic Sea Traffic

Figure 7 illustrates the shipping intensity/traffic density (obtained from AIS for the period of 15 days, July 15th–31st 2015), clockwise from upper left in the northern Adriatic: density in the Gulf of Venice; traffic distribution at the ‘entrance’ to the Gulf of Venice; density before and within the Port of Koper; and through the Slovenian waters of the Gulf of Trieste. Clearly the traffic is intense and variegated, converging on three main ports in the Gulf of Venice.

The irony – and challenge – is that despite a practically miniscule size, Slovene territorial waters host the majority of traffic in the Adriatic, considering the combination of the two ports, Koper and Trieste, and even the port of Monfalcone.

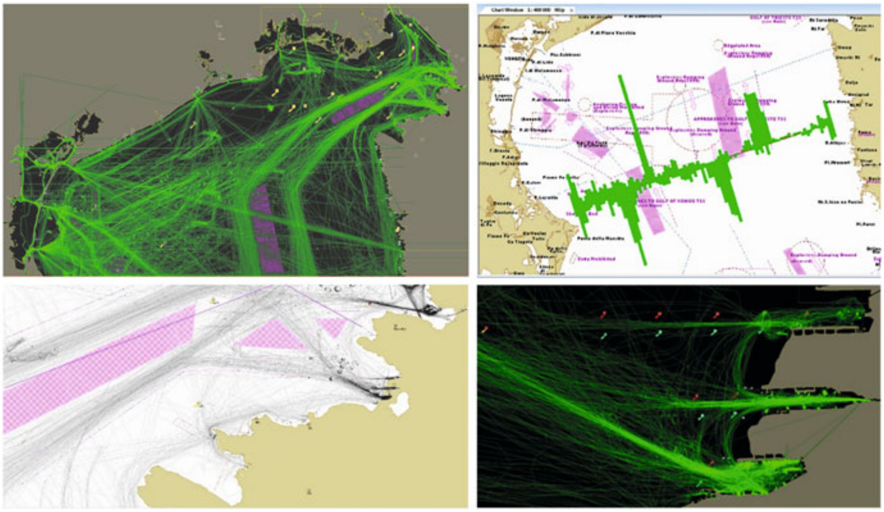


Fig. 7 Traffic density; July 15th–July 31st 2015 (generated with *Tran Viewer* software of Transas)

The amount of crude oil and its derivative products and liquid chemical cargos transported through Slovenian waters currently amounts to some 45 million tons per year and is increasing (total traffic exceeds 70 million tons – around 6,000 vessels – per year). The greatest increase has been and is likely to continue to be in the number and size of large ro-ro vessels, container ships and tankers, each bringing with them their own specific hazards.

Effects on Slovenian waters and the coastline are not limited to events in the Gulf of Venice, for the entire northern third of the Adriatic may be considered one systemic unit. Hence, the significance of the fact that from 1990 to 2013, the commercial marine traffic of NAPA ports (Koper, Trieste, Venice, Ravenna, and Rijeka), increased at an average of 7 % per year [14] with a total throughput cargo of 106 million tons in 2014 [15].

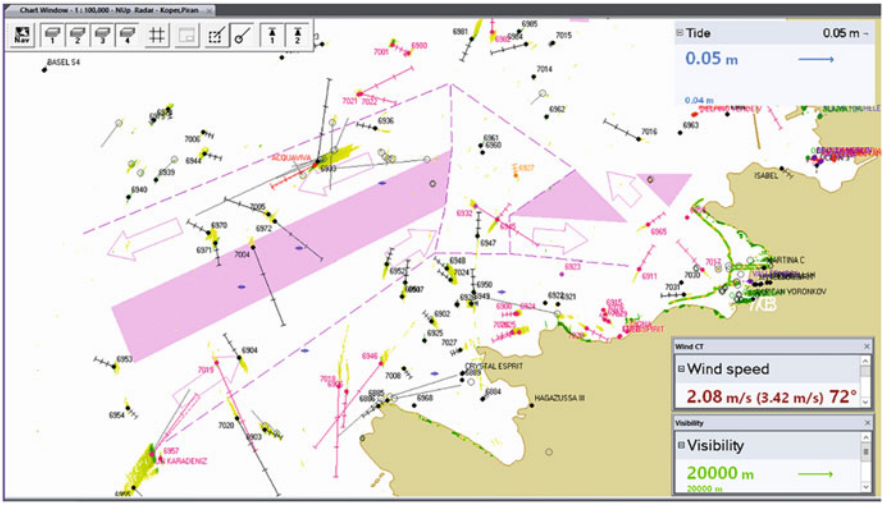
Figure 8 shows the magnitude of the growth of the cargo passing through Slovene waters, calling at the ports of Koper, Trieste, and Monfalcone. The port of Koper is a multi-purpose port that tranships different types of cargo, with three basins and two piers around which the terminals are arranged [16, 17].

In recent years (2010–2015) the cargo throughput in the port of Koper has averaged an annual growth of 8 % with container growth as much as 16 % yearly without an increase in the number of vessel calls (Fig. 8a). This growth was made possible by dredging activities and pier extension, allowing for the reception of larger vessels. Five years ago, the largest container vessel calling at the port of Koper was the Panamax size vessel, 292 m in length and 32.2 m abeam with a 11.4 m draft. Today mother vessels are calling at Koper. Trieste is the largest Italian port in the Adriatic. In 2015 the total volume of goods handled reached 57.1 million tons. It should be stressed that almost 41 million tons of this throughput went

Fig. 8 Cargo throughput for the Port of Koper, Trieste, and Monfalcone. (**a**) Port of Koper throughput [17]. (**b**) Port of Trieste throughput [18]. (**c**) Port of Monfalcone throughput [19]

through the oil terminal 'Siot' (the black line in Fig. 8b) [18]. The port of Monfalcone received 768 vessels in 2015 and discharged 3.8 million tons of cargo, while loading was close to 0.7 million tons (Fig. 8c) [19].

Figure 9 is a snapshot of traffic in Slovenian water at one moment in time.



Tide 0.05 m

0.05 m

Wind speed

2.08 m/s (3.42 m/s) 72°

Visibility

20000 m

Fig. 9 Traffic in Slovenian waters at one moment in time. Small boats and those close to the shore do not appear, but one gets an impression of the variety and complexity that the density of traffic presents. Data taken from the Vessel Traffic Monitoring System at the Slovenian Maritime Administration. Data visualised with *Navi Harbour* application by transas

4 Accidents in the Northern Adriatic

With increasing density of traffic, increasing ship sizes, increasing numbers of pleasure crafts, the risk of accidents inevitably increases – yet the number of serious accidents, and even overall accidents, at least outside ports, has been decreasing. This may be attributed to advances in such technical solutions as VTS, modern navigational systems aboard ships, and perhaps most importantly a series of measures taken to avoid explosions on board tankers.

Eight explosions/serious fires occurred on vessels in or very near the Gulf of Venice, six of them tankers, from 1985 through 2008 [20, 21]. Oddly, none of these resulted in appreciable pollution. Over roughly the same period, six collisions occurred, four resulting in pollution. Of four groundings during this period, two caused significant pollution (see Table 1 for accidents with notable pollution in Slovenian waters). According to the EMSA report on marine casualties and incidents in 2015, 98 instances were reported in the northern Adriatic (34 were recorded in 2014) [22].

The quiet conflict is between the technologies of safety and those of scale. From an examination of the rather brief period from the mid-1980s to the present, it appears that the mechanisms of safety have been making headway. Nonetheless, a reduction in the number of major accidents does not indicate a great deal lesser likelihood of a larger accidental spill that could have disastrous effects on the vulnerable Slovene coastal environment.

Table 1 Accidental pollution exceeding 1 m^3, other pollutions and major accidents in Slovenian waters [10, 11]

Year	Location	Vessel name	Quantity of oil	Type of oil	Comment
1953–1958	Izola	*Rex*	Unknown	Bunker oil	Wreck from WWII, scrapping
1973	Savudrija	*Nonno Ugo*	Unknown	Bunker oil	Grounded in heavy weather
1983	Izola Shipyard	*Ledenice*	90 m^3	Bunker oil	Heavy weather, collision with mooring dolphin
1983	Bele skale	Danish cargo vessel			Grounding
1990	Bay of Koper	Mystery Spill	>10 m^3	Sludge or Bunker	Oil spread from beyond Slovene waters in Gulf of Trieste
1999	Slovenian waters	n/a		Debris	After heavy rain enormous amounts of debris drifted from a flooded hinterland; the port of Koper was forced to close
2001	Izola Shipyard	*Atlantic Star*			Firefighting on-board the ship (3 days)
2005	Port of Koper; Basin I	*Blue Moon* or *MSC Anastasia*	1–5 m^3	Sludge or Bunker	Could not find responsible vessel, cleaning cost over one million euros
2006	Bay of Koper	*Guo Dian 6*			Grounding
2010	Port of Koper; Basin I	*UASC Madinah*/*Thomson Spirit*			Collision
2011	Slovenian waters	*Palamida*			Collision, fishing boat capsized, fisherman found alive 6 h later
2014	Port of Koper; Basin II	*Harmony* or *CS Caprice*	1–3 m^3	Sludge or Bunker	Could not determine the responsible vessel

Illustrations, particularly photos, alert one to the immediacy of the threat of pollution. Figure 10 provides a range of such examples. *Photo (a)* from Fig. 10 shows the passenger ship *Rex*, destroyed by allied bombs during WWII. The sheer size of the vessel, appearing almost to dwarf the coast, indicates the size of the problem – during the 5 years of scrapping the wreck oil leaked frequently, at times the pollution spreading along virtually the entire Slovenian coast. *Photo (b)* illustrates a rather typical case of grounding, the tanker *Nonno Ugo* having just embarked from Trieste that has been more or less shoved by a bora against the coast of Savudrija. The case is a good example of how simple and sensible rules may prevent accidents, for in 1973 no laws spelled out the minimum distance

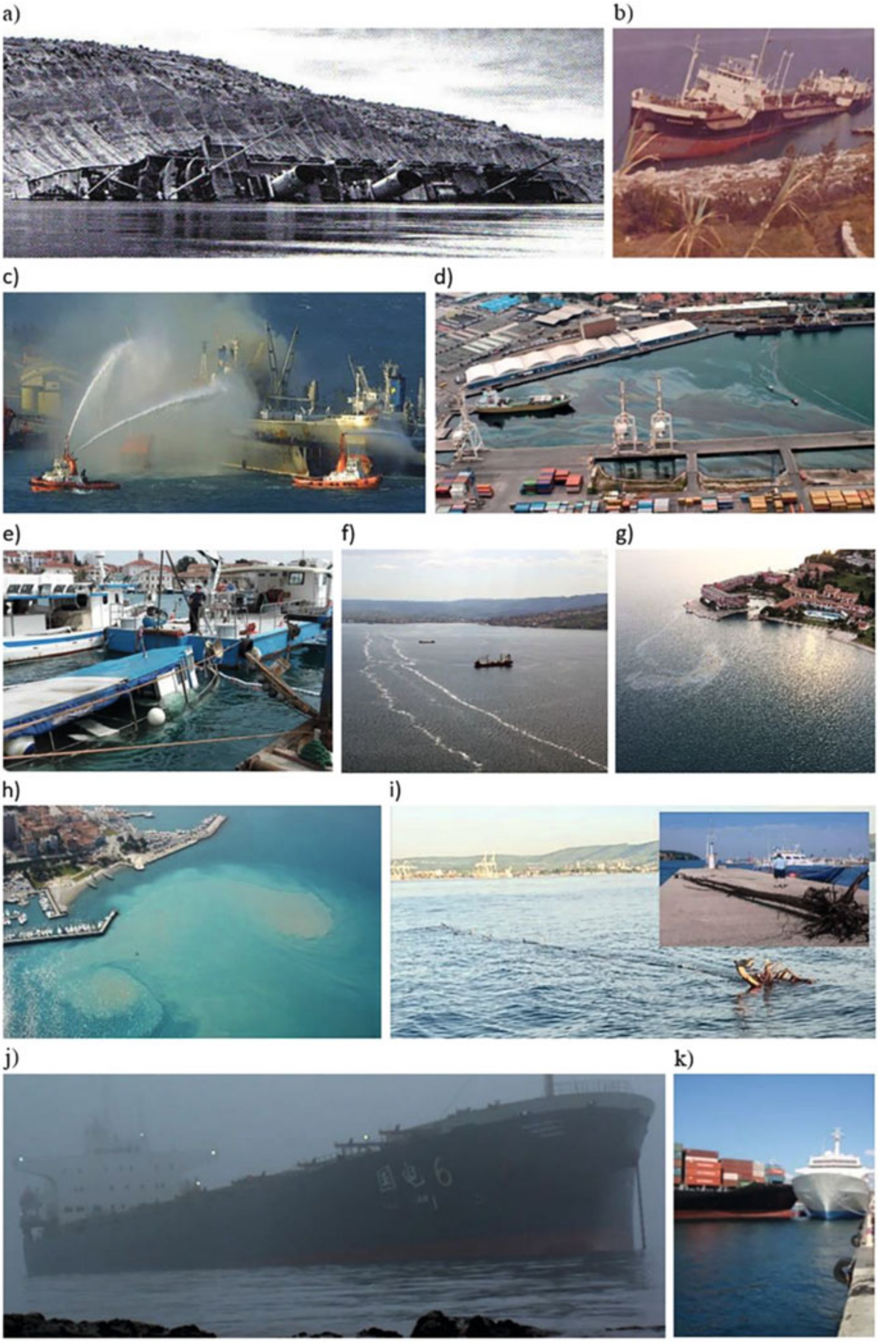


Fig. 10 A series of photos illustrating a variety of instances of pollution and other hazards in Slovenian waters. Photos adopted from port of Koper, *paluba.info*, Benjamin Licer and [23]

commercial vessels, particularly tankers, needed to maintain from shore, nor the optimal route. This ship chose the shortest path, which would only have made sense in a sea undisturbed by weather and, say, traffic – finally, nearly 20 years after that accident a Traffic Separation Scheme was implemented. *Photo (c)* helps one understand the common saying ‘Ships like to burn’. While berthed at the shipyard in Izola a fire broke out that, though the ship was easily accessed, took 3 days to put out. *Photo (d)* is an unfortunate illustration of the effects of a spill that is insignificant enough that it does not make international headlines, yet has an enormous local impact. The clean-up cost over one million euros and a combination of rapid response and good fortune was all that prevented an inundation of nearby beaches; further, given a lack of heavy weather, the town itself, which could have been endangered, was not. In this case, the primary problem was that the polluter did not report the accident, which occurred during the night. Crowded marinas, mainly in Izola and Portorož, make for a scenario in which small plastic boats often burn and/or sink, as in *Photo (e)*, a case that invariably would end in enough pollution to require a professional response and salvage. *Photo (f)* shows the tracks of an unknown substance, not so uncommon an occurrence; and if one cannot determine the substance from the photo, one can at least conclude that whatever it is, it should not be in the sea. A different footprint is often left by coal barges distributing coal from Koper, which has sufficient depth to receive bulk carriers, to small regional ports in the near vicinity that are too shallow – winds whip the coal dust into the air and it scatters onto the sea where it appears with the signature rainbow of oil pollution, for which it is often mistaken. Even a sailing boat, free of accident, can cause visible pollution (*Photo g*). The port of Koper may be deep enough for bulk carriers, but as ships increase in size, more often and to greater extent do their manoeuvrings disturb the sediment (*Photo h*), which is mistaken for pollution from, for instance, nearby hills – and which indeed may be problematic at times, leading to various residues (the seabed of Trieste Bay is highly contaminated with mercury) entering the system of currents and spreading beyond the bay. Lest absolutely all pollution be assigned to man, here is included a natural case – trees, for instance (unfortunately among a great deal of human-made garbage), are washed from inland, delivered by flooded rivers to the sea, posing a real hazard to smaller boats.

Photo (j) captures a 220 m fully loaded Chinese bulk carrier that grounded in heavy fog/low visibility, representing an extremely lucky accident that caused harm neither to the environment nor the ship. The circumstances of the accident are as unclear as the weather, for the ship despite repeated warnings from the port simply drove at a somewhat reduced speed, straight into the mud near shore – it was the mud itself that saved the situation: any penetration of the double hull would likely have caused devastating pollution. This was the third grounding along the Slovene coast in 33 years, for aside from the *Nonno Ugo* in 1973, in 1983 an 80 m Danish cargo vessel grounded in Bele skale between Izola and the Strunjan nature park, somehow without any spillage. So Slovenia has been rather lucky in its groundings. More lucky, and considerably more dangerous, was the collision seen in *photo (k)*, where one sees the moment of impact: a container vessel ramming a passenger ship in the basin of the port of Koper, having made the mistake of actually entering the basin at 7 knots – reversing of the main engine failed, but a pulling stern tug managed to reduce the impact speed.

Unfortunately, a few navigation related accidents have been fatal. During the last few decades at least six people have died: on two occasions pleasure crafts hit swimmers; two fishermen were lost at sea; and two smugglers died at sea in some unknown manner. On the other hand, in 2011, a Turkish ro-ro hit a fishing boat collided with a fishing boat and didn't notice, yet the lone fisherman was found alive few hours later.

5 Pollution, Figures, and Case Studies

Maritime pollution is a variegated and complex subject that includes several vectors. The following graphics illustrate to a degree the circumstances of pollution in Slovenian water in general and in the immediate area of the port.

Figure 11 is a time series schemata, in cases, of pollution in Slovenian water exclusive of the port, showing that generally oil pollution is about a third of the total. The most trustworthy figures are those of the last 10 years or so, during which time observation, reporting, identifying, and classifying methods have all improved – and if these figures are indeed more reliable, the amount of pollution is decreasing significantly. Pollutants other than oil tend to be ship-borne, such as coal dust (from ships outside the port and in transit), and, for instance, debris from the hinterland that often includes human-made products that have degenerated into garbage. Most notably, assuming that the figures from the late 1970s and over the next decade or so

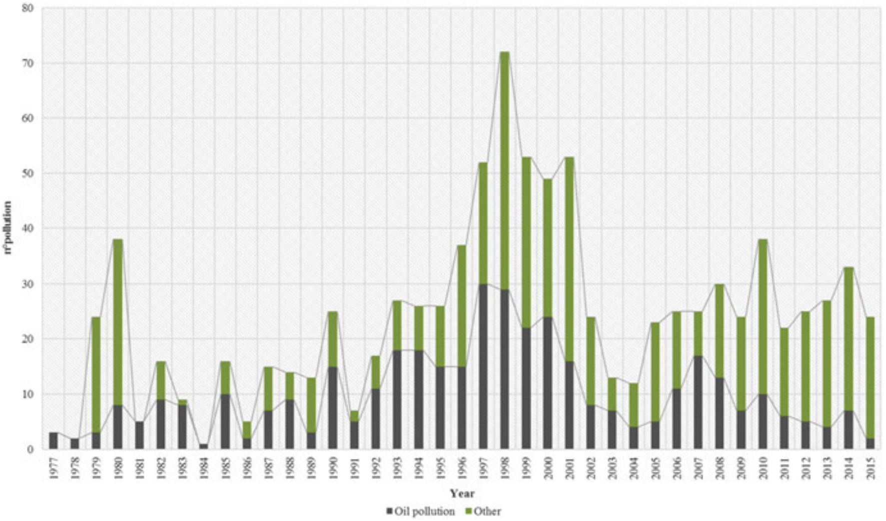


Fig. 11 Pollution – number of cases – in Slovenian waters (outside port area). Data adopted from Slovenian Maritime Administration and Slovenian Environment Agency

Table 2 Type and number of cases of pollution in the Port of Koper area

Year	Coal dust	Oil	Riverine debris	Rižana river	Soot (funnel/ scrubber)	Other	Sum	Intervention at sea
2007	32	12	7	0	1	5	57	50
2008	20	22	1	0	2	1	46	40
2009	2	18	6	8	1	0	35	27
2010	3	10	3	1	0	3	20	15
2011	7	12	0	1	0	0	20	19
2012	10	3	1	4	0	1	19	18
2013	6	4	0	1	1	0	12	12
2014	11	6	3	0	0	5	25	22
2015	10	6	0	3	1	3	23	23
Sum	101	93	21	18	6	18	257	226

Data adopted from Port of Koper

reflect fewer hours of observation and inferior methodology in general, there is an evident decline in oil pollution.

Table 2 presents minor and common enough instances of port pollution, figures for the port of Koper. As can be seen, coal dust appears again, this time in a more specific quantified manner. Oil is the second most frequent pollutant, though the table does not indicate the amount, nor the cost of damages. In all likelihood, most of the oil spilled is a result of operational pollution. Again, a decrease over the past decade or so gives rise to some optimism.

5.1 *Operational Pollution in the Northern Adriatic Sea*

Operational pollution is a sort of wild card when it comes to both reckoning with extant pollution and attempting to prevent oil spillage, as it is done by intention by humans and may happen anywhere at any time where a vessel happens to be. The EMSA approach to the problem and the development of CleanSeaNet [24] has led to enhanced monitoring and surveillance, warning systems, and some violators have actually been apprehended. The red marks in Fig. 12 are likely oil spills, mostly operational and discharges *en route* as can be seen from the predominance of red within main shipping lanes, but also includes spills from offshore installations.

No single spill is within Slovenian territorial waters – three are quite close – but many are close enough to present some risk, and most alarming is the long, wide line stretching parallel to Istria from around the latitude of Pula to the Limski kanal, which represents oil that is available and susceptible to common conditions that could deliver pollution to the Slovenian coast. This point is underscored by the

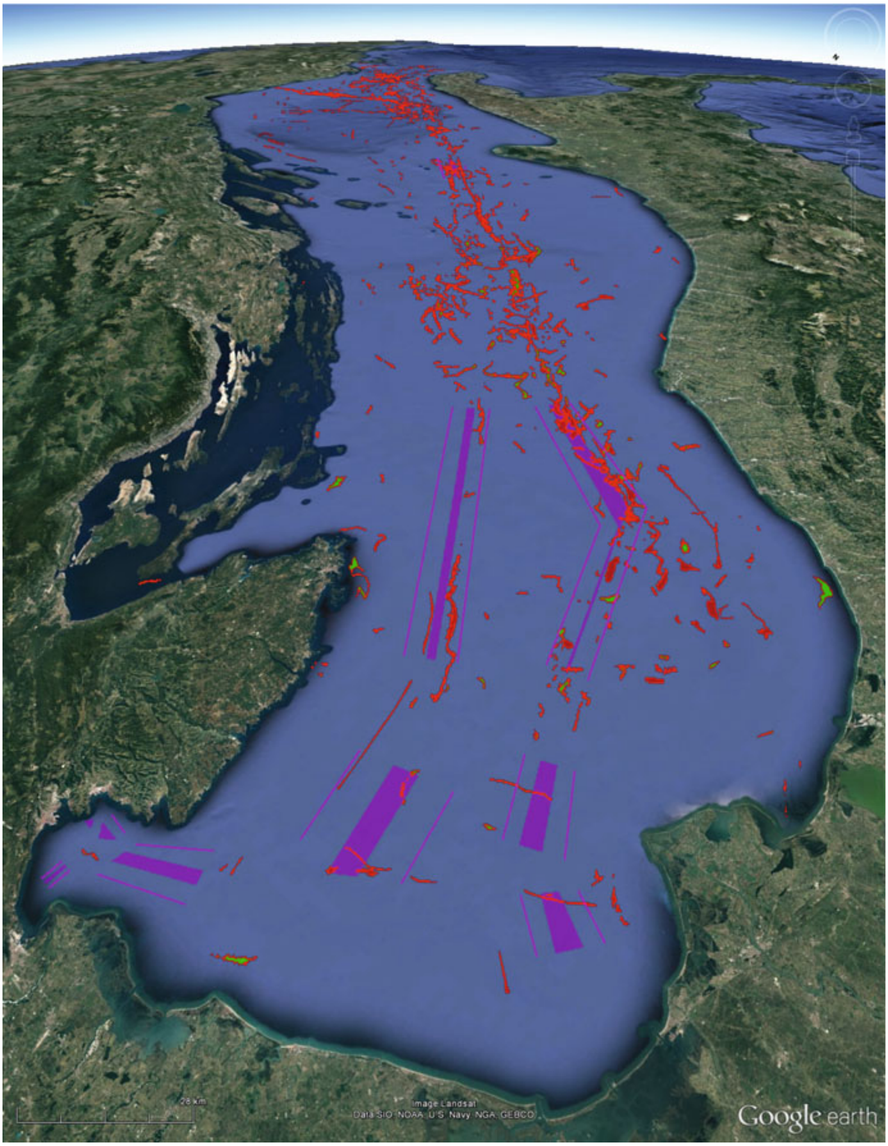
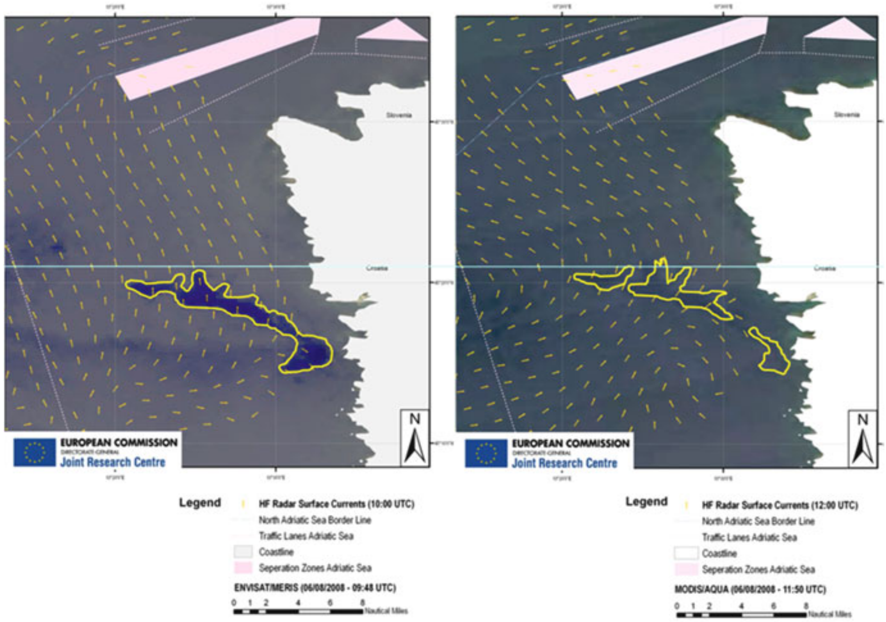


Fig. 12 Possible oil spills in relation to traffic separation schemes in the Adriatic (2011–2016). Source: Authors adopted from [24], Source of map data: Google, Landsat

following case study describing a near miss for Slovenia's Secovlja salt pans, in which operational discharge was discovered during the summer of 2008 along the Istrian coast and tar balls actually beached in the bay of Piran.



(ESA) ENVISAT/MERIS
09:48

(NASA) MODIS/AQUA
11:50

Fig. 13 Oil slick position and *HF Radar* currents [25]

5.2 *Case Study: Operational Pollution ‘Istria’*

In the early morning on August 6, 2008, oil was seen by fishermen approximately three nautical miles off the Croatian coast between Porec and Novigrad. Later, at 09:45 local time, the port authority vessel confirmed the oil slick and determined the size to be 2 NM in length and half a mile in width. An oil combating vessel was immediately deployed and began to collect the oil, which meanwhile had already coagulated into tar balls – so an easy procedure of collecting was reported and no threat to the coastline was foreseen due to expected northeast winds, which it was assumed would keep the oil away from the Istrian coast (Fig. 13).

The case was not considered a threat to the coast, so no crisis team was activated and neighbouring states (Italy and Slovenia) were not informed. The plan was to collect the oil without raising any alarms during the midst of the most intense period of the tourist season. That such a scenario in this instance might not be so simple was first discovered by a group of Slovenian dolphin researchers from the ‘*Morigenous*’ who were sailing around noon from Porec toward Novigrad. On the way they crossed three large oil strips (separated from each other by some 500–1,000 m). Each was of some 50 m in width, the lengths undetermined though clearly oriented from WNW to ESE. The oil was dark brown to black adhesive and highly viscous [25].

Figure 13 shows satellite images (Meris and Modis/Aqua) 2 h apart with corresponding currents acquired by high-frequency (HF) radars. It is evident that the slick moved according to the HF detected currents. At that time HF radars were deployed (temporarily for research purposes) along the Italian and Croatian coastlines.

Two days later, after a particularly violent storm, oil was found to have beached some 10 miles further north [25].

Figure 14 is a composition of a detected slick area, currents, and wind field, AIS archive tracks for the previous 2 days as well as hindcast and progressive simulation. The detected pollution layout acquired via the Modis Aqua platform around midday is located in the middle of the figure, which presents the different parts of the slick at 12:00 GMT on the sixth and the final position of part A after running a progressive simulation of Heavy Crude Oil with HF currents over 60 h using the PISCES simulation packages [26]. The final position corresponds to the moment just before a tramontana hit the area. The actual report from the early morning of 9 August disclosed 1 km of polluted beach around Savudrija cape. The nearby salt pans were clearly under threat, being in the Bay of Piran just around that cape. The winds preceding a tramontana are moving clockwise; therefore, gathering winds were gusting from the west and rotating toward the north. So the last frame of Fig. 13 shows the oil before it virtually wrapped around the cape. Had the tramontana occurred somewhat later, one among a variety of worse scenarios up to and including the catastrophic would have been inevitable – oil north of Cape Savudrija could quite easily have entered into the Bay of Piran and consequently the salt pans.

For future assessment purposes, one important result was the matching of the discovered pollution area with the progressive simulation based on HF currents, another positive validation of that measurement tool [13]. The same image also illustrates the results of backward simulation – to the origin of the released oil. At this point what can be summarised for this particular case is that this oil when moving backwards (the red print) orients toward a straight line located close to the traffic lane within the traffic separation scheme. The south-western ‘tail’ of the backtracked spill is not modeled correctly because it is on the edge of the available current field. Combining backtracking utility with AIS archives provides us some ratings of possible oil spill source identification. This rating is based only on ship passing distance and course relating to the slick orientation. From the polluter identification research aspect of this case, it is important to note that this was the first time HF radar currents data were used for progressive and hindcast simulation of an oil spill. It was proven that HF currents data used here enabled a very precise progressive simulation.

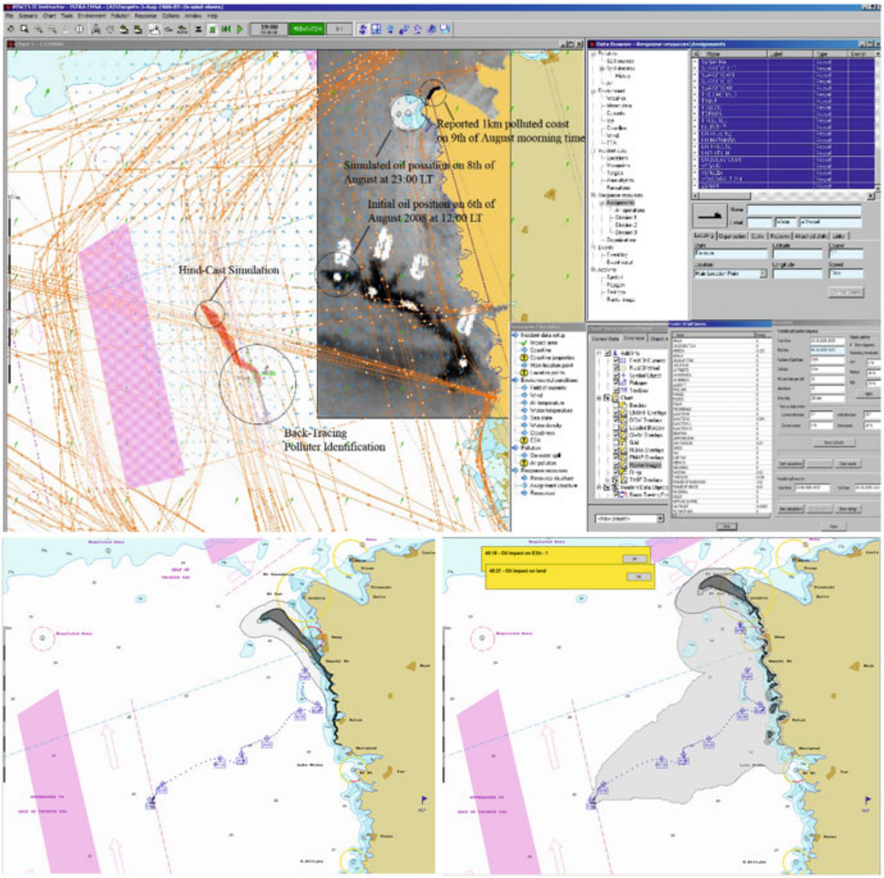
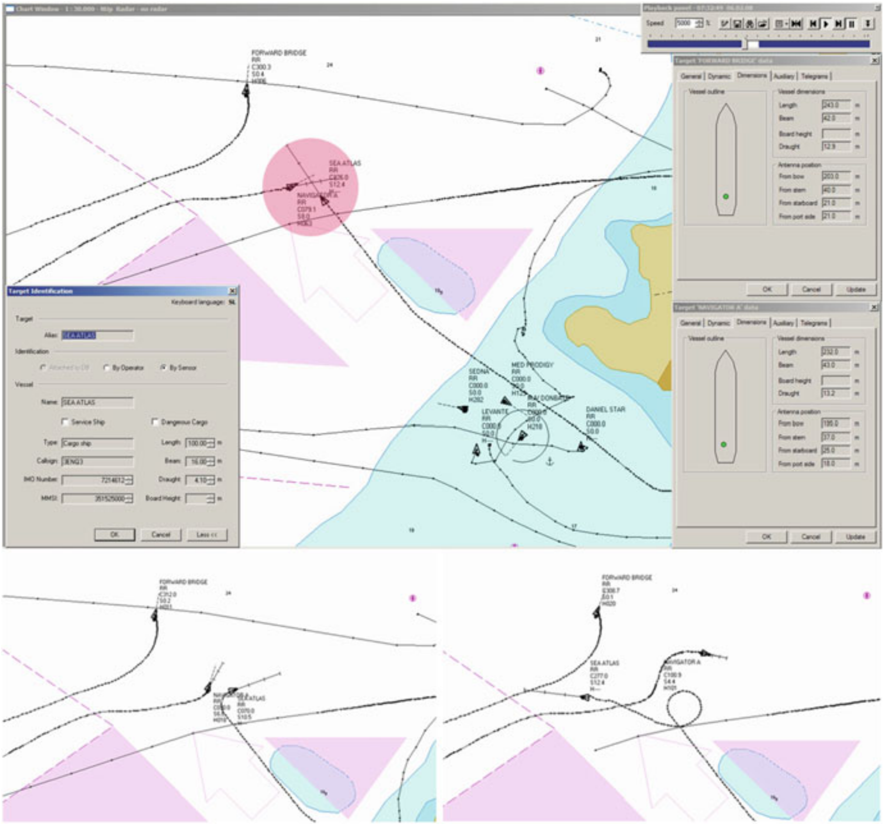


Fig. 14 Hindcast and progressive simulation based on currents measured by the *HF Radars* [25]

5.3 Case Study: Near Collision

In the morning on February 6, 2008 (at the same time the Und Adriyatik was burning just off the Istrian coast [27], creating an inadvertent diversion so that VTS operators on duty were likely focused on that event), two large crude oil tankers approached the Trieste anchorage at the same time that a cargo vessel departed from the port of Koper, heading directly toward their path at a near perfect right angle at a speed of 12.4 knots. The departing vessel had the right of way, and one of the two tankers appears to have made an evasive manoeuvre; but the nearer seems to have been oblivious to the cargo vessels approach. As a result, the departing vessel was forced to make an emergency avoiding turn, narrowly avoiding an accident which would have resulted in a spillage of a minimum 10,000 tons of crude oil in a position from where the spill could have effected virtually the entire Bay of Trieste.



Target Identification

Keyboard language: SL

Target

Alias: SEA ATLAS

Identification

○ Attached to DB ○ By Operator ● By Sensor

Vessel

Name: SEA ATLAS

☐ Service Ship ☐ Dangerous Cargo

Type: Cargo ship Length: 100.00 m

Callsign: 3ENG3 Beam: 16.00 m

IMO Number: 7214612 Draught: 4.10 m

MMSI: 351525000 Board Height: m

Target 'FORWARD BRIDGE' data

Vessel dimensions: Length 243.0 m; Beam 42.0 m; Board height m; Draught 12.9 m

Antenna position: From bow 203.0 m; From stern 40.0 m; From starboard 21.0 m; From port side 21.0 m

Target 'NAVIGATOR A' data

Vessel dimensions: Length 232.0 m; Beam 43.0 m; Board height m; Draught 13.2 m

Antenna position: From bow 195.0 m; From stern 37.0 m; From starboard 25.0 m; From port side 18.0 m

Fig. 15 Near collision; Trieste Bay 2008/02/06 07:35 LT. Data obtained from Slovenian VTS. Data analysed with *Navi Harbour* of Transas

In Fig. 15 one can see that the accident would have occurred just around 2 NM from the nature preserve Debeli Rtic.

Following are the simulated results of the spillage of 10,000 tons of Arabian medium crude oil based on the HF currents described in Fig. 3, a scenario narrowly avoided on February 6, 2008, and one that poses a perpetual risk to the Gulf of Trieste, including the Slovenian are of the sea. Space/time development of the case is presented in Fig. 16, while more precise weathering parameters can be obtained from Fig. 17.

The snapshots present the extent of the oil at sea every 60 min. The duration of leakage from the damaged tanker was chosen to be 1 h. The initial spill rate began at 8,000 kg/s and linearly decreased to 1,550 kg/s for the first 30 min and in the second half hour gradually came to a stop. Seven hours after the collision the oil at sea will reach the coast of 'Bele Skale', Piran with most undispersed oil beaching near Izola. The last sequence presents the situation after 9 h. At this moment 54.3 tons of oil is

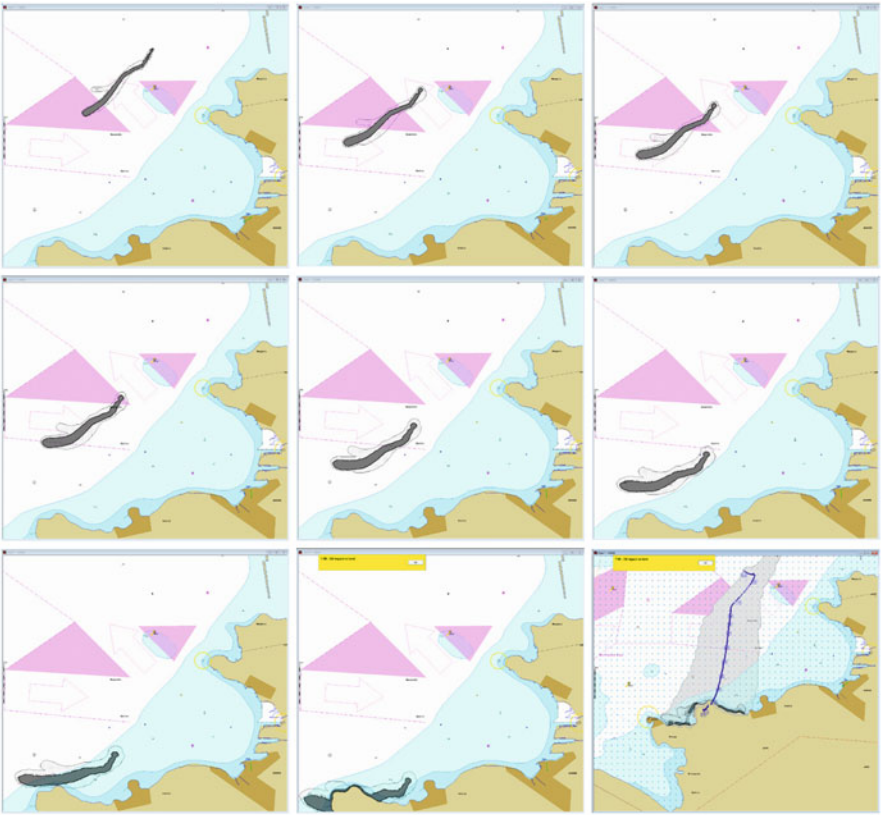


Fig. 16 Space-time development of oil spilled. Simulated using Transas *PISCES 2* software

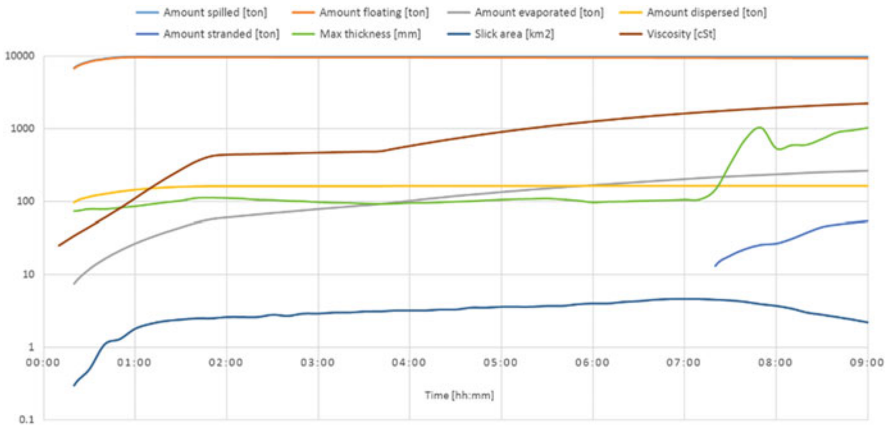


Fig. 17 Oil spill transport, spreading and weathering process. Simulated using Transas *PISCES 2* software

already stranded, polluting 6.097 m of the mostly rocky coastline, contaminating a mussel farm, salt fields, and other protected area of the Strunjan nature park.

At this point, considering the boundary conditions set for this case study it must be stressed that the existing structure and available resources cannot prevent beaching of the oil – it is hard to believe that one could respond and reach the location within 3 h after the accident and at this point the oil at sea will already have spread over an area of 3 km^2.

6 Conclusion

Nature has remarkable abilities to recover from oil pollution. There are plants (mangrove trees) that when coated with oil go into a sort of dumb emergency mode, sending out through the oil pimply projections seeking 'contact' with the sun by which means they prevent their death. In high seas, the volume of water itself is of most value, diluting the oil. But in a shallow enclosed sea like that of the Gulf of Trieste, where all Slovenian waters are located, a natural recovery from a catastrophic spill would only occur after an extremely long dormant period.

As no such event has yet occurred, the nature of the paper is primarily that of a warning – but as illustrated by the spill that polluted Savudrija, the operational pollution, the several lucky groundings, etc., the risk of such an event is high enough; and as suggested by the descriptions of the inestimable heritage value of the Slovene coast, the cost impossible to measure.

Tools are available to mitigate against the threat. Traffic Separation Schemes, Vessel Traffic Services, advances in the science of backtracking spills, oil spill response regimes, advances in communications between countries (the sub-regional contingency plan must be formalised); but as more and larger ships powered by petroleum derivatives continue to make their way to the north-eastern Adriatic Sea, the Slovene Sea will remain at high risk.

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References

1. Harsch R (2016) Personal communication with Terry O'Reilly, geologist, numerous conversations initiated by Mr. O'Reilly's reaction to daily observations of oil on water in the mandrač of Izola, Slovenia
2. Jacques E (1964) The Technological Society. Vintage Books, New York, NY
3. Vidmar B, Turk R (2011) Marine protected areas in Slovenia: how far are we from the 2012/2020 target? Varstvo Narave, Supl. 1 pp 159–170. http://www.zrsvn.si/dokumenti/63/2/2011/Vidmar_Turk_2538.pdf. Accessed Aug 2016

4. International Maritime Organization (2009) Identification and protection of special areas and particularly sensitive sea areas; designation of the Adriatic Sea as a particularly sensitive sea area, Marine Environment Protection Committee 59/8/X pp 1–47
5. United Nations Environment Programme Mediterranean Action Plan (2015) Adriatic Sea: ecology (draft report), Twelfth meeting of focal points for specially protected areas, UNEP (DEPI)/MED WG.408/Inf.14 pp 1–84. http://www.rac-spa.org/nfp12/documents/information/wg.408_inf14_eng.pdf. Accessed Aug 2016
6. Crise A, Querin S, Malacic V (2006) A strong bora event in the Gulf of Trieste: a numerical study of wind driven circulation in stratified conditions with a preoperational model. Acta Adriat 47 (Supp.): 185–206
7. Malacic V, Petelin B, Vodopivec M (2012) Topographic control of wind-driven circulation in the Northern ADRIATIC. J Geophys Res 117:1–16
8. Eric M, Poglajen S (2014) Seriously endangered maritime underwater heritage in Slovenia. In: Borker C (ed) Fourth International Congress on Underwater Archaeology (IKUWA 4), German Society for the Promotion of Underwater Archeology, Zadar, Croatia, 29 September–2 October, pp 27–35
9. ECOLAS NV (2004) National Oil and Chemical Spill Contingency Plan for Slovenia (NOCSCP): risk assessment. Co-operation Project Slovenia – Flemish Government (SLO/002/03), Antwerpen – Portoroz, pp 1–72
10. URSZR, Emergency Response Plan in the Event of Accidents at Sea (2003) RS ministry of defence, RS administration for civil protection and disaster relief, pp 1–40
11. Sub-Regional Contingency Plan for Prevention of, Preparedness for and Response to Major Marine Pollution Incidents in The Adriatic Sea (2005), Portoroz 9th Nov, pp 1–44
12. Perkovic M, Suban V, Petelin S, David M (2006) Using a navigation simulator to combat oil spills more effectively, INSLC – 14th International Navigation Simulator Lecturer's Conference of IMLA – International Maritime Lecturers Association, Genoa
13. Cosoli S, Licer M, Vodopivec M, Malacic V (2009) Surface circulation in the Gulf of Trieste (northern Adriatic Sea) from radar, model, and ADCP comparisons. J Geophys Res Oceans 118(C7):6183–6200
14. Twrdy E, Batista M (2016) Modelling of container throughput in northern Adriatic ports over the period 1990–2013. J Transp Geogr 52:131–142
15. NAPA (2014) Comparison of European ports: total throughput of cargo in million of tonnes, http://www.portsofnapa.com/about-napa. Accessed Aug 2016
16. Perkovic M, Brcko T, Luin B, Vidmar P (2016) Ship handling challenges when vessels are outgrowing ports. In 19th International Navigation Simulator Lecturers' Conference – INSLC 19, The South African Maritime Training Academy (SAMTRA), Cape Town
17. Perkovic M, Twrdy E, Batista M, Gucma L (2013) Container transport capacity at the Port of Koper. In: Weintrit A, Neumann T (eds) Marine navigation and safety of sea transportation: maritime transport & shipping. CRC Press, Leiden, pp 207–213. doi:10.1201/b14960-36
18. Info Data (2016) Traffico merci nei porti italiani. +3,7% le tonnellate movimentate, container a −0,5%, http://www.infodata.ilsole24ore.com/2016/02/17/traffico-merci-nei-porti-italiani-37-le-tonnellate-movimentate-container-a-05/?refresh_ce=1. Accessed Aug 2016
19. Porto di Monfalcone (2016) Port activity, http://www.porto.monfalcone.gorizia.it/eng/traffic.asp. Accessed Aug 2016
20. Domovic D (2005) Origin and sources of marine oil pollution. Medexpol 2005, regional seminar on the use of remote sensing in oil pollution control. Nicosia
21. REMPEC. Alerts and accidents database, http://www.rempec.org/tools.asp?theIDS=2_71&theName=Tools&daChk=1. Accessed Aug 2016
22. EMSA (2015) Annual overview of marine casualties and incidents 2015, http://www.emsa.europa.eu/news-a-press-centre/external-news/download/3833/2551/23.html. Accessed Aug 2016
23. Suligoj B (2010) Rešena ladja jutri na pot? Delo, http://www.delo.si/novice/slovenija/resena-ladja-jutri-na-pot.html. Accessed Aug 2016

24. EMSA CleanSeaNet Service, http://www.emsa.europa.eu/operations/cleanseanet.html. Accessed Aug 2016
25. Perkovič M, Harsch R, Muellenhoff O, Ferraro G, Cosoli S, Delgado L, Hribar U (2009) Maritime transport in the Gulf of Trieste – a threat to Sečovlje saltpans? In: Žitko D (ed) Saltpans: cultural landscape in danger, (Annales Mediterranea). Piran, Institute for Mediterranean Heritage, University of Primorska, Science and Research Centre, pp 47–56
26. PISCES II resource management simulator, Transas, http://www.transas.com/products/simulation/navigational-simulators/Oilspillsim. Accessed Aug 2016
27. Perkovič M, Harsch R, Suban V, Vidmar P, Nemec D, Muellenhoff O, Delgado L (2008) The use of integrated maritime simulation for education in real time. V: Safety, security and quality objectives of MET institutions: proceedings. Izmir: Dukuz Eylul University, pp 461–478

Mapping of Oil Slicks in the Adriatic Sea: Croatia Case Study

Mira Morović, Andrei Ivanov, and Marinko Oluić

Abstract Spaceborne synthetic aperture radars (SAR) are used as major instruments for operational oil spill detection and monitoring, and for this reason attract significant research interest. A large number of SAR images acquired and collected over the Adriatic Sea provided high number of oil slicks to be analysed. These slicks may come from different sources, from natural to anthropogenic, accidental or deliberate. Given are examples of oil slicks detected on the images of the Envisat and Radarsat-1 satellites in the period 2003–2016. The SAR images were obtained mainly through research projects from ESA and other sources. The images were processed via ESA software and integrated using Geo-Mixer by SCANEX RDC (www.scanex.ru). We presented and discussed the most pronounced causes of oil pollution, their sizes, shapes and prevailing locations in the Adriatic Sea as well as oil spill distribution maps. Main sources are considered to be due to routine tank washing operations and illegal discharges. The Adriatic Sea is a small semi-enclosed sea, and oil spill accidents could have far reaching consequences for the encompassing countries. Because of the general regime of circulation and its variability the coast of Croatia is highly vulnerable. Presented are also geographical and geological features and physical properties of the Adriatic Sea, particularly those relevant for transport and dispersions of oil pollution. Discussed are possible threats to the Croatian coastal communities, regarding increased transport in the Adriatic and new investigation and exploration, some of which is about to be

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executed in the Southern and Middle Adriatic, and some are already going on in the west coast.

Keywords Adriatic Sea, Circulation regime, Environmental impact, Marine oil pollution, SAR images, Satellite monitoring

Contents

1 Geographical Settings of the Adriatic Sea

The Adriatic Sea is a small semi-enclosed sea covering 138,595 km^2, situated in the Northern edge of the European Mediterranean. Adriatic Basin is surrounded by mountain chains Dinarids–Albanids, Alps and Apennines. Its longer axis is about 800 km and it is up to 200 km wide. It is a relatively shallow marine basin (Fig. 1) with average depth of about 173 m and reaches depths below 1,230 m. Two thirds (2/3) of the Adriatic Sea area is less than 200 m deep, e.g. most of the Adriatic Sea located in shelf area. Usually it is divided into Northern, Middle and Southern parts. The Northern Adriatic is very shallow, reaching 100 m depth and extending to Zadar–Ancona line, from where it extends to the 170 m deep Palagruža Sill. The Middle Adriatic encompasses the 270 m deep Jabuka Pit. The South Adriatic extends over the South Adriatic Pit, 1,267 m deep, to a narrow Otranto Strait, 780 m deep, its connection to the Ionian Sea and the greater Mediterranean. The turnover time for the Adriatic water mass (35,000 km^3) is estimated from 1 to 5 years [1, 2] but is usually considered 3.3 years [3]. The west coast is rather smooth contrary to the east coast, being very fractal, containing thousands islands, particularly in the Croatian waters.

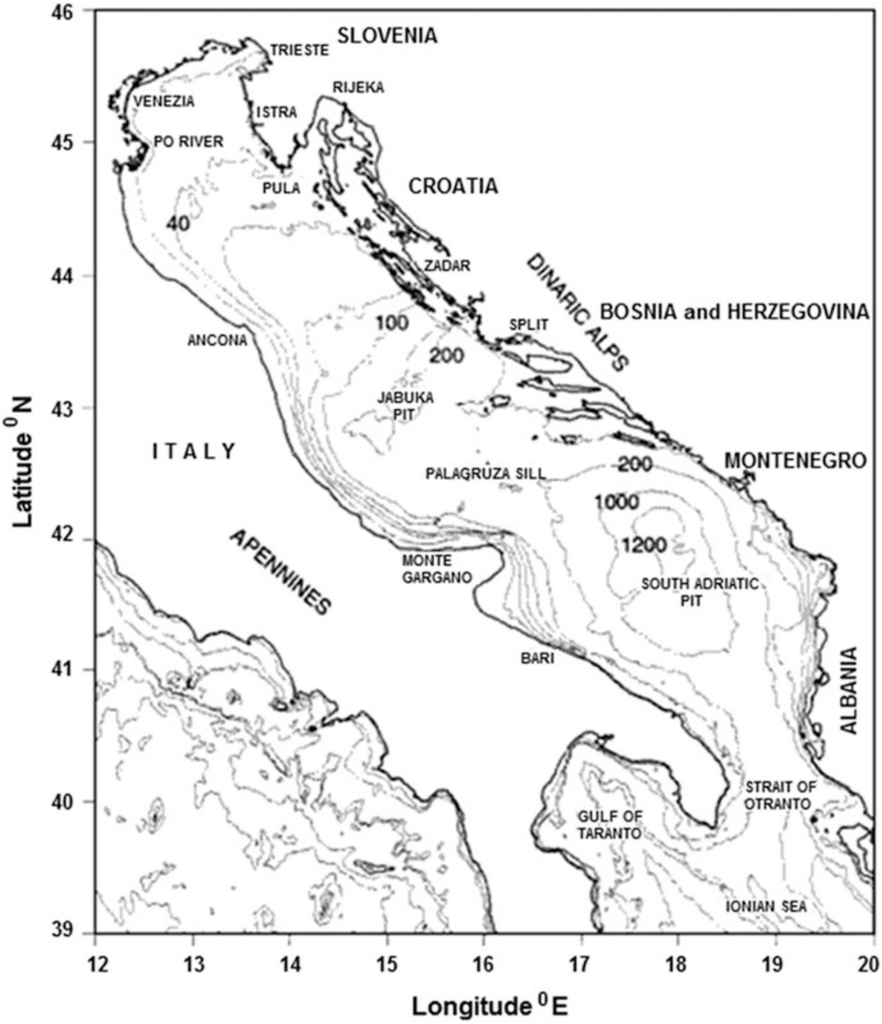

Fig. 1 The Adriatic Sea, coastal features, settlement and bathymetry. *Source*: GEBCO Free Map Data

2 Physical Properties of the Adriatic Sea Important for Dispersion of Oil Pollution

The geographical settlement of the Adriatic Sea is in the zone known for high seasonal mesoscale atmospheric disturbances, governed by solar forcing. In the atmosphere this results in high variability of wind, precipitation and temperature and the response in the sea is high variability of salinity, temperature and currents.

The Adriatic circulation at the surface is generally cyclonic [4, 5], characterized by northwest directed current along the East coast and West Adriatic Current

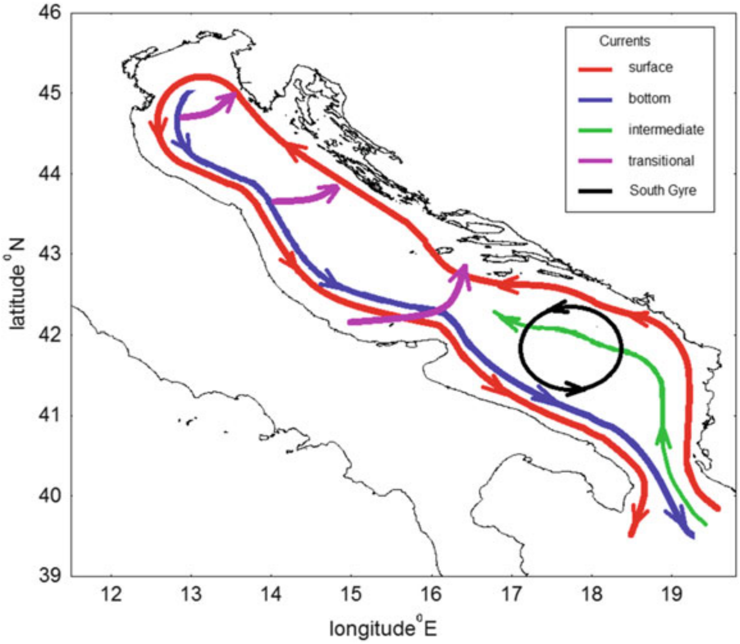

Fig. 2 Main features of the Adriatic general circulation and potential pathways of transitional currents. *Source*: Author's own map

(WAC), flowing southward along the West coast (Fig. 2). Such circulation is a consequence of freshwater input, from Northern Adriatic Rivers, especially the Po River, and of cooling of water in the north Adriatic during winter period. The circulation and winds alternate between winter and summer regimes [6]. Winter cooling is forced by outbursts of cold and dry bora wind which cause water density increase forming North Adriatic deep water (NAdDW). In such periods the South Adriatic deep water (SAdDW) is also formed. NAdDW flows southward along the west coast filling the Jabuka Pit. In harsh winters, when considerable quantity of deep water is formed, it flows further to the south and joins the SAdDW on the way through the Otranto Strait, where both exit the Adriatic Sea in deep layers. This exiting flow of water is compensated by incoming warmer and saltier Mediterranean water from the surface to the intermediate layer.

This process basically drives the Adriatic Sea thermohaline cyclonic circulation but is variable due to stronger or weaker intrusions of Mediterranean waters into the Adriatic [7, 8] and more of less efficient formation of NAdDW. The variability of this processes ranges from annual to decadal scale, depending on climate conditions on a scale larger than the Mediterranean and is also associated with bimodal Adriatic–Ionian oscillation [9, 10]. Generally, warm winters weaken the water exchange and the circulation between the Adriatic and the Mediterranean basin.

In addition to the cyclonic circulation oscillations, which govern the rate of basins exchange, there occur short term phenomena at the scales from days to weeks, provoked by strong synoptic disturbances which can locally overturn the circulation pattern. Both, strong sirocco and bora winds could force the WAC to change direction and flow towards Croatian coast. This phenomenon is observed in the Adriatic through several investigations detecting directly deviation of currents [11] or salinity decrease at the east coast [12, 13]. These transitional currents occur particularly at the Palagruža Sill and off Ancona.

The frames of the Adriatic Sea vertical dynamic and surface circulation are generally as presented here. However, spreading of potential spills at the sea surface, their dispersion and mixing through the water column largely depend on a number of factors. These are actual local thermohaline conditions, depending on seasons, winds, local currents, tides, free and inertial oscillations that all generate conditions of currents and mixing at shorter time scales.

In the Northern Adriatic, the bora winds force currents towards Italy, but local compensation currents can occur due to differences in topography at the East coast, and the flow from Italian side can reach the coast of Istra Peninsula. The tides can cause very strong variations of currents particularly in the Northern Adriatic [14]. As a result of wind and pressure variability, free oscillations (seiches) can cause strong currents [15]. The phenomenon of resonant energy transfer (meteorological tsunami), when occur, may locally produce flood and strong currents [16].

Taking into account the general circulation, we can suppose that most of the spills which would occur in the Southern Adriatic, closer to the Albania and Montenegro coasts would end to the Croatian coast, and especially at the Croatian South Adriatic islands. This statement is supported by findings of a lot of sewage (accidentally dumped from Albania) found at the Mljet Island, not in one isolated accident.

The Middle Adriatic is potentially endangered from accidents that could occur on the Italian side, or along the main transport routes in the Central Adriatic, since the conditions may evolve to turn the WAC to the east towards the Island Vis or Lastovo.

3 Causes of Oil Slicks and Look-Alike Signatures

As proven by many investigations, detection of oil spills/slicks on synthetic aperture radar (SAR) images is often a problem [17] due to appearance of similar signatures on the sea surface, because certain wind conditions [18] must be fulfilled that allow detection of oil spills. At low wind speed <2 m/s the scattering radar signal at the sea surface is extremely low, the required contrast is insufficient and the oil slicks are not detectable by SAR. The minimum wind speed of 2–3 m/s allows creation of sufficient roughness on the sea surface and, in turn, backscatter and brightness on the SAR images. As established by [18] optimal wind speed is between 3 and 6 m/s, but oil spills may still be visible at wind speed up to 10–12 m/s [19, 20], while the wind above 12 m/s makes the spills to disappear from the sea surface due to oil film breaking and water mixing.

False observations (and false alarms) may come from hydrodynamic phenomena like current shears, upwelling zones, internal waves and even sea surface temperature variations, which can create a number of ‘thermo-hydrodynamic’ slicks on the sea surface. Manifestations of meteorological phenomena in the lower atmosphere may be also mistaken for slicks, these are calm zones, wind shadows, rain cells, atmospheric gravity waves, etc. Marine biota can create biogenic slicks due to activity of plankton and fishes, algal blooms, floating seaweeds, sperm and eggs of marine animals. Also there may be manifestations of oil seeps of natural origin leaking from the underwater oil deposits, usually triggered by a local seismicity. Existing methods of discovering oil leaks tend to rely on SAR that can detect bottom sources through multi-temporal oil slicks floating on the sea surface [21].

Besides these, a ship-made turbulent wake can give impression of a spill and sometimes even shallow bottom topography in tidal seas. The list of potential look-alikes is not complete yet and experienced expertise is needed to distinguish between real oil spills and look-alikes.

Oil slicks occur on the sea surface in different forms and dimensions, depending on the amount of oil, the strength of winds and currents, and the time passed from a discharge. They could be linear or amorphous, sometimes perturbated with feathered edges or totally diffused. Fresh and old differs as well as the spills caused by different oil products and fractions.

4 Available Data and Methods

The large ESA archive of Envisat SAR images was available for inspection in the frame of the ESA research project #19234. The area of interest was the open sea of the Middle and Southern Adriatic. First, the image quick-looks were examined through the EOLISA on-line catalogue for the period 2003–2010, and the SAR images with pronounced oil spills were ordered from ESA for further analysis. The raster images were imported to the NEST program, processed (geo-referenced) with the NEST ESA SAR ToolBox to geographical grid and exported to geotiff format. Each image was in details analysed with purpose to determine oil slicks and enlarged to get clear view of a particular slick. After analysing the images visually, the properties like size, shape and contrast were considered. The wind conditions during the image acquisitions were also taken into account. SAR images with inappropriate wind conditions (too strong or very low wind) were excluded from analysis. Wind data (10 min averaged wind speed, direction and gust data) were obtained from the State Hydrometeorological Office in Zagreb (for details, see [22]). Also the wind data were available from several weather stations in the Adriatic islands. For more comprehensive analysis we also used Radarsat-1 SAR images acquired in 2011 in the framework of the pilot project with Russian collaborators. Two Sentinel-1A SAR images from 2016 were also used.

After that, all images were imported to the GeoMixer tool (http://geomixer.ru). GeoMixer is a GIS technique, on-line API application and interactive tool for storage, integration, visualization, interactive analysis and publishing of satellite images, other remote sensing and geophysical data and results of analysis using the on-line GIS tool. In it, it is also possible to integrate SAR images with other geospatial data about oceanography, meteorology, bathymetry, offshore oil-and-gas infrastructure, digital nautical charts, marine boundaries, ship lines and other useful information. In the Scanex software the tools are developed to automatically calculate number of detected slicks and determine the areas they cover, which was also utilized in this analysis.

Collection as many data and information about marine basin as possible in such an application allows proper identification of oil spills and discrimination of them from look-alikes, with a very high confidence level, although there may be uncertainties in oil spill identification on SAR images without additional airborne survey or in situ sampling. The SAR images also enable ship detection, as ships appear as small bright spots, and wind speed retrieval using CMOD-type model.

5 Requirements in Support of Operational Monitoring System

Due to fractal coastal geography and a thousand islands the Croatian coast is quite difficult to 'defend' from potential spills. In the present situation with SAR satellite sensors, the protection system cannot be based on real time satellite data.

A well-prepared meteorological and oceanographic system is needed to control and prevent harmful consequences of eventual oil spill accidents. All the mentioned oceanographic processes could be predicted, if the system of adequate monitoring existed. This should include availability of real time satellite data that can provide information about spills. Also meteorological and oceanographic forecasts are needed.

Croatia Hydrometeorological Office (in Zagreb with the branches in Split and Rijeka) is in charge for meteorological measurements and weather forecast and also for weather alarm, including the weather at the sea. Oceanographic measurements are organized mainly through several scientific institutes (in Split, Rovinj, Zagreb and Dubrovnik). These institutes possess the state-of-the-art oceanographic equipment, vessels, buoys and a few coastal stations, most of it operational. However, in Croatia oceanography does not provide a continuous service, neither an operational model (the exception is the State Hydrographic Institute that provides on-line tidal measurements and publishes forecast for astronomical tides). However, the scientists from these institutes are proficient in oceanographic measurements and were experienced in numerical hydrodynamic modelling through several recent projects. Numeric model under the project ADRICOSM (2001–2005) enabled forecasts of short term changes in the circulation of the Adriatic Sea and in the coastal area of the Central Adriatic [23]. Recent modelling simulations on the scale of the Adriatic have been carried within the two phases of the Adriatic Project [24] and numerical simulations have been carried out for a period of 1 year. The results of these studies are available, and can serve for environmental studies and estimates of anthropogenic influence to the marine environment. The mentioned activities and studies of water dynamics in the Adriatic Sea in which the numerical models have an important role show the potential of the numerical methods for assessing and forecasting the state of the marine environment during the planned exploration and exploitation of hydrocarbons as well.

At the moment in Croatia there is an initiative to connect the activities of oceanography and meteorology and produces coupled oceanographic meteorological model and forecast.

In order to protect very long shoreline, there were activities with intention to lower the damage, if the oil spill accidents occur. In the year 2009 the project took place that has defined the so-called the places of refuge [25, 26] where a leaking ship could eventually hide, to prevent larger damage. These places have been determined considering the position of a ship and supposed trajectory of a spill regarding the meteorological and oceanographic conditions. The estimates for the best places of refuge were based on modelling simulations for prevailing winds.

Recently one of the results of a MONGOOS initiative and through the Copernicus project, presented is oceanographic service [27] that provides oceanographic forecast for various users, from citizens to companies, and such a service can also be used in case of accidents. It is based on model, and a number of fields from satellite data including air and sea temperature and winds.

Although the effort of ESA is huge, to provide SAR images, we are missing an organized service to collect and make available these images at the national level.

6 The Concerns of Croatian Coastal Population

About a million people inhabit the Croatian coast and islands, having on the average half income per capita than the capital city. The economy of this population is directly oriented to the sea and its resources. The main economy branches in the coastal area are tourism, fisheries, aquaculture, shipping, transport, marinas, etc. The tourism is considerably gaining importance lately.

The fear of domestic population from possibility of oil or other large marine accidents is not irrational. There are dozen tankers and other cargo ships travelling along the Adriatic Sea every day from the Otranto to the Northern Adriatic ports. It is estimated that in the Adriatic transported are many million tons of oil per year [28]. Due to ever increasing demands for fuel, such transport has increasing trend.

The transport of passenger ships is especially frequent in warm season and daily several times operate between the coast and islands. Between east and west coasts from May to October on the routes on lines Pula–Venezia, Zadar–Ancona, Split–Ancona, Dubrovnik–Bari, Bar–Bari and Durres–Bari the ships operate several times during a week. The lines between Italian ports Venice, Ancona and Bari to Greek ports of Patras and Igoumenitsa are also intensified in touristic season. Large number of fishing ships, crossing the main transport routes, work in fishing areas. Tankers and cargo ship transport routes concentrate along the long axis of the Adriatic Sea, while fishing areas are dispersed both in the coastal and open sea (Fig. 3).

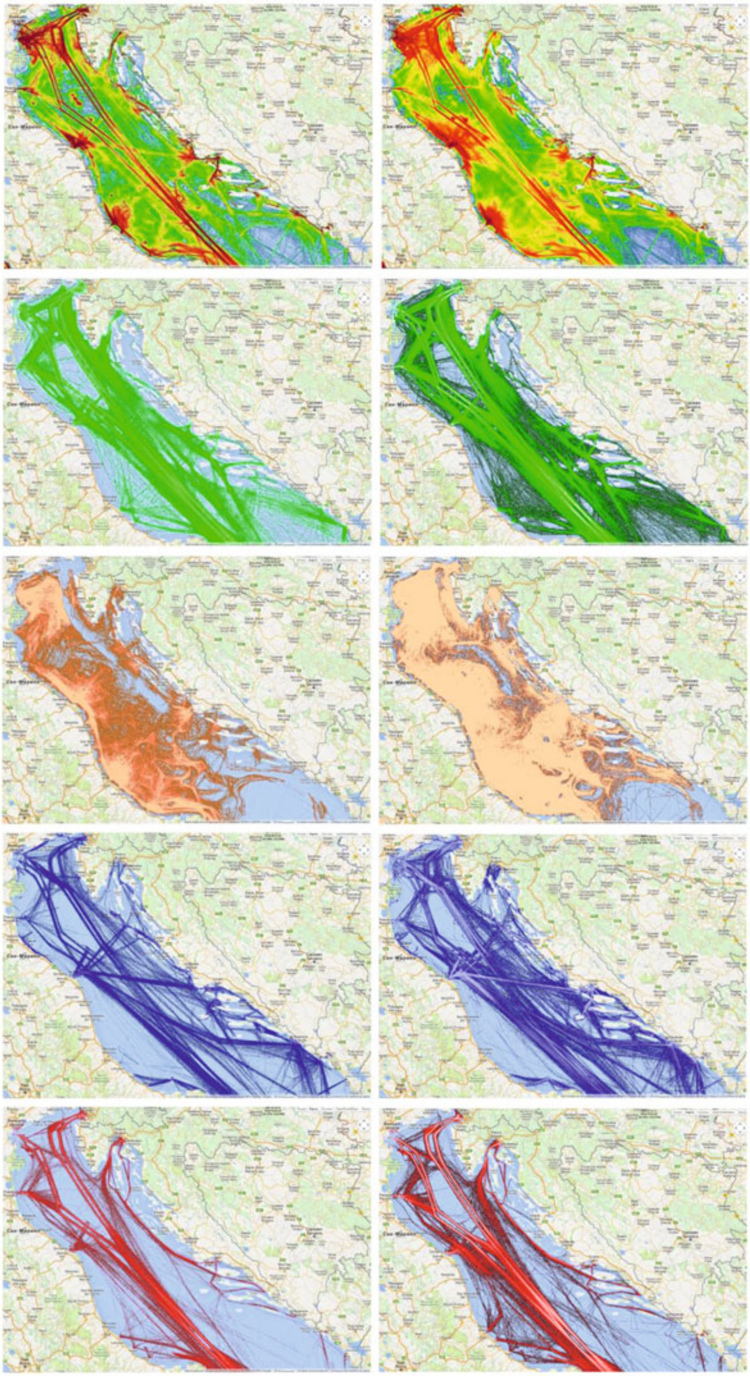

Fig. 3 Density of ship traffic in the Adriatic Sea in 2013 (*left*) and in 2014 (*right*). The all traffic intensity (*first row*) is represented by colour, the most intensive by *red–yellow*, clearly marking the ship routes. Separately the traffic of tankers (*second row*), cargo ships (*third row*), fishing

Although not very large, but there were a few accidents in the Adriatic Sea like *Brigitta Montanari* near Šibenik in 1984, *Val Rosandra* in Brindisi in 1990, *Alessandro Primo* near Molfetta in 1991 [29] and *Und Adriyatik* Turkish-flagged cargo ship in 2008 in the Northern Adriatic. The probability of accidents increase with increasing traffic, and this is a fact in the Adriatic. Increased is not only transport of oil, but also transport in general, which is directly linked to the risk of oil and other pollution.

In the west coast there are about thirty active oil rigs in Elsa, Elsa West, Rospo mare, Ombrina mare, situated off Ancona and further southward. There are also several prospective fields like Tremiti and Pianosa in the Middle Adriatic to be exploited in the future. In the open sea of the South Adriatic, towards the west coast, there are several active oil rigs.

Now, other three nations (Albania, Montenegro and Croatia) are preparing to drill for oil in the Southern and Middle Adriatic. If new oil deposits would be found, this will pose additional risk of oil spill accidents. The consequences of these would be unforeseen for the national economy of Croatia, of which tourism contributes considerably and with increasing trend. Some of the investigations, in spite of given concessions, seem now to be stopped due to the loss of interest of investors. Drilling for oil from the Southern Adriatic is rather expensive, which may not be so profitable with regard to the dumped prices of oil lately. Also, yet undefined borders at the sea between Montenegro and Croatia that encompass potential exploration areas may be part of a problem.

The people are worried what threats future investigation and exploration of oil may bring. Will the prospective oil fields be so close to the islands as to ruin the nice view? The permitted distance for exploration of 10 km from the coast and 6 km from islands is below normally high visibility. The Croatian coasts with its clear and clean sea than may not be so attractive to the tourists, with a view to the oil platforms. Not to mention the possibility that one day an environmental disaster might occur.

Income from fisheries and aquaculture is also important for coastal population, and risk during investigation and exploration is possible. Aquaculture ponds are situated not only in the coastal area but also on the south sides of several east Adriatic islands, making them highly vulnerable to oil pollution. Protection is especially necessary for maintaining normal wild fish reproduction. In the phase of investigation for oil the precautions must be made, since disturbing the fish during spawning and growing could be fatal for young fish. The threat during the oil exploitation phase comes also from a disturbing factor of noise. It is essential to protect the migration locations of different fish species, especially those of commercial interest. However, it is very difficult to find in the Adriatic Sea isolated areas where numerous fish species do not migrate during spawning or growing [30].

Fig. 3 (continued) vessels (*fourth row*) and passengers ships (*fifth row*) are shown in *red*, *green*, *light brown* and *dark blue*, respectively. © Marinetraffic.com

7 SAR Image Analysis for Oil Spills

From approximately four hundred examined Envisat SAR images from the period 2003–2010, after careful inspection 29 images showed clear middle and large size oil spill signature and were selected for analysis. Also we used the oil spills detected on 27 Radarsat-1 SAR images in 2011 during the pilot project. Selected Envisat and Radarsat-1 SAR images were integrated in GeoMixer together with geographical maps and other data useful for analysis. The coverage by Envisat SAR images from our analysis is shown in Fig. 4. On 29 archived Envisat SAR images the 380 slicks (from small to large) were detected (and marked) with the total area of about 670 km^2. On 27 operational Radarsat-1 SAR images 16 slicks were detected with total area of 77.7 km^2. In total, from this analysis the 396 slicks were observed, covering the area of 457.7 km^2.

On some SAR images ship wakes and spills (Fig. 5) were visible along the main transport routes that concentrate along the long Adriatic axis, and in fishing areas that are dispersed both in the coastal and open sea. When the spill manifestation is linear like in Fig. 5, it is probably fresh and very likely made by illegal discharges of intentional ships that travelled fairly rapidly through the region. These are not spills from big cargo ships or tankers, but most probably come from small vessels, fishing boats or may have been either caused by accidents or by dumping of oily wastes. The ships could have used different tactics to avoid identification: after discharges

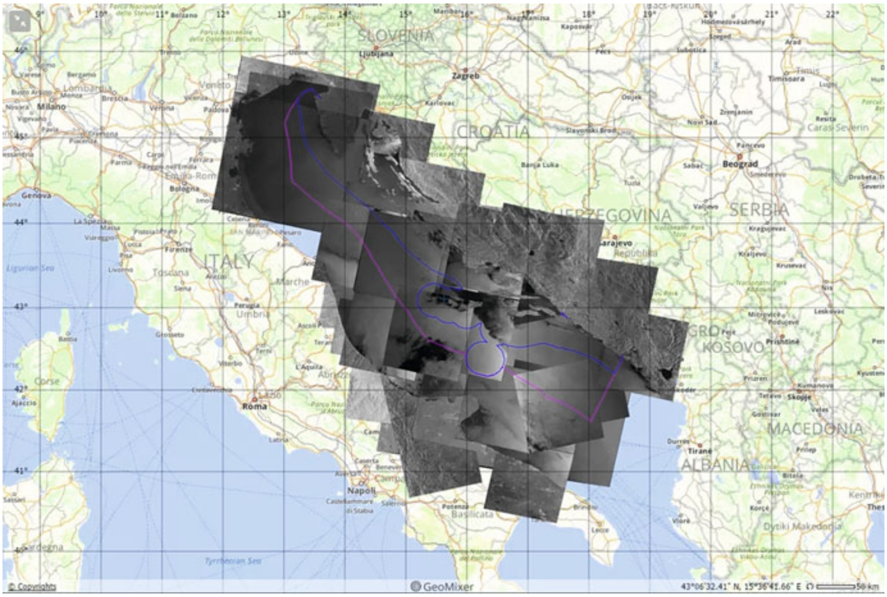

Fig. 4 Coverage of the Adriatic Sea by Envisat SAR images acquired in 2003–2010 and Radarsat-1 SAR images acquired in 2011, selected for analysis in the GeoMixer application. © ESA, MDA, SCANEX

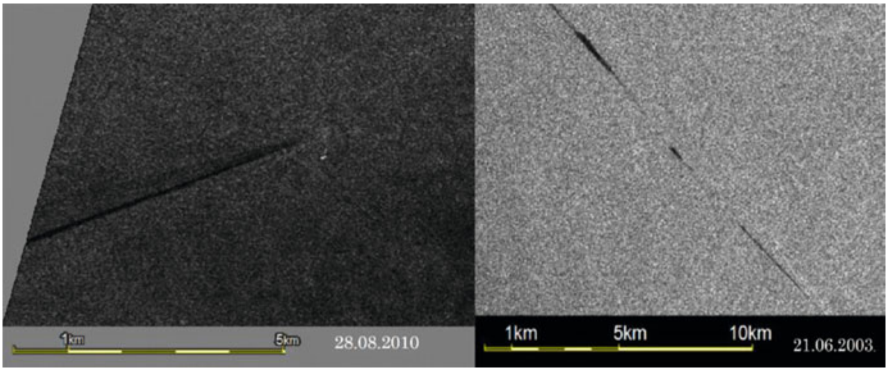

Fig. 5 Subscenes of Envisat SAR images of 28.08.2010 and 21.06.2003 with probable oil spills in the ship wakes. © ESA

they could slow down and turn in the opposite direction, or stop moving for a while and wait until spill origin cannot be connected to them, if currents or winds are strong and move the oil away from them.

In Fig. 6 rather narrow slicks are presented. The manifestation on the image of 10.05.2008 (Fig. 6, left) could be oil spill; the deviation from a straight line may be caused by wind or local differences in the current field. The manifestation on the image of 01.05.2004 (Fig. 6, right) may have similar cause, but is more probably a deliberate oil spill. Here we see that either the ship that was dumping the oil changed direction or there was a divergence in the wind field.

On some SAR images we have found rather large spills (Figs. 7 and 8). We assume all these were definitely caused by dumping of different mixtures with oil and produced by discharges from cargo ships or chemical tankers. For example, ship-generated oil spills can be produced via ballast water discharges, tank washing residues, oily mixtures from the engine room, bilge waters and even oily fish wastes, some of which is produced during routine fishing boats operations. On the SAR image of 19.07.2008 (Fig. 7) feathered edges can be seen, indicating the presence of different oil fractions that have spread the spill under the influence of the wind (Fig. 9).

Summary maps of all large and medium oil slicks having different man-made nature detected in 2003–2011 in the Adriatic Sea, created and analysed using GeoMixer technology, are shown in Figs. 10 and 11.

In Fig. 12 the distribution of the oil spills detected in the central part of the Adriatic Sea appears along the main shipping routes. Here one very large spill of 108 km^2, the largest observed throughout analysis, is observed. For largest spills date and size are indicated in the callouts. Main ship routes (hatch blue lines), boundaries (shadowed light blue lines) of the territorial waters and ZERP (Zaštićeno ekološko ribarsko područje or Croatian Fishery and Ecological Zone) (dark blue line) are shown.

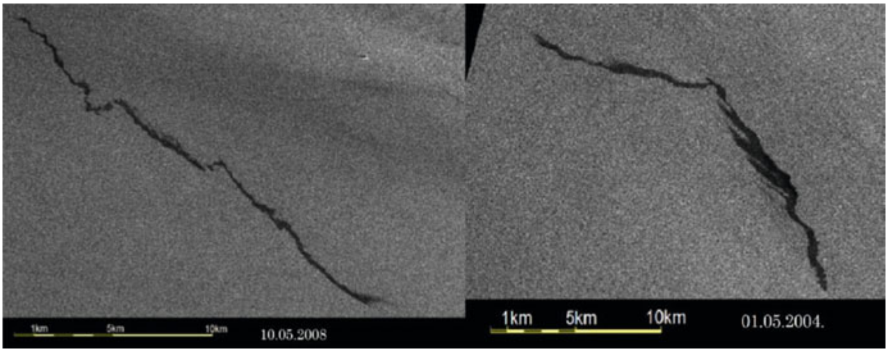

Fig. 6 Subscenes of Envisat SAR images of 10.05.2008 and 01.05.2004 with oil spills modified under action of wind and currents. © ESA

The maps show many large oil slicks especially in the central part of the Adriatic Sea. Large oil spills are mostly found in the ZERP and close to this area. The slicks/spills are as large as 9–108 km^2. Such slicks may come into the water during routine tank washing operations and illegal discharges, and are dispersed in the course of time and under the action of wind and currents. Most of these oil spills were intentionally released during night, since were detected on the SAR images acquired during descending morning passes of the satellite between 05:00 and 09:00 UTC.

The highest amount of largest oil spills is detected in the open sea, at the boundaries of the Italian and Croatian sectors and along the main ship routes. Although it would be possible to track ships that caused such types of pollution, for example, using data of automatic ship identification system – AIS [31], but there is a problem that the satellite images are not accepted as proves in the court, and it would be difficult to press charges to any suspected ship.

Furthermore, our analysis of Envisat SAR images and oil spill distribution maps for the Adriatic Sea confirmed general conclusion from other seas that most oil pollution occurred along the main ship routes [31]. Analysis of distribution of large oil spills also revealed that tank washing occurs frequently in the Central Adriatic Sea like it does in the Black Sea [32].

Although the tankers claim to have rather strict controls of all waste waters from port to port, it is still possible that some of these spills were produced by multipurpose chemical tankers. They transport liquid substances of different toxicity, including crude oil and oil products of which most are carcinogenic and toxic for marine life. These liquids together with emulsifiers and surface active substances used for tank cleaning can form different surface active films on the sea surface.

Also quantity and quality of spilled oil and oily products remain unknown. Even with the Sentinel-1A, new SAR-equipped satellite with coverage of every second day over the mid-latitudes, a lot of spills would pass undetected due to other

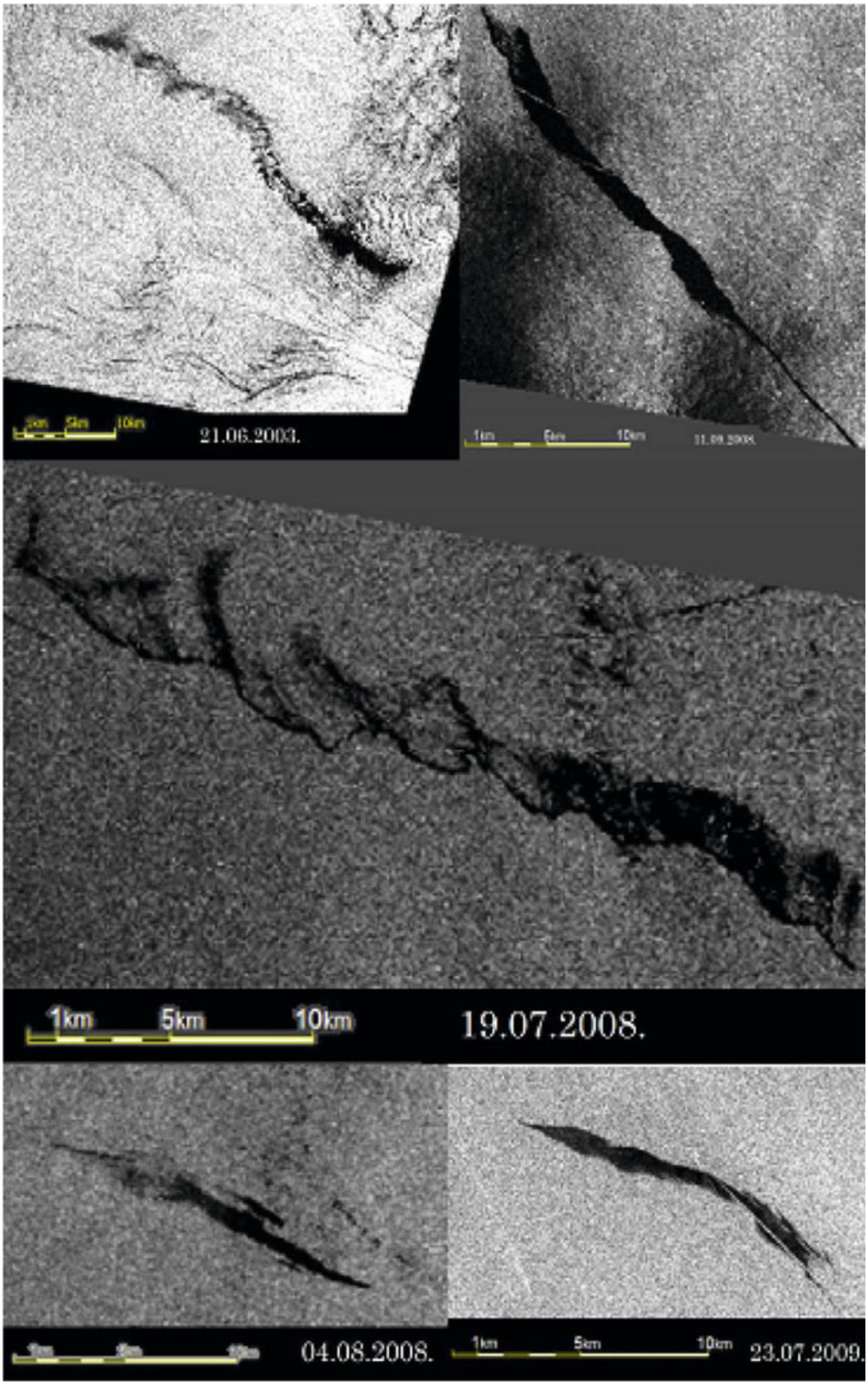

Fig. 7 Subscenes of Envisat SAR images of 21.06.2003, 11.09.2008, 19.07.2008, 04.08.2008 and 23.07.2009, with very large slicks, which are definitely ship-made oil spills. © ESA

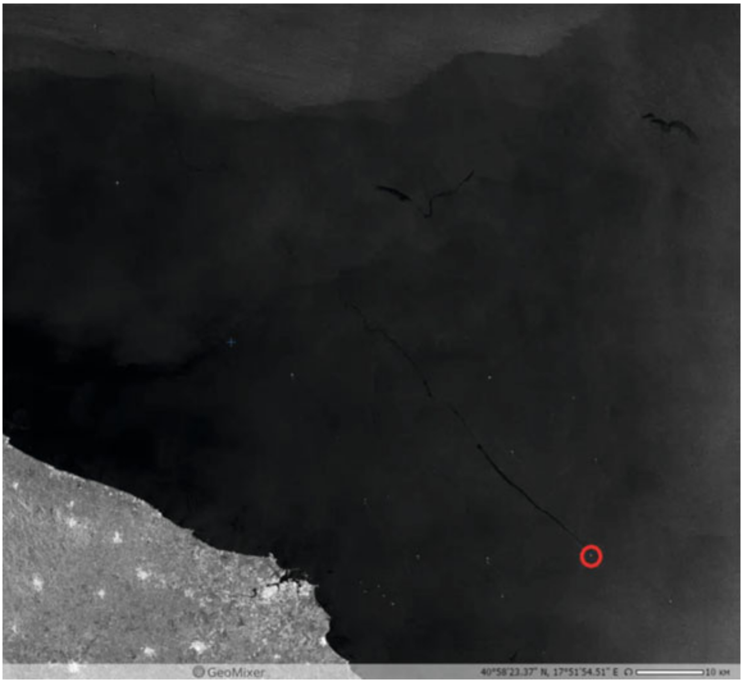

Fig. 8 Subscene of Sentinel-1A SAR image (1.02.2016, 04:55 UTC) with oil spills off Italian port of Brindisi (the longest spill is 116 km, start at 41°23″N, 17°35″E; end (*red circle*) at 40°41″N, 18°30.5″E). © ESA

reasons, often due to the absence of the favourable conditions in the sea and atmosphere that allow recognition of the oil slick phenomena.

Although the Adriatic Sea is declared as a Special Zone according to the MARPOL Convention, tank washing is sometimes legal under specific conditions [33]. In the Adriatic Sea under Croatian jurisdiction there are protected areas national parks, special reserves, significant landscapes and monuments of nature. The ecological network [34] of marine protected areas is a part of European Union Ecological network, Natura 2000. It encompasses 16.4% of Croatian sea and covers 5,205 km^2. It is composed of hundreds of polygonal or point areas important for the conservation/preservation of species and habitat types. However, these areas count for about only 10% of the total Croatian sea territory and the rate is the same in Italian side. Although human activities are limited in the protected areas, these measures cannot save these areas of accidental oil pollution that could occur nearby.

As a result of undefined marine borders between the republics of the former Federation of Yugoslavia, the agreements are still missing between Montenegro and Croatia in the South Adriatic, and the border is not completely clear between Bosnia-Herzegovina and Croatia in the Neum-Klek Bay. Also the delimitation

Fig. 9 Subscene of Sentinel-1A SAR image (6.04.2016, 05:03 UTC) with recent large oil spill (total area about 16.5 km^2) close to the Ancona–Igoumenitsa ship lane. © ESA

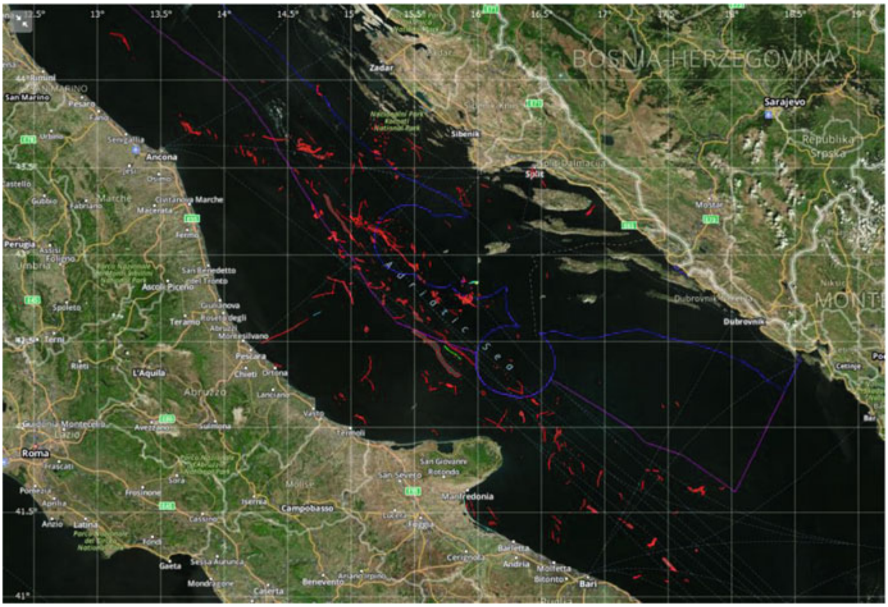

Fig. 10 Summary map of oil slicks of different nature detected in the SAR imagery of the Adriatic Sea. Extent of oil pollution along the main shipping routes is clearly seen. © SCANEX

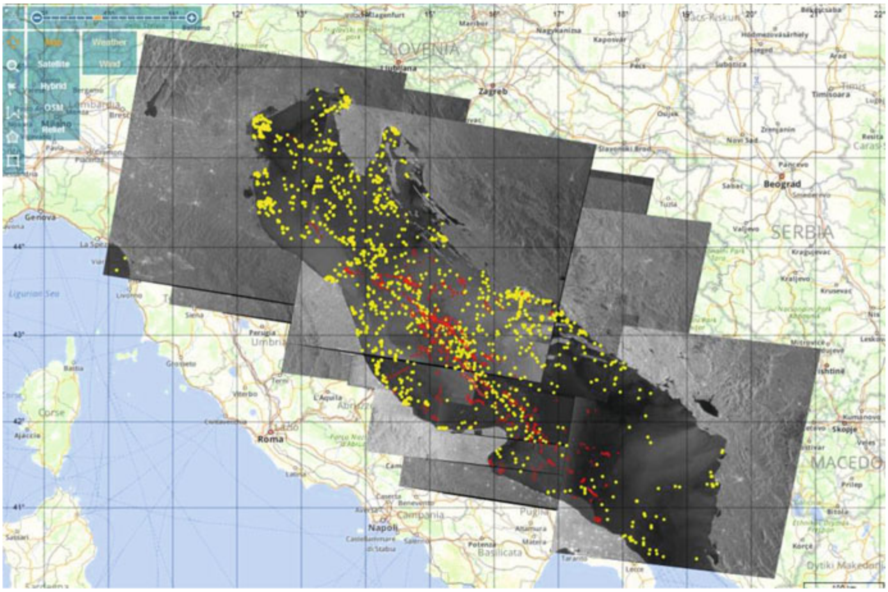

Fig. 11 Map of all oil slicks/spills detected on Radarsat-1 and Envisat SAR images (*red spots*), and collocated with the detected ships (*yellow dots*) from all analysed images. © MDA, ESA, SCANEX

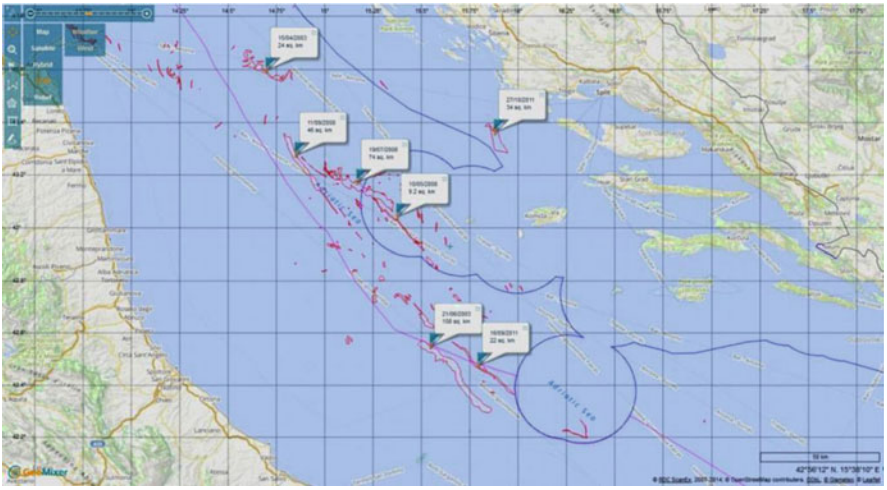

Fig. 12 Distribution of the oil spills detected on the SAR images in the central part of the Adriatic Sea along the main ship routes. For largest spills date and size are indicated in the callouts. Main ship routes (*hatch blue lines*), boundaries (*shadowed light blue lines*) of the territorial waters and ZERP (*dark blue line*) are shown. © SCANEX

agreements are still pending, between Slovenia and Croatia about Savudrijska vala (or Piran Bay) and marine border between Croatia and Montenegro.

It is very important to define marine borders of the States surrounding the Adriatic Sea especially not only for their obligations concerning protection, search and rescue, but also for the rights for exploration of underwater oil and gas reserves.

8 Conclusions

Continuous SAR observations from space have significantly contributed in oil spill monitoring and provide a new knowledge on oil pollution. The most important findings from this study can be summarized as follows:

- Most of oil spills were detected along the main international shipping routes at the boundaries of the Italian and Croatian sectors, while large oil spills are mostly observed in the Croatian ZERP.
- The sizes of the detected oil spills varied between 0.1 and 108 km^2.
- In total, 396 slicks were observed covering the area of 457.7 km^2.
- Feathered edges of oil slicks indicate heavy and middle fractions of oil in a slick that also can be a sign of routine tank washing operations or illegal discharges.
- The number and the total area of detected oil spills depended on the particular time/season and ship traffic.
- Most of oil spills have been released during night time, and were detected during descending (morning) satellite passes.
- Oil spills have been more often detected on SAR images in the open parts of the sea beyond the territorial waters, rather than in the coastal waters.
- Other, yet not estimated source of oil pollution may be bottom seepage.

As established, prevailing distribution of oil spills in the Central Adriatic is along its longer axis, along the main ship lines, and it may be concluded: the more intensive traffic the more intensive oil pollution. It is also obvious that many detected oil slicks are of anthropogenic origin, caused mostly by deliberate dumping of waste oily waters or oil products from ships of all kinds. Of course, there is a reasonable doubt that oil spills in the Adriatic Sea occur much more frequently than could be detected by satellites.

The Adriatic Sea with increasing frequency of oil tankers, other cargo ships and increased transport in general, is potentially endangered from marine accidents that could result with oil pollution. Being a small semi-enclosed sea with valuable resources concerning biodiversity and importance for economy of surrounding population is in need of additional measures to protect it.

Finally, collection of SAR images, their geospatial analysis is very useful either from practical and scientific points of view, because, first, it clearly shows the sources of oil pollution in the sea, second, reveals a specific pattern of spill distribution that definitely connected with ship traffic in the open sea and, third, allows finding new, earlier unknown sources. These results increase knowledge about the level of oil pollution and its sources in the Adriatic Sea.

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References

1. Mosetti F (1983) A tentative attempt at determining the water flow through the Otranto Strait: the mouth of the Adriatic Sea. Criterion for applying the computation of dynamic height anomalies on the water budget problems. Boll Oceanol Teor Appl I:143–163
2. Lušić Z, Kos S (2006) Glavni plovidbeni putovi na Jadranu (The Main Sailing Routes in the Adriatic). Naše more 53(5–6):198–205
3. Franić Z (2005) Estimation of the Adriatic Sea water turnover time using fallout 90Sr as a radioactive tracer. J Mar Syst 57:1–12
4. Zore M (1956) On gradient currents in the Adriatic Sea. Acta Adriat 8:1–38
5. Artegianni A (1996) The Adriatic sea hydrography, the European anchovy and its environment (Palomera, I. and Rubies P. eds.). Sciencia marina 60(Suppl 2):33–43
6. Artegianni A, Bregant D, Paschini E, Pinardi N, Raicich F, Russo A (1997) The Adriatic Sea general circulation. Part II: Baroclinic circulation structure. J Phys Oceanogr 27:1515–1532
7. Buljan M (1953) Fluctuation of salinity in the Adriatic. Izvještaj Republičke Ribarstveno-biološke ekspedicije "Hvar" 1948–1949. Acta Adriat 2:1–64
8. Grbec B, Morović M, Beg Paklar G, Kušpilić G, Matijević S, Matić F, Ninčević Gladan Z (2009) The relationship between the atmospheric variability and productivity in the Adriatic Sea area. J Mar Biol Assoc U K 89(8):1549–1558. doi:10.1017/S0025315409000708
9. Civitarese G, Gačić M, Lipizer M, Eusebi Borzelli GL (2010) On the impact of the Bimodal Oscillating System (BiOS) on the biogeochemistry and biology of the Adriatic and Ionian Seas (Eastern Mediterranean). Biogeosciences 7:3987–3997. doi:10.5194/bg-7-3987
10. Gačić M, Borzelli GLE, Civitarese G, Cardin V, Yari S (2010) Can internal processes sustain reversals of the ocean upper circulation? The Ionian Sea example. Geophys Res Lett 37, L09608. doi:10.1029/2010GL043216
11. Vilibić I, Book JW, Beg Paklar G, Orlić M, Dadić V, Tudor M, Martin PJ, Pasarić M, Grbec B, Matić F, Mihanović H, Morović M (2009) West Adriatic coastal water summertime excursion in-to the East Adriatic. J Mar Syst 78:S132–S156
12. Grbec B, Vilibić I, Bajić A, Morović M, Beg Paklar G, Matić F, Dadić V (2007) Response of the Adriatic Sea to the atmospheric anomaly in 2003. Ann Geophys 25:835–846
13. Grbec B, Morović M (1997) Seasonal thermohaline fluctuations in the middle Adriatic Sea; Nuovo Cimento della Societa Italiana di Fisica C. Geophys Space Phys 20(4):561–576
14. Malačič V, Viezzoli D, Cushman-Roisin B (2000) Tidal dynamics in the northern Adriatic Sea. J Geophys Res 105(C):26265–26280
15. Vilibić I (2000) A climatological study of the uninodal seiche in the Adriatic Sea. Acta Adriat 41(2):89–102
16. Šepić J, Vilibić I, Fine I (2015) Northern Adriatic meteorological tsunamis: assessment of their potential through ocean modeling experiments. J Geophys Res 120(C):2993–3010
17. Espedall HA, Johannessen OM (2000) Detection of oil spills near offshore installations using synthetic aperture radar (SAR). Int J Remote Sens 21:2141–2144

18. Bern T-I, Wahl T, Andersson T, Olsen R (1992) Oil spill detection using satellite based SAR: experience from a field experiment. Proceedings of the 1st ERS-1 symposium, Cannes, France, 4–6 November, 2, pp 829–834
19. Ivanov AY, Litovchenko KT, Ermakov SA (1998) Oil spill detection in the sea using Almaz-1 SAR. J Adv Mar Sci Technol Soc 4(2):281–288
20. Litovchenko K, Ivanov A (2006) Oil spills on ALMAZ-1 and ERS-1 SAR images: results from DOSE-91 experiment. In: Gade M, Huhnerfuss H, Korenowski G (eds) Marine surface films. Chemical characteristics, influence on air-sea interaction and remote sensing. Springer, Berlin/Heidelberg, pp 299–313
21. Ivanov A (2011) Remote sensing of oil films in the context of global changes. In: Remote sensing of the changing oceans. Springer, Berlin/Heidelberg, pp 169–194
22. Morović M, Ivanov A, Oluić M, Kovač Ž, Terleeva N (2014) Distribution and sources of oil slicks in the Middle Adriatic Sea. In: Proceedings of the 12th Pan Ocean Remote Sensing Conference (PORSEC-2014), 4–7 November 2014, Bali, Indonesia, O-109, pp 1–8
23. Orlić M, Dadić V, Grbec B, Leder N, Marki A, Matić F, Mihanović H, Beg Paklar G, Pasarić M, Pasarić Z, Vilibić I (2006) Wintertime buoyancy forcing, changing seawater properties and two different circulation systems produced in the Adriatic. J Geophys Res Oceans 111. doi:10.1029/2005JC003271
24. Andročec V, Beg Paklar G, Dadić V, Đakovac T, Grbec B, Janeković I, Krstulović N, Kušpilić G, Leder N, Lončar G, Mara-sović I, Precali R, Šolić M (2009) Coastal cities water pollution control project, Part C1: strengthening of coastal water monitoring network. The Adriatic Sea monitoring program
25. Beg-Paklar G, Dadić V, Grbec B, Ivanković D (2007) Simulations of physical properties in south part of the Croatian Adriatic using numerical model – case study. In: Kereković D (ed) Richness and diversity of GIS. Croatian Information Technology Association – GIS Forum, University of Silesia, Zagreb, pp 119–126
26. Bradarić Ž, Mladineo N, Srdelić M (2010) Sensitivity index of the coast of the place of refuge to oil pollution. In: Kereković D (ed) Space, heritage and future. Croatian Information Technology Association – GIS Forum, University of Silesia, Zagreb, pp 222–228
27. Coppini G (2016) MONGOOS: Mediterranean operational oceanography in support of sea situational awareness services. Webinar, 13 April 2016
28. OCEANA. http://eu.oceana.org/en/eu/media-reports/features/oil-slicks
29. CEDRE. www.cedre.fr
30. Institute of Oceanography and Fisheries (IOF) (2015) Prilozi za dopunu Strateške procjene utjecaja na okoliš, Okvirnog plana i programa istraživanja i eksploatacije ugljikovodika na Jadranu [Contribution to complement the strategic study for environmental impact and framework plan of investigation and exploration program for hydrocarbons in the Adriatic Sea, Institute of Oceanography and Fisheries, in Croatian]. Institut za oceanografiju i ribarstvo, Split, pp 1–191
31. Ivanov AY, Kucheiko AA (2014) Large discharges from ships in the Black Sea studied by synthetic aperture radar with the support of automated identification systems. Int J Remote Sens 35(14):5513–5526
32. Morović M, Ivanov A, Oluić M, Kovač Ž, Terleeva N (2015) Oil spills distribution in the Middle and Southern Adriatic Sea and intensive ship traffic. Acta Adriat 56(2):143–150
33. International Maritime Organization (2009) International convention for the prevention of pollution from ships, 1973, as modified by the protocol of 1987 (MARPOL 73/78). IMO, London, Available at: http://www.imo.org/About/Conventions/ListOfConventions/Pages/International-Convention-for-the-Prevention-of-Pollution-from-Ships-(MARPOL).aspx
34. http://www.dzzp.hr/ekoloska-mreza/natura-2000/ekoloska-mreza-rh-natura-2000-1300.html, http://www.bioportal.hr/gis/. Accessed 14 Apr 2016

Oil Pollution in Turkish Waters of the Mediterranean Sea

Fatma Telli Karakoç, Dilek Ediger, and Aslı Süha Günay

Abstract The Mediterranean Sea was defined as a "special area" under the MARPOL Convention in 1983 for its oceanographic and ecological conditions and maritime traffic. 30% of all international seaborne trade are originating from or directed to Mediterranean ports or passing through these waters. The Mediterranean Sea is under heavy use by Russian and Middle East Asia petroleum transport lines which threaten the Turkish coasts. Turkish strategy for the responding accidental oil pollution is to respond as fast as possible on the sea with mechanical oil recovery techniques. The use of dispersants as a chemical recovery technique is not allowed without permission from the Ministry of Environment and Urbanization of Turkey. Preparedness for the accidental oil pollution emergency response infrastructures such as risk analysis, semi-online oil spill model, determination of the places of refuge for ships in need of assistance and decision support system and contingency plans in three tiers are completed and have been available in an emergency situation. In Turkey, illegal discharges are monitored by coast guard ships, and penalties are imposed on polluters according to the related law. Emergency response plans are in force in Turkey and renewed every 2 years.

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Keywords Emergency response infrastructures, Environmental impact, Legislation, Oil spill, Pollution

Contents

Abbreviations

Com-TAF	Turkish Army Force, General Commander
DAC	Damage assessment commission
EG&E	Environment Group and Experts
GERC	Group in the Emergency Response Centre
LAS	Legal Advisers Secretariat
M of FA	Ministry of Foreign Affairs
M of I-CGC	Ministry of Interior Turkish Coast Guard Command
M of TMC	Ministry of Transport, Maritime Affairs and Communications
M of TMC-DGCS	Ministry of Transport, Maritime Affairs and Communications, Directorate General of Coastal Safety G of ERC
PCC	Provincial Crisis Center
PM-DEMA	Prime Ministry-Disaster and Emergency Management Authority
PPRC	Press and Public Relations Committee
RCC	Regional Crisis Committee
TM-EU	Ministry of Environment and Urbanization
TM-TMAC	Turkish Ministry of Transport, Marine Affairs and Communications
YAKAMOS	Help Search Rescue Emergency Response Automation System

1 Geography and Maritime Traffic

Turkey is located between Asia and Europe like a bridge. Turkey is semi-surrounded by four seas which are the Black Sea in the north, the Sea of Marmara in the north-west, the Aegean Sea in the west and the Mediterranean Sea in the south. The Aegean Sea, the part of the Mediterranean Sea, is connected to the Marmara Sea and the Black Sea by the Çanakkale Strait (Dardanelles) and the Istanbul Strait (Bosphorus), respectively. This system is called "Turkish Straits Systems". These consecutive straits, which connect the Mediterranean Sea to the Black Sea, are extremely vital for migrating marine organisms between the two seas and also for maritime transports.

The Mediterranean Sea was defined as a "special area" by the International Convention for the Prevention of Pollution from Ships (MARPOL Convention) in 1983 for their oceanographic and ecological conditions and maritime traffic [1]. The Mediterranean Sea is a landlocked sea with limited water exchange with other seas and oceans, an active deep overturning circulation, a shallow circulation cell and a complex upper layer circulation with several permanent and quasi-permanent gyres [2]. The dominating term in the water balance of the Mediterranean Sea is the exchange with the North Atlantic Ocean through the Strait of Gibraltar. The Mediterranean Sea also exchanges water with the Black Sea through the Turkish Straits System. This flow shows large temporal variability partly associated with variability in the river runoff to the Black Sea and is also influenced on shorter timescales by atmospheric variability. The flows, in both directions, at the Bosphorus exit to the Black Sea are significantly lower, a result of significant recirculation and vertical mixing in the strait system. Although the inflow from the Black Sea to the Mediterranean Sea is small in comparison to the inflow of the Atlantic Water through the Strait of Gibraltar, it is still significant, in particular due to the low salinity of the Black Sea inflow water [2, 3]. The surface of the Eastern Mediterranean Sea is characterized by high salinity, whereas the relatively low salinity inflow of Atlantic Water (AW) through the Strait of Gibraltar dominates the western Mediterranean Sea [3].

The Mediterranean Sea is generally characterized by very low nutrient concentrations, in particular the Eastern Mediterranean [3, 4]. The surface layers are generally almost fully nutrient depleted so that the Mediterranean is an oligotrophic or even ultra-oligotrophic basin. However, an increasing trend for nitrate and phosphate concentrations in the deep water of the western Mediterranean has been observed and attributed to anthropogenic perturbations [3]. The Eastern Mediterranean is known to be one of the oligotrophic seas, where the surface inorganic phosphate and nitrate concentrations vary in the range of 10–20 nM and 0.10–0.30 μM, respectively [5]. The physical characteristics of the Turkish Mediterranean coast such as water and air temperature, sea water salinity, rain, humidity and tide variation are listed in Table 1.

Around 90% of world trade is carried by the international shipping industry. Without shipping the import and export of goods on the scale necessary for the

Table 1 The average values of the physical characteristics of the Aegean and Eastern Mediterranean Sea [6]

Parameters	The Aegean Sea	The Mediterranean Sea
Water temperature (°C) min-max	16–22	16–27
Salinity (%**o**) min-max	30–39	30–39
Tide height (cm) mean	12	18
Air temperature (°C) min-max	10–24	5–25
Rain (mm/day) min-max	0–1.8	0–3.0
Humidity (%) min-max	65–85	65–85

modern world would not be possible. The Regional Seas Programme (RSP) of UNEP (United Nations Environment Programme) covers many regions of the world, resulting in a range of globally comprehensive initiatives for the protection of marine and coastal environments. RSPs have adopted legally binding conventions that express the commitment and political will of governments to tackle their common environmental issues through joint coordinated activities. The Barcelona Convention (1976) is intended to protect the Mediterranean Sea against pollution, while the Regional Marine Pollution Emergency Response Centre (REMPEC) was founded for regional cooperation in the fields of prevention of, preparedness for and response to marine pollution from ships in the Mediterranean Sea.

Maritime trade brings benefits for consumers across the world. There are over 50,000 merchant ships trading internationally, transporting every kind of cargo. The world fleet is registered in over 150 nations and over a million seafarers from almost every nationality. 30% of all international seaborne trade are originating from or directed to Mediterranean ports or passing through its waters. Nearly 25% of the world's sea-transported oil transits from Mediterranean. That is why, maritime traffic and sea-based pollution are among the key causes of pollution of this sea. It is estimated that 2,000 commercial vessels of over 100 tons are at sea at any moment, with a total of 200,000 crossing the Mediterranean annually. Maritime traffic is particularly congested in narrow passages through which ships enter and exit the Mediterranean Sea. This is the case of the Strait of Gibraltar, with around 14 km width, through which almost 61,000 ships of all types transited in 2003. The Suez Canal, 300 m wide, has over 14,500 transit ships during the same year [7]. The Turkish Straits System is another example of maritime traffic congestion, with more than 55,000 ships passing through the Çanakkale Straits in 2008 [8]. Russian and Middle East Asia petroleum transport routes pose threats for the Turkish coasts (see Figs. 1, 2 and 3).

In addition, Turkey has a geopolitical and strategically important location between two continents, and the Turkish Straits are the only way between the Black Sea and the Mediterranean Sea. The Turkish Straits System is one of the busiest natural channels with national and international maritime traffic, and their loads are mainly dangerous goods like crude oil and its products, chemicals, etc.

During the last few decades, the pollution of the world's oceans has become a matter of increasing international concern. Nevertheless, a significant amount of

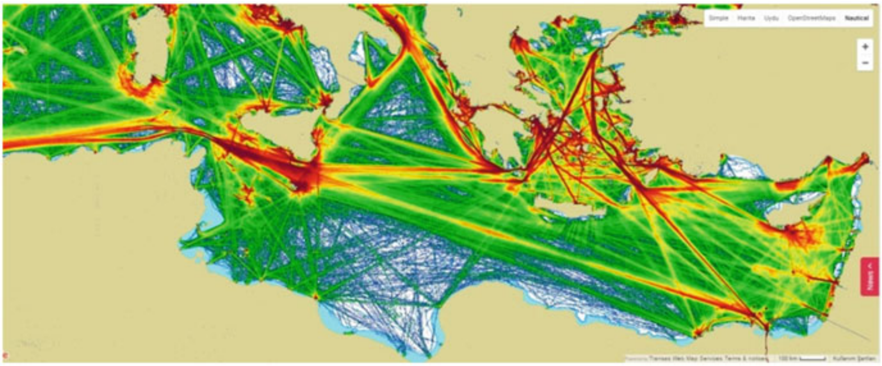

Fig. 1 Intensity of ship traffic in the Mediterranean Sea [9]

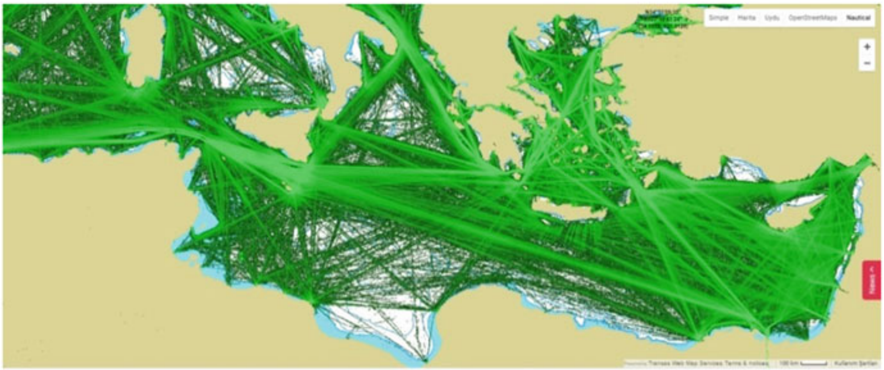

Fig. 2 Intensity of bulk carrier ship traffic in the Mediterranean Sea [9]

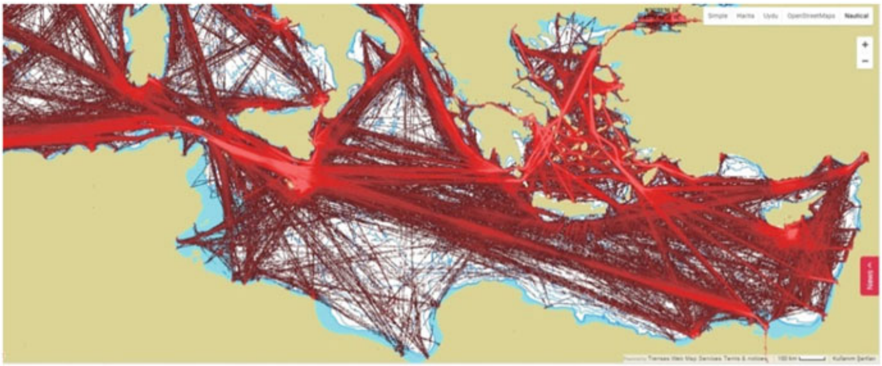

Fig. 3 Intensity of tanker traffic in the Mediterranean Sea [9]

pollution is caused by shipping and maritime activities generally. The best known cause of oil pollution is that arising from tanker accidents [10]. Although this may contribute a comparatively small percentage of the total oil entering the sea in a year, the consequences of an accident can be disastrous to the immediate area, particularly if the ship involved is a large one and the accident occurs close to the coast such as the wrecks of *Torrey Canyon* (1967), *Amoco Cadiz* (1978) and *Exxon Valdez* (1989) [10].

2 Pollution Response Authorities and Their Roles in Turkey

An increasing marine transportation triggered marine incident risks especially since the 1970s when serious marine pollution such as *Amoco Cadiz* (1978), *Independenta* (1979), *Exxon Valdez* (1989), *Nassia* (1994), etc. have occurred. These incidents were taken into account as a signal for the protection of the sea by national and international regulations (e.g. the International Convention on Oil Pollution Preparedness, Response and Cooperation (OPRC Convention), the MARPOL Convention, etc.).

2.1 Organization of Pollution Response in the Turkish Coasts

At the national level, responsible ministries (Ministry of Transport Maritime Affairs and Communication (TM-TMAC) and Ministry of Environment and Urbanization (TM-EU)) in Turkey were regulated under national legislation for *the protection of the seas from oil and other harmful substances pollution* [11]. In addition to the Environment Law, another law related with oil and other harmful substances called in English "Marine Environment Pollution from Oil and Other Harmful Substances and Compensation for Losses in Emergency Response Situations" was adopted in 2005. According to this law, TM-TMAC identified and prepared infrastructure necessities for Turkish coastal areas, while TM-EU prepared laws and regulations according to the level of responsibilities starting from coastal facilities to national levels and even international level. Contingency Plans were prepared by coastal facilities and were approved by the Ministry of Environment and Urbanization. Regional and national Contingency Plans were prepared by the Ministry of Environment and Urbanization. The role of the other ministries, regional governments, cleaning facilities, NGOs and experts (according to specific subjects such as plant, animals, oil response, etc.) was identified and integrated in the Contingency Plans [12, 13].

Law and regulations were adopted according to the national necessities and regional and international responsibilities. With this law, the duties of the related public enterprises and private organizations are regulated. Preparedness activities are carried out and coordinated by TM-TMAC. Emergency response facilities are based on tiered-based approach. Tier 1 consists of small-scale pollution from coastal facilities and ships. Tier 2 is activated in the middle-scale pollution events. Tier 3 is activated in large-scale pollution and covered national capabilities [12, 13]. With the application of this law, it:

1. Prepared the Regional and National Emergency Action Plan related to the oil spill and other hazardous substances.
2. Determined the best place for the local emergency response centre (Antalya), stock piles according to the risk analysis, number of personnel, quality and quantity of equipment and materials, etc.
3. Installed the GIS-based decision support system (YAKAMOS) for decision makers to give the most reliable action during intervention of the marine pollution.
4. Identified and mapped *natural protected areas* (coastal natural gardens, coastal natural protected areas, coastal special protected environments, coastal natural and cultural areas, important bird areas, important turtle areas, important monk seal areas, important plant areas and important sea meadow banks), *important economic activity areas* (marine fishing, fishing closed areas, fishermen ports and fishermen shelters, tourist facilities and tourism areas, beaches, industrial facilities, shipyards, load and passengers ports and marinas and slipway areas) and *human settlement areas* are integrated in the YAKAMOS.
5. Analysed accidental risk for the coastal areas by using related parameters such as maritime traffic, previous accident locations, importance of the coastline, bathymetry, distance from land, etc.
6. Installed a semi-online oil spill model in the YAKAMOS.
7. Analysed geomorphological structure of the Mediterranean coasts according to the Environmental Sensitivity Index (ESI) for choosing the most suitable clean-up techniques during emergency response action.
8. Investigated and identified places of refuge (PoRs) in the Mediterranean coasts for vessels in distress. Turkey has not announced PoRs according to her legislation.
9. Determined ten stock pile stations and one local emergency response centre along the Turkish Mediterranean coasts (included Aegean Sea cost), which was built in Antalya City according to the risk analysis. The number of the stock piles and their contents was determined.
10. Determined background concentrations according to the "polluters' pay" for the petroleum hydrocarbons (dissolved dispersed petroleum hydrocarbons, polycyclic aromatic hydrocarbons (16 compounds)), BTEX, salinity, temperature and dissolved oxygen along the Mediterranean coastal waters of Turkey. In the Aegean Sea and South-eastern Mediterranean, 1 mile off the coast and at 50 nautical mile intervals, between 19 and 22 sampling stations were sampled,

Table 2 Measured ranges of background pollutant concentrations in the Aegean Sea and the South-eastern Mediterranean Sea [6]

Parameters (µg/L)	Aegean Sea		Mediterranean Sea	
	Surface min-max	10 m min-max	Surface min-max	10 m min-max
Naphthalene	0.001–0.31	0.001–0.07	0.001–0.28	0.001–0.12
Acenaphtylene	0.001–0.11	0.001–0.06	0.001–0.09	0.001–0.12
Acenaphthene	0.001–0.35	0.001–0.07	0.001–0.08	0.001–0.09
Fluorene	0.001–0.14	0.001–0.07	0.001–0.14	0.001–0.1
Phenanthrene	0.001–0.02	0.001–0.02	0.001–0.03	0.001–0.03
Anthracene	0.001–0.05	0.001–0.04	0.001–0.06	0.001–0.04
Fluoranthene	0.001–0.03	0.001–0.01	0.001–0.02	0.001–0.04
Pyrene	0.001–0.015	0.001–0.02	0.001–0.04	0.001–0.02
Benz(a)anthracene	0.001–0.01	0.001–0.01	0.001–0.01	0.001–0.006
Chrysene	0.001–0.006	0.001–0.003	0.001–0.01	0.001–0.003
Benzo(b)fluoranthene	0.001–0.02	0.001–0.03	0.001–0.03	0.001–0.01
Benzo(k)fluoranthene	0.001–0.04	0.001–0.02	0.001–0.09	0.001–0.1
Benzo(a)pyrene	0.001–0.04	0.001–0.02	0.001–0.03	0.001–0.01
Dibenz(a,h)anthracene	0.001–0.09	0.001–0.01	0.001–0.1	0.001–0.07
Benzo(g,h,i)perylene	0.001–0.03	0.001–0.03	0.001–0.05	0.001–0.07
Indeno(1,2,3-c,d)pyrene	0.001–0.007	0.001–0.002	0.001–0.01	0.001–0.003
PAH (µg/L) (total of 16 compounds)	0.001–1.39	0.003–0.93	0.02–0.44	0.02–0.53
Total dissolved dispersed petroleum hydrocarbons (µg/L)	0.17–2.65	0.11–1.69	0.11–1.41	1.05–0.12
BTEX (µg/L)				
Benzene	<0.5	<0.5	<0.5	<0.5
Toluene	0.5–0.98	0.5–3.47	<0.5	<0.5
E-Benzene	<0.5	<0.5	<0.5	<0.5
Xylene	<0.5	<0.5	<0.5	<0.5

respectively, from surface to 10 m depth, to define background concentrations of the areas (see Table 2).

3 Oil Pollution Monitoring Practice and Existing Systems

The representatives of the organizations and institutions who serve in Contingency Plans were trained and have observed how these plans are applied. Three theoretical exercises in İzmir, Antalya and Mersin were carried out. In order to see how the plans were applied, a regional practical exercise was carried out in Çanakkale, and a national practical exercise was carried out in Antalya with the participation of relevant participants. According to the law and related regulations, two exercises are carried out twice yearly for coastal facilities, and ones every 3 years for national exercises.

The framework of the oil spill emergency response exercises were determined by law. With this law, the type of exercises, number of theoretical and practical exercises, stages and periods of the exercises were determined.

3.1 Aerial Surveillance

Surveillance at sea can be carried out using an aircraft or a helicopter. Airborne remote sensing equipment may be of value in this regard. Aerial surveillance allows the movement and extends the oil slick to be plotted in order that appropriate response action may be taken. Aerial surveillance is also useful for determining the overall extent of shoreline pollution. Continuous surveillance may be required during some phases of the clean-up operation.

Visual observation of floating oil from the air is the simplest method of determining the location and scale of an oil spill. The purpose of aerial surveillance is to detect oil spills and thus prevent violations of the existing regulations on prevention of pollution from ships. Such illegal spills represent a form of pollution which threatens the marine environment of the Mediterranean. The Turkish Coast Guard has the capability to observe marine pollution. Coast guard helicopters are monitoring the marine environment when patrolling over the Aegean and Mediterranean Seas. In addition, some of the local municipalities have aerial surveillance aircraft.

3.2 Satellite Monitoring

Satellite-based remote sensing systems can also detect oil on water. The sensors on board those satellites are either optical (detecting in the visible and near infrared bands of the spectrum) or radar based. Satellite radar images provide day and night coverage independent of fog and cloud cover. Satellite optical images can be acquired only in daylight and cloud-free conditions, but they provide very-high-resolution colour images of ports, coastlines and targeted activities at sea.

During the last decade, satellite monitoring has become an integral part of oil pollution surveillance. However, all the satellite-based detections have to be checked by either an aircraft, a helicopter or a vessel. As a rule of a thumb, it has been estimated that about 50% of the possible oil spills detected by the satellite service are identified as oil by the verification flight [14]. Satellite images can be considered as an imported supplementary tool for aerial survival activities. The satellite service of the European Maritime Safety Agency (EMSA) may serve to identify oil spill to support the aerial environmental surveillance. The European satellite-based oil spill detection service, *CleanSeaNet*, operated by EMSA provides access to oil spill satellite surveillance. Istanbul Technical University (ITU) Research and Application Center for Satellite Communications and Remote Sensing (CSCRS) is working on oil spill detection by using radar data. To detect ship-source pollution at the open seas and report them to the relevant departments, real-time data are processed and analysed (within 30 min after satellite overpass) by CSCRS.

4 Amount of Oil Pollution

4.1 *Maritime Accidents*

During the last few decades, the pollution of the world's oceans has become a matter of increasing international concern. Nevertheless, a significant amount of pollution is caused by shipping and maritime activities generally. The best known cause of oil pollution is that arising from tanker accidents [10]. Although this may contribute a comparatively small percentage of the total oil entering the sea in a year, the consequences of an accident can be disastrous to the immediate area, particularly if the ship involved is a large one and the accident occurs close to the coast such as, *Torrey Canyon* (1967), *Amoco Cadiz* (1978), *Independenta* (1979), *Exxon Valdez* (1989) and *Prestige* (2002) [10, 15].

The serious marine pollution incidents related with maritime accidents have forced countries to take precaution for protection against and diminution of the impacts of such incidents. Every serious accident forced the authorities to adopt new regulation for preventing accidents and protecting marine environment (Table 3).

There has been no significant accident resulting in marine pollution along the Turkish Mediterranean coastal areas including the Aegean Sea. However, the international waters of the Eastern Mediterranean were polluted by two oil spill

Table 3 Accidents regulations linkages

Accident	New regulation
Titanic (1912)	First SOLAS (International Convention for the Safety of Life at Sea) convention was driven before IMO and adopted in 1914 COLREG (Preventing Collisions at Sea)
Torrey Canyon (1967)	MARPOL 1973/75 International Convention for the Prevention of Pollution from Ships
Amoco Cadiz (1978)	Significant updates to both MARPOL and SOLAS And Port State Control established
Exxon Valdez (1989)	Oil Pollution Act (OPA) 1990; all tankers entering US waters must be double hulled
Erika (1999)	Triggered a discussion as to regulate the situation of a ship in need of assistance
Castor (2000)	IMO documented guidelines on Places of Refuge for Ships in Need of Assistance were adopted (Resolution A.949(23)) in December 2003
Prestige (2002)	In parallel, EU Directive 2002/59 of 27 June 2002 establishing a Community vessel traffic monitoring and information system was adopted

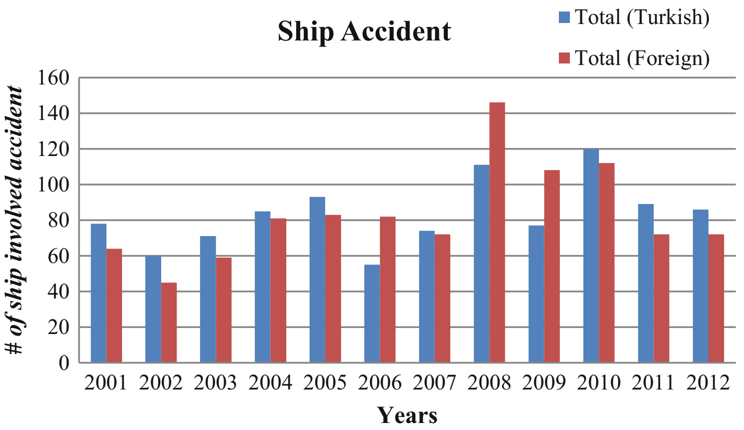

Fig. 4 Ships involved accidents in 2001–2012 in the Turkish Search and Rescue Zone [15]

incidents. One of them was an oil spill from the Jiyeh electric power plant (30 km south of Beirut) on 13–15 July 2006 as a result of bombings. Part of the heavy fuel oil stored in the power plant burned. According to the Lebanese authorities' estimations, between 10,000 and 15,000 tonnes of unburned fuel oil were spilled onto the shoreline and drifted at sea, pushed by south-westerly winds. The pollution soon extended to impact almost half of the 200 km length of the Lebanese coastline. Several types of substrates were affected: sand, stones, rocks and port facilities [16]. The other oil spill incident was in the Northern Cyprus coast (Kalecik City in the Gulf of Gazimagusa) on July 2013. Northern Cyprus coastal areas were polluted with instantaneous release of 100 tonnes of heavy fuel oil when a tanker was off-loading at a power plant [17].

The Aegean coast was polluted while a Panamanian gas tanker was in dock at Perama Shipyard (Greece). On 24 July 2008, during repairs, it suffered an explosion and caught fire. There was no marine pollution declared; however, eight crew members were killed, four went missing and four were injured [16].

Turkish flag and foreign flag ship accidents in Turkish coastal waters are demonstrated in Fig. 4. Both flagged ship accidents are included in the peak appearing at 2008, while 2012 identified a trend of a decrease in accidents. The locations of the accidents are shown in Fig. 5. The Aegean and Eastern Mediterranean coasts are very vulnerable to oil pollution because of natural protected areas, with monk seal habitats, sea turtle habitats, beaches, etc. being very dense in this region. Fortunately, maritime-based oil pollution did not affect these areas.

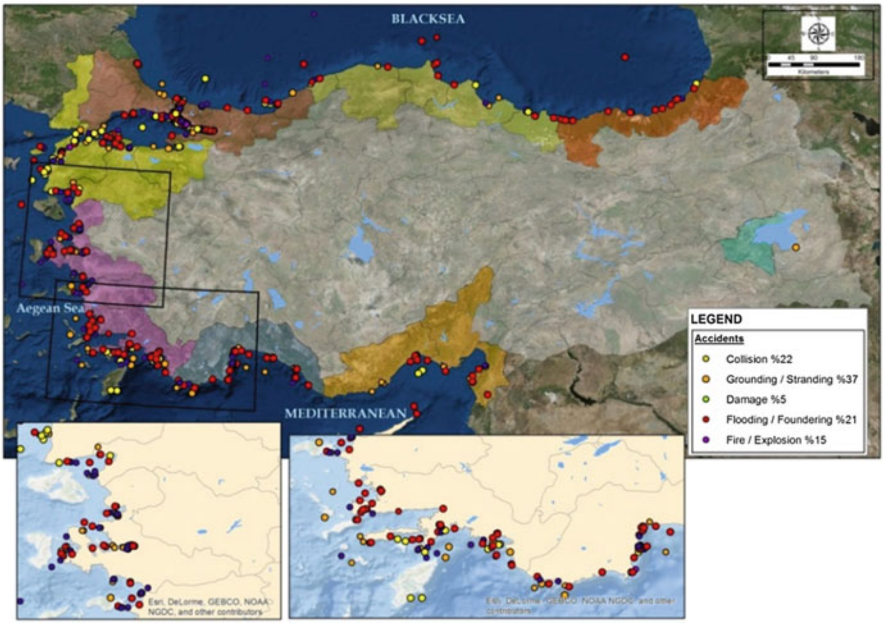

Fig. 5 Ship accidents along the Turkish coasts in the Black, Aegean and Mediterranean Seas [18]

4.2 Operational Discharges from Vessels

There are two refineries and many harbours, marinas and other coastal facilities which have potential oil pollution sources for the Eastern Mediterranean coasts of Turkey. Harbours, which have large petroleum handling capacities, may present higher environmental pollution risks according to their handling capacities. Two refineries (in İzmir and in İskenderun) have handling capacities and pollution risks that are much higher than the other harbours. The Baku–Tbilisi–Ceyhan (BTC) pipeline passes through İskenderun City, and it also has a very high pollution risk. According to the risk analysis result, the Aegean Sea coastal areas have higher risk based on intensity of pollution (because of protected natural areas), but refineries also have a higher risk based on frequency of pollution (based on loads and maritime traffic) (see Fig. 6). The North-east Mediterranean and Aegean Sea coasts' risk assessments were determined and mapped in Fig. 7.

4.3 Penalties for Oil Discharges

In Turkey, environment law was changed for the revision of the administrative penalty fee in 2006. According to this revision, environmental damage based on oil pollution for loading facilities is punished with penalty fee according to ship gross

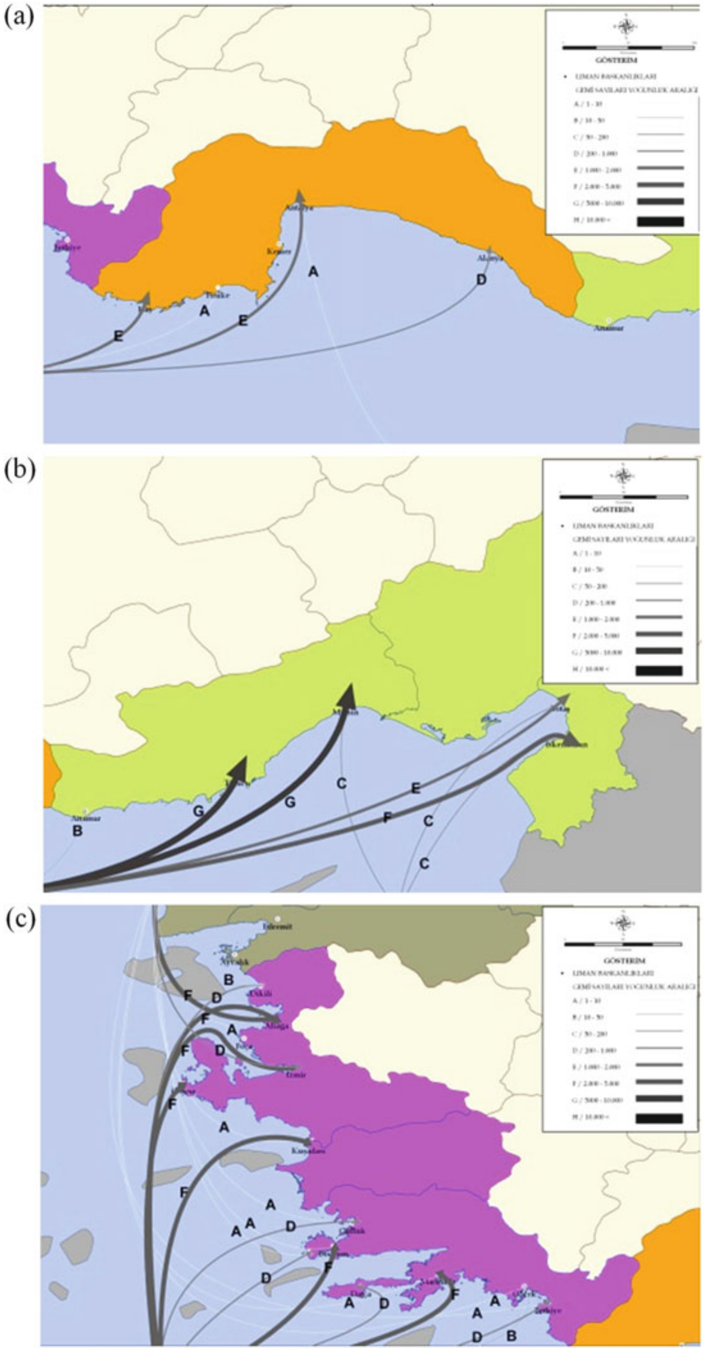

Fig. 6 Maritime traffic pressure in the Aegean Sea and South-eastern Mediterranean Sea [12] (**a**) shows western range of the Turkish Mediterranean Sea coast, (**b**) shows eastern range of the Turkish Mediterranean Sea coast and (**c**) shows Turkish coast along the Aegean Sea

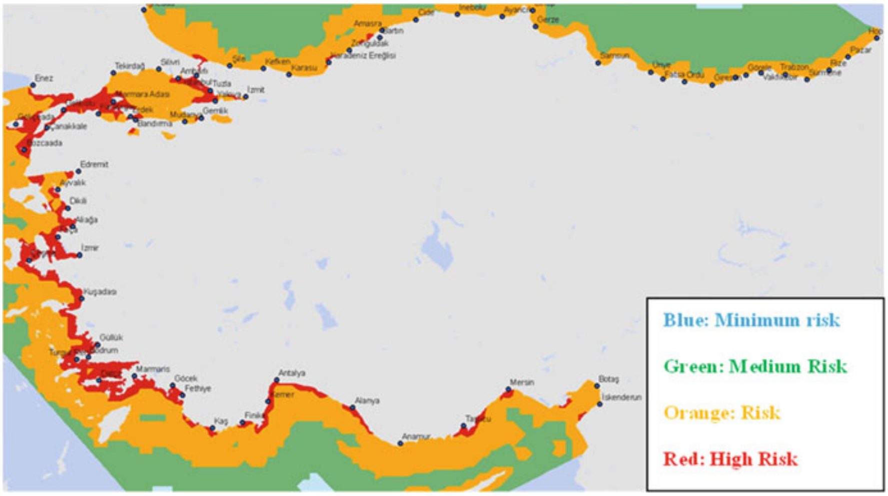

Fig. 7 Risk map of the Turkish coastal waters [18]

tonnage (for ≤1,000 gross tonnage, 8,178 TL/tonnage; for 1,000 > –5,000 ≤ gross tonnage, 10,218 TL/tonnage; for >5,000 gross tonnes, 10,414 TL/tonnage). Petroleum products and wastes such as sludge, bilge slops, etc. are also punished with penalty fees. There is another article in the law related to the response of their pollution and recoveries. If polluter is responsible for their pollution and cleaned area, at that time, the penalty fee is reduced at ratio 1:3. The accidental oil pollution and cleanup environment and compensation of the losses are controlled by Law Number 2872 which is called "Environmental Law and its Notification 2016/1" [19].

5 Impact on the Environment

In general, oil spills can affect marine organisms either externally or internally. Digestion or inhalation of the oil by the organism could be an example for the internal exposure, and external exposure affects the skin, carapax, stem, leaf and eye. Oil can also smother some small species of fish, invertebrates, birds or mammals and coat their skin, feathers, fur or gills to stop the maintain their body temperatures. Some of marine organisms are relatively immobile such as bivalves and molluscs that are filter feeders, and this means that they may not be able to avoid exposures to oil. In addition, they do not possess the same suite of enzymes in their systems to breakdown contaminants unlike some fish or other vertebrates. The type of oil spilled behaves differently in the environment, and marine organisms are affected differently by different types of oil. In general, oil is classified as a "light oil" such as fuel oil and "heavy oil" such as crude oil. Light oil is easily evaporated and more toxic, although heavy oil looks black and sticky. They can persist in the environment for months or even years if not removed. Heavy oils can be very persistent and be less acutely toxic but may have some chronic effects like cancer and mutation [20].

Some of hazardous substances were measured in the Mediterranean Sea for the determination of the background concentrations would be occurred accidentally [6]. In the Eastern Mediterranean Sea dissolved and dispersed petroleum hydrocarbons, potential carcinogen/mutagen PAHs and other pollutant concentration were low in open sea, but in the gulfs and heavily industrial areas, like refineries areas, concentrations were relatively high (Table 2). When an accident happens, many natural protected areas and economically important areas such as fish cages and fishing areas are impacted for a long time. These coastlines are busy with tourism and marine aquaculture activities (Fig. 8).

6 Principles of the Oil Pollution Response Activities

Turkey has many laws and regulations related with pollution control, diminishing wastes and penalties according to the “polluter pays” opinion. Protection of the seas from petroleum pollution is taken into account since 2005. Law and regulations were adopted according to the national necessities and regional and international responsibilities.

In the national level, responsible ministries (TM-TMAC and TM-EU) in Turkey were regulated under national legislation for the protection of the seas from oil and other harmful substances and pollution. For this purpose, the preparedness of the infrastructure such as stock piles and emergency response centres and decision support system installation are TM-TMAC responsibilities. However, preparation of the laws and regulations are TM-EU responsibilities [13].

According to the Turkish Law for the protection of the seas from petroleum pollution called “Law No: 5312, Fundamentals of Emergency Responses and Loss Compensation in Marine Environment Pollution Caused by Petroleum and Other Harmful Substances”, Turkish national and local Contingency Plans were prepared on a city basis. City-based Contingency Plans were prepared for seven cities located along the shorelines of the South-east Mediterranean Sea and the Aegean Sea coast. The National Contingency Plan organization flowchart is shown in Fig. 9.

The Contingency Plan consists of the coordination and the operation units, and their responsibilities in the plans are identified [13]. In a situation where the accident is on a national scale, the National Contingency Plan is activated, and general coordination is carried out by the Ministry of Environment and Forestry. Many related guidelines based on national and local Contingency have been prepared that have:

- Defined marine and shoreline response system and general shoreline cleaning methods

Fig. 8 Natural protected areas and important industrial areas [12]. The upper image shows marine protected areas in the coastal waters of Turkey. The lower image shows economic activity areas in the coastal waters of Turkey

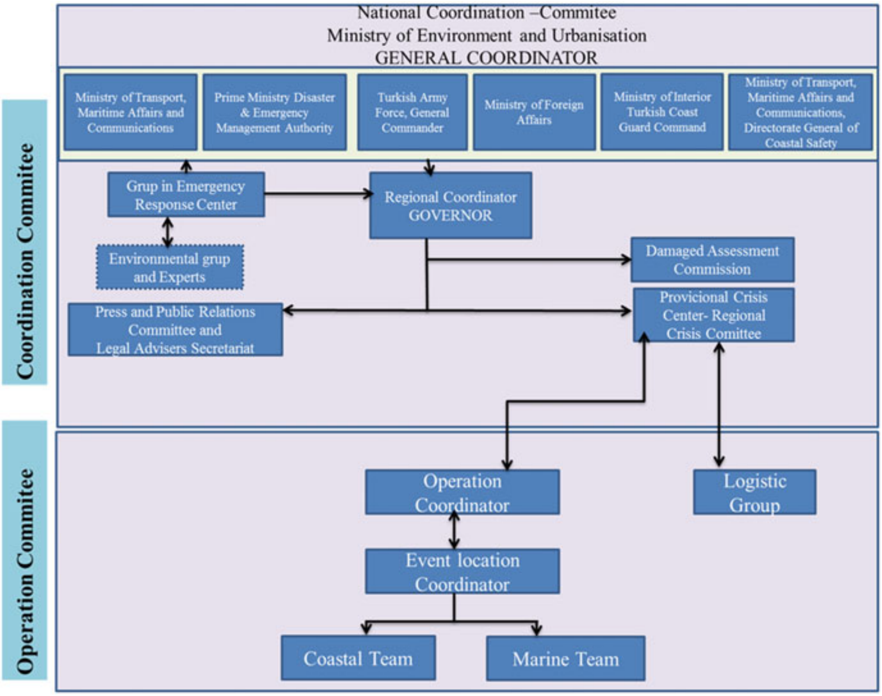

Fig. 9 National Contingency Plan [13]

- Determined the rudiment requirements of the acceptance of vessels into the places of refuge, in accordance with national and international regulations
- Defined the use of dispersants in emergency response situations
- Defined the transportation and elimination of the waste materials during/after accidents
- Terminated response operations and determined rehabilitation operations
- Determined the compensation demands and a comparative analysis between the international agreements and national regulations within the framework of the Contingency Plan
- Identified and documented an emergency response situation, communication among the teams and informing the public

7 Conclusions

Turkey has a very good but risky geographical position with coastlines on the Black, Aegean and Mediterranean Seas and major shipping routes through the Çanakkale Strait (Dardanelles) and the Istanbul Strait (Bosphorus). This position, with its high levels of maritime traffic, threatens its coasts, natural, and industrially important areas with the risk of pollution from petroleum and petroleum-related products. Turkey, like other countries, has prepared its infrastructures and contingency plans for such pollution. In Turkey, all components for pollution preparation are integrated into a decision support system which is called YAKAMOS. National, regional and international requirements for the pollution prevention of the Turkish surrounded seas are controlled and protected with these preparations.

References

1. IMO (2016) http://www.imo.org/en/OurWork/Environment/SpecialAreasUnderMARPOL/Pages/Default.aspx
2. Unluata U, Oguz T, Latif MA, Ozoy E (1990) On the physical oceanography of the Turkish straits. In: Pratt LJ (ed) The physical oceanography of sea straits, NATO ASI Series. Kluwer Academic Publishers, Dordrecht, pp 25–61
3. Tanhua T, Hainbucher D, Schroeder K, Cardin V, Alvarez M, Civitarese G (2013) The Mediterranean Sea system: a review and an introduction to the special issue. Ocean Sci 9: 789–803. doi:10.5194/os-9-789-2013
4. Yılmaz A, Tuğrul S (1998) The effect of cold- and warm- core eddies on the distribution and stoichiometry of dissolved nutrients in the northeastern Mediterranean. J Mar Syst 16:253–268
5. Doğan Sağlamtimur N, Tuğrul S (2008) Doğu Akdeniz’de Akarsu Etkisindeki Kıyısal Bölge Sularının Özelliklerinin Açık Denizdekiler ile Karşılaştırılması. Ekoloji 17(68):17–23
6. AMM (2008) Acil Müdahale Merkezlerinin Oluşturulması Ve Muhtelif Denizlerimizde Mevcut Durumun Tespiti İçin Fizibilite Çalışması (Constitution of the Emergency Response Centers and Determination of the Present Situation of the Turkish International Waters for the Feasibility Works), Project No. 506 G 217. 72 pp. Interim Report-2. March 2008
7. UNEP (2016) http://www.unep.org/regionalseas/programmes/unpro/mediterranean/
8. AMM (2007) Acil müdahale merkezlerinin oluşturulması ve muhtelif denizlerimizde mevcut durumun tespiti için fizibilite çalışması (constitution of the emergency response centers and determination of the present situation of the Turkish international waters for the feasibility works), Project No. 506 G 217. 149 pp. Interim Report-1 April 2007
9. MVT (2013) http://www.marinevesseltraffic.com/2013/06/mediterranean-sea-marine-traffic.html
10. IMO (1998) Focus on IMO. MARPOL 25 years. 33 pp
11. Law (2005) Law on Marine Environment pollution from Oil and Other Harmful substances and Emergency Response and Damages Compensation. Offcial Newspaper No. 5312, 03 March 2005, Issue 25752 (in Turkish)
12. AMM (2010) Acil Müdahale Merkezlerinin Oluşturulması Ve Muhtelif Denizlerimizde Mevcut Durumun Tespiti İçin Fizibilite Çalışması (Constitution of the Emergency Response Centers and Determination of the Present Situation of the Turkish International Waters for the Feasibility Works), Project No. 506 G 217. 149 pp. Final Report November 2010
13. AMP (2011) Deniz Çevresinin Petrol Ve Diğer Zararlı Maddelerle Kirlenmesinde Acil Durumlarda Müdahale Ve Zararların Tazmini Esaslarina Dair Ulusal Acil Müdahale Planı (National Emergency Response Plans). Final Report. 285 pp. September 2011, Ankara
14. Haapasaari H, Tahvonen K (2013) Oil pollution in waters of Finland in oil pollution in the Baltic Sea. In: Barcelo D, Kostianoy AG (eds) The handbook of environmental chemistry, vol 27. Springer, pp 54–59. doi:10.1007/978-3-642-38476-9
15. MTMAC (2013) Transportation accident statistics. Accident free roads, safe transportation. Ministry of Transportation, Maritime Affairs and Communications, Accident Investigation Board. Ankara, Turkey, 58 p (in Turkish)

16. CEDRE (2015) http://wwz.cedre.fr/en/Our-resources/Spills/Spills/Lebanon-conflict
17. Reuters (2013) http://www.reuters.com/article/cyprus-spill-idUSL, 6N0F N1Z320130717
18. AMM (2008) Acil Müdahale Merkezlerinin Oluşturulması Ve Muhtelif Denizlerimizde Mevcut Durumun Tespiti İçin Fizibilite Çalışması (Constitution of the Emergency Response Centers and Determination of the Present Situation of the Turkish International Waters for the Feasibility Works), Project No. 506 G 217. 72 pp. Interim Report-4. August 2008
19. Environment Law and its notification (2015) Environment Law 2872 and its notification (number 29576), 2015. (2872 Sayili Çevre Kanunu Uyarinca Verilecek İdari Para Cezalarina İlişkin Tebliğ (2016/1)). http://www.resmigazete.gov.tr/eskiler/2015/12/20151228-16.htm
20. NOAA (2016) http://response.restoration.noaa.gov

Oil Pollution in the Marine Waters of Israel

Ran Amir

Abstract The Eastern Mediterranean Sea, to which the State of Israel is a part of, is an area susceptible to pollution by and large because of the extra dense transport of oil products as well as oil and gas exploration and production activities. As a party to the main international legal instruments aimed at preparing to and combating oil pollution emergencies, Israel is striving continuously to have in place the structural, procedural, technical, and human means and measures that will enable it to respond to such events effectively. The basic legal framework was derived from the international agreements, and the budgets are allocated from a special fund. To this end the Marine Environment Protection Division of Israel's Ministry of Environmental Protection is the national competent authority for many of the marine environmental protection subjects, as well as oil pollution preparedness and response. Although a response system to an oil spill must be in place, prevention at source always proves to be the most cost-effective and environmentally sound strategy in the marine environmental management. That is the reason Israel demonstrates rather rigorous Port State Control efforts of the proper regulations and standards, in order to create the appropriate deterrence effect. Last but not least, enforcement measures against polluters are taken on regular basis.

Keywords Barcelona convention, Israel, MARPOL, MEPD of IsraelMoEP, National contingency plan, Oil pollution preparedness and response, OPRC 1990

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Contents

1 Characteristics of the Eastern Mediterranean and of Israel

Israel stretches along 195 km of coastline on the Mediterranean Sea and 14 km on the Gulf of Aqaba in the Red Sea. All liquid and solid fuel energy requirements (oil and coal) are imported and transported by ocean-going tankers and ships, arriving into ports and oil terminals along the Mediterranean Sea and at Eilat Port, in the Gulf of Aqaba. Since 2002 and mostly since 2012, natural gas has been flowing into Israel from recent reservoir findings in the Israeli EEZ, through marine pipelines which are transporting the gas from two production platforms.

Natural, economic, and cultural resources are abundant along these coastlines; therefore, a major oil spill could result in a catastrophic event.

Figure 1 illustrates the space in the Levantine Basin between Israel, Cyprus, Lebanon, Gaza, and Egypt. The colors represent the subsea gas fields that have been

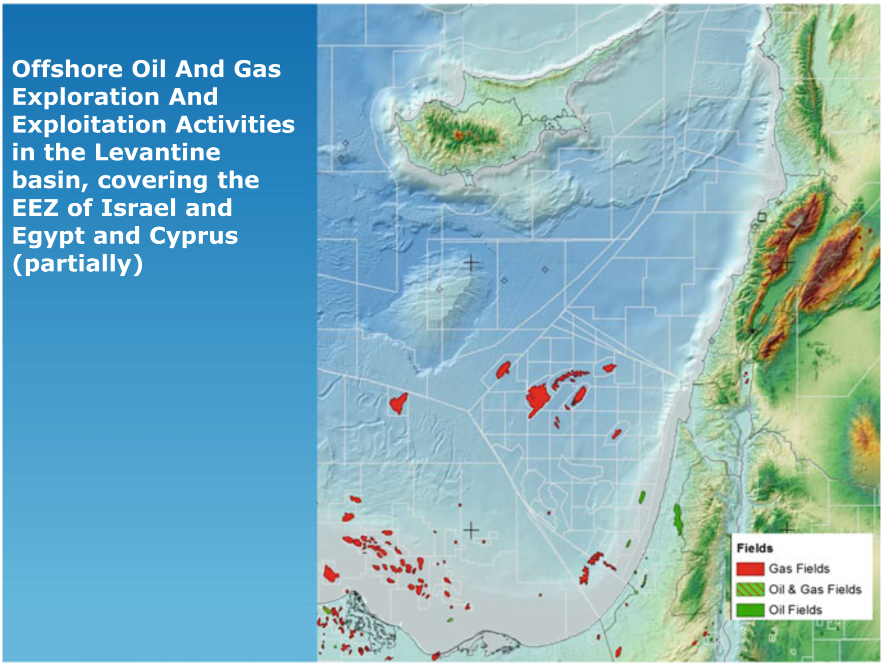

Fig. 1 The Levantine Basin area, including subsea fields and EEZs. Source: Presentation by Yoav Ratner, MEPD, 6/4/2017, Ravenna Italy

discovered so far. Also the rough white lines represent the EEZ limits between countries.[1]

1.1 *High Risk Area*

Along the Mediterranean shores of Israel, the major risk to the marine environment stems from importing oil by ocean-going vessels and offloading it into onshore terminals. About 10 million tons of crude oil and about 4 million tons of oil products are imported, annually. Also about 2 million tons of oil products are exported annually. Due to predominantly westerly winds and south to north sea currents, in the Eastern Mediterranean Basin, almost all oil spills tend to drift toward the Eastern MED coastline, creating a possible threat of pollution to Sinai, Gaza, Israel, Lebanon, and Syria.

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[1] Not all EEZ borders are agreed and finalize according to the international law. The EEZ between Israel and Cyprus is agreed and signed in 2014.

The major sources that were identified, during the preparatory work of risk assessment and analysis done in Israel between the late 1990s until 2007, are:

1. *Open sea oil terminals* – Along the Mediterranean coastline are located two crude oil terminals Haifa (oil infrastructures) and Ashkelon (EAPC, Eilat Ashkelon Pipeline Company) and two product terminals (Hadera and Ashdod). In Eilat – on the Red Sea – there is also one crude oil terminal.
2. *Oil terminals within closed ports* – Along the Mediterranean Coast of Israel exist two product terminals, Haifa Port and Kishon Port.
3. *Oil and gas exploration and exploitation activities* – Intensive prospecting and drilling operations are being performed in recent years along the Israeli Mediterranean continental shelf, mostly at its EEZ. With its blessed outcome of freeing the Israeli market of total dependence of outer energy sources and cleaner energy production, these pose an additional oil spill threat. During the period 2008–2012, there has been the discovery of the gas fields of Tamar, Dalit, Karish, and Tanin and the largest prospect of gas in the Leviathan field. All findings are ultra-deep water gas prospects of 1.5 km water depth and more. In addition, in some of these reservoirs, there is also a relatively high probability of oil reservoirs beneath the gas.
4. *Shipping activities* within the main ports are mostly the source of small to medium and relatively frequent oil pollution incidents. Among these accidents the most frequent are the result of de-ballasting operations, bunkering, small-scale collisions, and on-shore oil facilities located in proximity to coast or in ports.
5. According to REMPEC,[2] the chances of a major oil spill in the eastern basin of the Mediterranean are relatively high, since about 30% (by volume) of the world total marine trade and about 20% (by volume) of the world marine oil trade are transported across the Mediterranean.

Figures 2, 3, 4, and 5 are taken from REMPEC's MEDGIS-MAR[3] tool and show the intensity and location of the characteristics of the Eastern Mediterranean waters.

1.2 Territorial Waters and the Exclusive Economic Zone (EEZ)

While the land area of Israel is around 22,000 km^2, the territorial waters cover an area of 4,060 km^2 (18.5% of the land area). However, the total marine area of the exclusive economic zone plus the territorial waters together covers some 30,000 km^2, which is around 136% of the total land area of the country.

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[2] REMPEC – Regional Marine Pollution Emergency Center, for the Barcelona Convention's contracting parties. http://www.rempec.org/.

[3] http://medgismar.rempec.org/.

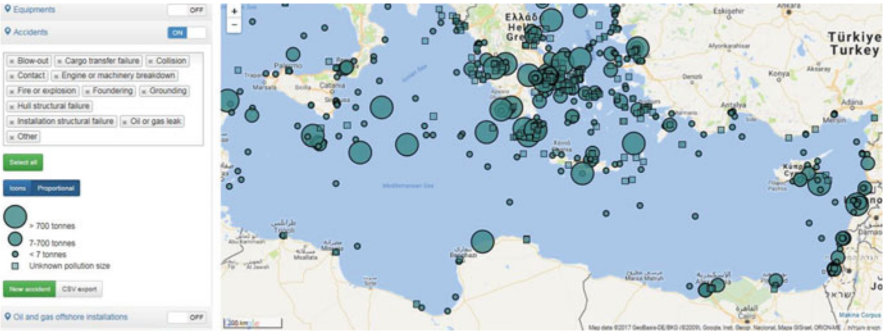


Fig. 2 Density of oil pollution accidents in the Eastern Mediterranean in 1990–2013. Source: REMPEC MEDGIS-MAR tool [24]

Fig. 3 Oil terminals and ports in the Eastern Mediterranean in 2013. Source: REMPEC MEDGIS-MAR tool [24]

Taking into account the above, the marine area of the Mediterranean Sea of Israel (EEZ + territorial waters) and its inherent coastline, contains:

1. Marine and coastal nature reserves
2. Five major coastal desalination plants producing drinking water, annually around 550 Million m^3 (80% of Israel's drinking waters, supplying also to Gaza and Jordan)
3. Three major electric power stations
4. Two main commercial ports to which around 95% of commodities are imported to Israel
5. Energy source for both natural gas coal and imported oils
6. Major leisure place for public use;
7. Intensive yachting, leisure craft, and water sports
8. Fishing areas and developing aquaculture grounds for extensive use

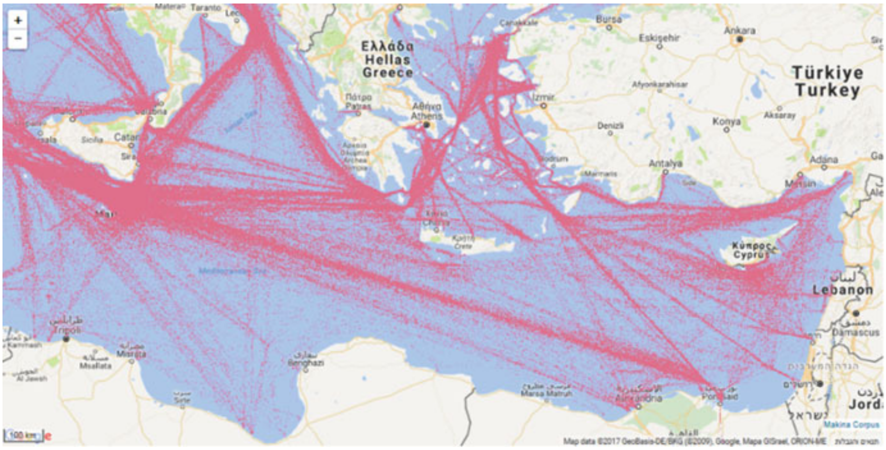


Fig. 4 Oil tankers route density in the Eastern Mediterranean, based on AIS data for 2013. Source: REMPEC MEDGIS-MAR tool [24]

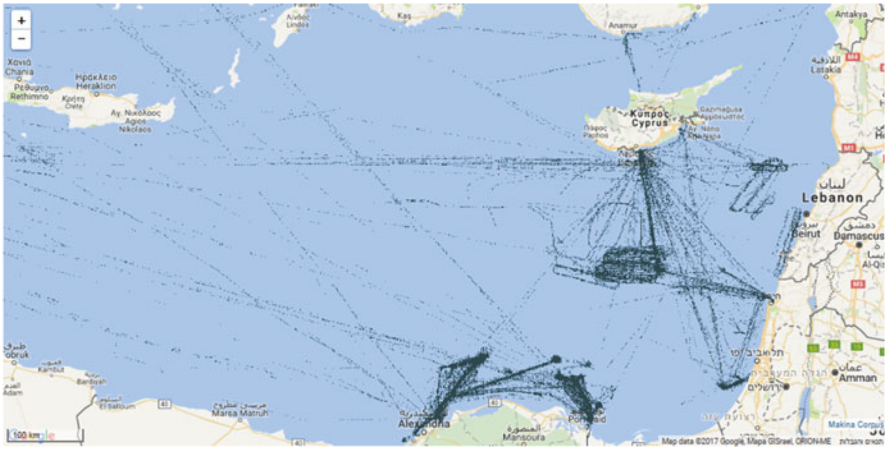


Fig. 5 Offshore activities in the Eastern Mediterranean, based on AIS data for 2013. Source: REMPEC MEDGIS-MAR tool

Israel's Mediterranean and Red Sea coastlines are among the country's most valuable natural assets. Israel's Mediterranean coastline extends along nearly 190 km from north to south. Israeli Red Sea coastline stretches for around 14Km and possess the most northern rich and live coral reef in the world.

About 70% of Israel's population lives within 15 km of the Mediterranean coastline, and the country's major economic, commercial, and tourist activity is concentrated along the shores.

Protecting the sea from pollution and from the conflicting demands of urbanization, industrialization, agriculture, recreation, and tourism is a national priority.

2 International Conventions and Agreements for the Control of Marine Oil Pollution

International conventions that deal with marine oil pollution prevention and combating, to which Israel is committed, are as follows:

- International Convention on Oil Pollution Preparedness Response and Cooperation (OPRC 1990) [1].
- Convention for the Protection of the Mediterranean Sea Against Pollution 1976 (hereinafter, the Barcelona Convention) [2] and its 2002 Protocol – Protocol Concerning Cooperation in Preventing Pollution from Ships and, in Cases of Emergency, Combating Pollution of the Mediterranean Sea, 2002 (Prevention and Emergency Protocol) [3].
- The International Oil Pollution Compensation Funds (IOPC Funds), namely, the 1992 Civil Liability for Oil Pollution Damage Convention (CLC) [4] and the 1992 International Fund for Compensation for Oil Pollution Damage (FUND) [5].
- The International Convention for the Prevention of Pollution from Ships (MARPOL) – Annexes 1, 2, 3, and 5 (4 and 6 are in the process of ratification) [6].

International subregional agreements to which Israel is committed are as follows:

- An agreement on the subregional plan for preparedness and response to pollution of the Mediterranean Sea between Israel, Egypt, and Cyprus – Agreement on the Sub-Regional Contingency Plan for Major Marine Pollution Incidents, 1995 [7]. This SCP, although never formally approved by relevant parliaments in Egypt and Cyprus, is considered in Israel as a model trilateral arrangement that may also come useful if oil pollution will occur. This plan was established within the framework of the Barcelona Convention and with the assistance of the European Community and REMPEC. The main purpose of the plan was the establishment of a mechanism of mutual assistance which will facilitate cooperation and mobilization of equipment between Egypt, Israel, and Cyprus to coordinate their response and action in cases of incidents of sea pollution which endanger their coastlines or their territorial waters.
- Annex IV “Environmental Quality” of 1999, to the Israel-Jordan Peace Treaty of 1994 and a trilateral plan for the Gulf of Aqaba between Israel, Jordan, and Egypt (which is in the establishment stage) – Israel-Jordan Peace Treaty Annex IV “Environment” and Upper Gulf of Aqaba Oil Spill Contingency Plan. Within the cooperation between Prince Hamza Oil Combating Unit of Aqaba Port and the Eilat Marine Pollution Prevention Station of the MEPD, there have been annually conducted oil pollution exercises for the purpose of mutual trainings, since 2002. Figure 6 demonstrates cooperation in an exercise, where the Jordanian OCV HAMZA1 and the Israeli SVIVA 2 are at berth, Eilat Marine Pollution Prevention Station, 2008.

Fig. 6 Jordan-Israel Cooperation Exercise, 2007. Source: Ran Amir, MEPD, Israel

- In 2016 the Ministers of Environment of Greece, Cyprus, and Israel had declared their wish for a new Sub-Regional Contingency Plan between the three countries to fight marine oil pollution, among other things. This trilateral agreement is foreseen to be signed by the countries by the end of 2017.
- Paris MoU on Port State Control is the main guiding instrument according to which Israel's Administration of Shipping and Ports are inspecting calling vessels to Israeli ports [8].

2.1 State of Ratification of Multilateral Environmental Agreements

The relevant international agreements and conventions concerning marine oil pollution (for Israel) are presented in Table 1.

Table 1 International agreements ratified by Israel

Date and city of convention	Convention/protocol/agreement	Ratification by Israel/date
1978 London	Protocol – Prevention of Pollution from Ships (MARPOL)	1983
	MARPOL Annex I (oil)	1983
	MARPOL Annex II (noxious liquids)	1987
1976 Barcelona, 1995 Amended Convention	Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean	1978 Amended convention – 2005
1976 Barcelona	Protocol for the Prevention of Pollution of the Mediterranean Sea by Dumping from Ships and Aircraft	1984
1976 Barcelona, 2002 Malta	Protocol Concerning Cooperation in Preventing Pollution from Ships and, in Cases of Emergency, Combating Pollution of the Mediterranean Sea	1978 – Barcelona, Emergency Prevention Protocol – 2003
1990 London	International Convention on Oil Pollution Preparedness, Response, and Cooperation (OPRC)	1999

3 The National Legislative Framework

In this section the main legal tools and frameworks which are used to establish Israel's commitment to prepare, response, and combat all sources of pollution to the marine environment and, in particular, from oil are outlined.

3.1 Prevention of Sea Water Pollution by Oil Ordinance, 1980 [9]

This law provides the legal basis for controlling marine oil pollution. It forbids discharge of oil or oily water into Israel's territorial and inland waters by any shore installation or vessel and makes any such act a criminal offense. The law provides for the appointment of inspectors authorized also to conduct criminal investigations, to prevent or discover violations of the Ordinance and its regulations. Other salient features of the Ordinance and its regulations include obligation to keep oil record books on vessels (MARPOL Annex 1), measures to be taken in case of discharge of oil, maximum fines for oil spillage, and liability for cleanup costs.

Regulations promulgated within the framework of this law require Israeli harbors to provide adequate reception facilities for oily wastes and require vessels to use these facilities. Other regulations provide for the operation of a Marine Pollution Prevention Fund to concentrate the financial resources for preventing and combating marine and coastal pollution and a Marine Environment Protection

Fee which is imposed on all ships calling at Israeli ports and on oil terminals. These fees, along with fines imposed on violators of the marine pollution prevention laws (“polluters pay principle”), constitute the major sources of budget which is utilized for all activities and operations such as procurement of antipollution equipment, law enforcement, beach and shore cleanups, marine monitoring, etc.

3.2 Prevention of Sea Water Pollution by Oil Regulations (Marine Environment Protection Fee), 1983 [10]

These regulations set a fee – as described above – on the owners of vessels and tankers calling at Israeli ports and on coastal installations handling oil. Different fees are set for vessels, depending on the size and purpose, and for tankers and terminals. Also there is a fee, calculated per 1 ton of oil, set on an incoming imported oil which is arriving in sea oil terminals. The fees are paid to the Marine Pollution Prevention Fund.

3.3 Licensing of Businesses Law, 1968 [11]

The Licensing of Businesses Law establishes a framework within which integrated permitting is required, with plans to update it in line with Integrated Pollution Prevention and Control (IPPC). The law empowers the Minister of the Interior to designate and define businesses requiring licenses in order to achieve six major aims, the first of which relates to environmental quality and nuisance prevention. Business licenses are granted by the Ministry of the Interior, by means of local authorities, and in consultation with relevant ministries. Special environmental conditions, which relate to both infrastructure and operation, may be imposed within the framework of the license with regard to air quality, waste, hazardous substance management, and water and sewage. The law provides administrative and judicial powers for the closure of non-complying businesses.

Numerous regulations have been promulgated pursuant to the law, including regulations on the disposal of hazardous waste (see below), hazardous industrial plants, and transfer stations for waste and industrial effluent treatment.

This law is the main framework for the MEPD to request the preparedness of local and facilities contingency plan for oil pollution.

3.4 Criminal Procedure Order Maintenance of Cleanliness, 2000 [12]

This fineable offenses order provides for the imposition of immediate monetary fines (similar to parking tickets) in lieu of an appearance in court for a variety of cleanliness offenses under the Maintenance of Cleanliness Law. The order enumerates the offenses for which fines may be imposed (23 categories of cleanliness violations) and sets different fine levels for individuals and corporations as well as for repeated offenses and for different areas in which the offense is committed. Higher fines are set for littering in sensitive areas such as nature reserves, national parks, memorial sites, archaeological sites, forests, beaches, or water sources. In addition, significantly higher fines are set for the disposal of waste containing hazardous substances such as in the cases of illegal oil discharge into the sensitive marine areas.

3.5 Licensing of Businesses Regulations (Disposal of Hazardous Wastes), 1990 [13]

These regulations require owners of a business to dispose of hazardous wastes originating or found on their premises, as soon as possible after production and no longer than 6 months after production, at the national site for the disposal and treatment of hazardous wastes in Ramat Hovav. Disposal or treatment of hazardous waste elsewhere for purposes of recycling, reuse, or other reasons requires the prior approval of the MoEP. Under these regulations the disposal of all oily waste, which will be collected from polluted coastlines, will be regulated.

3.6 Prevention of Sea Pollution (Dumping of Waste) Law, 1983 [14]

The law prohibits the dumping of any waste from vessels and aircraft into the sea, except under a permit issued by a special committee. Regulations list categories of substances prohibited or permitted to be dumped to the sea and establish procedures and considerations for issuing permits. Permits are granted or rejected according to criteria stipulated in the regulations and only when the committee is convinced that there are no reasonable land alternatives for disposal and treatment of the waste and that best available technological means have been implemented to prevent the pollution. The applicant must prove in a reasonable manner that no damage to the marine environment will be caused. Even when permitted, dumping must comply with detailed regulations specifying maximum levels of heavy metals in the residue, distance from shore, sea depth and rate of sedimentation at the dumping site, and type of vessel used to transport the waste. In addition, a monitoring program must be implemented around the dumping site. Severe penalties are imposed for unauthorized dumping.

3.7 Maintenance of Cleanliness Law, 1984 [15]

The law, implemented and enforced by MoE inspectors, the police, and "voluntary cleanliness trustees," prohibits the disposal of any refuse in public areas, including litter left on the beaches or thrown overboard from a vessel into the sea within Israel's territorial waters. The law holds the skipper and owner of a vessel responsible for violations, without the need to prove an intention or a certain state of mind. Fines are imposed and budget collected from fines, and penalties are deposited in a "Cleanliness Maintenance Fund," which is used for specific projects including beach cleanups campaigns and environmental education.

3.8 Ports Ordinance, 1971 [16]

This law provides for the operation and management of ports in Israel. It contains a specific section on handling hazardous substances in ports. Regulations promulgated under the law cover environmental matters such as collection of waste, bilge, and ballast water from vessels.

3.9 Ports Ordinance Regulations (Loading and Discharging of Oil), 1975 [17]

These regulations control all procedures for safe loading and discharge of oil and contain specific instructions on the following: entry into territorial waters and ports, vessel operations during their stay in terminal, measures for fire prevention and firefighting, conditions of oil terminals, the maintenance of flexible oil pipelines and cradles used in offshore oil terminals, transfer of oil from tankers including road tankers, and other regulations aimed at ensuring environmentally safe practices. While most of the port ordinance regulations are supervised and enforced by the Ministry of Transport, the MEPD marine pollution prevention inspectors regulate and enforce all environmental clauses in these regulations.

4 Israel Oil Pollution Preparedness and Response System

4.1 Marine Environment Protection Division, Ministry of Environmental Protection (MoEP-MEPD)

The Ministry of Environment was established in 1988. Since then, the Ministry's budget has increased significantly from 8 million US$ to nearly 50 million US$ in 1999. The Marine and Coastal Environment Division is funded by the Marine Pollution Prevention Fund (see Sect. 3.1), a dedicated fund which implements the "polluters pays" principle, per se.

The Marine and Coastal Environment Division of the Ministry of Environment is the national authority responsible for the large part of the activities and programs aimed at prevention, abatement, and reduction of marine pollution from land-based and sea-based sources.

Due to the international influence that actually created the need, the establishment of the MEPD was made possible in the early 1980s with the main target put forth for this division, namely, oil pollution combating and dealing with the problematic/challenging international shipping and environment.

To implement the ambitious protocols and action plans that the Barcelona Convention required, state funding was necessary. The legislative amendments for ratifying one of the Barcelona Oil Pollution Protocol as well as the MARPOL convention, which seeks to prevent pollution of marine environment from the discharge of oil from ships, established an independent funding mechanism for treating marine pollution.

In 1983 the Marine Pollution Prevention Fund was created on the legal basis of the Marine Oil Pollution Prevention Ordinance 1980.

Ship operators paid fines for noncompliance along with fees received from oil imported to Israel from sea-going tankers. The funds would enable the future MEPD to run an enforcement program that included an independent legal framework with lawyers filing criminal indictments against marine polluters. By 1987 the fund was generating $650,000 a year, and in 2015 it created a balance of 4,000,000$, and its total funds were summed up to almost 33,000,000$. This is the basic budget on which Israel's NCP stockpiles and oil-combating equipment are based on.

Obviously, to implement Israel's international commitments funding was not enough, and personnel capable of implementing it was also required. What makes this unit special is the capability of mixing: knowledgeable professional manpower, field operators/inspectors, unique subject and functions, and independent enforcement capacity.

Also unique to the MEPD is the exclusive oversight over all aspects of marine protection. It enjoys responsibility and authority for permits oversight, enforcement, international cooperation, scientific research, and marine monitoring as well as policy setting. While in the MoEP, divisions responsible for regulating other environmental media, responsibilities, and authorities are usually divided between the head department that sets the policies, the six districts that are in charge of monitoring, permitting, and implementing the policies, and the Green Police in charge of criminal investigations. The integrative structure of the MEPD created a sense of unit pride and sense of ownership in addressing marine pollution prevention and abatement.

Israel deals with all aspects of marine pollution: accidental and emergency oil and chemical spills from ships or terminals, polluting discharges from industrial or municipal land-based sources, dumping of waste at sea, and litter in the sea or on beaches. The activities of the division include also law enforcement and scientific research and monitoring of the marine environment.

Hence, the MEPD has adopted a multi-faceted working plan consisting of the following:

- Detecting environmental problems along Israel's marine coastlines and territorial waters
- Preventing and abating all types of marine pollution
- Enforcing national laws on the protection of the marine environment
- Updating relevant legislation in accordance with international conventions and modern environmental criteria
- Developing and implementing policies for sound environmental management of the marine and coastal ecosystems

On the Mediterranean coast, Gulf of Eilat, Lake Kinneret, and Dead Sea, for marine pollution prevention, professional inspectors carry out enforcement and monitoring. They are equipped with vessels, vehicles, and means of communication, monitoring, and enforcement equipment. Aided by aerial surveillance, the inspectors carry out marine and coastal patrols which include routine inspections of hundreds of vessels and oil tankers calling at Israel's ports, offshore installation handling oil, and industrial plants and wastewater treatment plants in local authorities. Figure 7 illustrates the vehicles available to the MEPD for inspections.

4.2 *The Israeli National Contingency Plan for Preparedness and Response to Marine Oil Pollution Events*

The Israeli Government (decree dated 29/3/1998) ordered the Ministry of Environment to prepare a NCP. The Director General of the Ministry appointed the Marine and Coastal Environmental Division for this task. A steering committee was appointed, comprising of 18 government ministries and concerned industrial and commercial enterprises.

"TALMAT" is the NATIONAL CONTINGENCY PLAN (NCP) for preparedness and response to incidents of oil pollution of the sea [18, 19]. It was approved by a governmental decision on 5/6/2008. This was done according to the provisions of the OPRC 1990, to which Israel is party.

The NCP provides organizational structure and an authoritative and commanding framework for the various entities involved in oil spill response. It provides for an efficient use of means in emergency situations involving up to about 4,000 tons of spilled oil. Larger spills would require international cooperation, either through

Fig. 7 Marine Environment Protection Division's inspection vehicles and unit symbol and logo. Source: Ran Amir, Director MEPD, 2017

the subregional conventions with Cyprus and Egypt in the Mediterranean, and with Jordan and Egypt in the Gulf of Aqaba, or through wider and more powerful response organizations.

Israel's NCP covers incidents of oil pollution of the sea which might occur:

- Within Israel's territorial waters (12 miles) and on its coastline, in the Mediterranean Sea, and in the Gulf of Eilat
- Incidents occurring outside the territorial waters which might pose a threat to Israel's coastline and/or to marine installations and/or resources, which are at risk of harm from pollution
- Incidents occurring outside Israel's territorial waters, to which Israel is committed in view of a request for assistance in dealing with them pursuant to the international conventions, to which the state is a signatory (Barcelona Convention, OPRC 1990, and subregional agreements)

The NCP has two basic parts:

- Part A – Contains background information and outlines strategic principles and national policy, which have been agreed upon by a multi stakeholder steering committee, which was set up between 1998 and 2004.
- Part B – Operational handbook, describing all response operations, procedures, data bank, and annexes relating to the preparedness and response operations.

The National Program for Preparedness and Response to Incidents of Oil Pollution of the Sea, the "TALMAT" [19], constitutes an organizational framework, which encompasses the various parties working in response to an occurrence of oil spillage that might give rise to pollution of the marine environment along the coastline of the State of Israel and in the Mediterranean Sea. This program is part of the regional organization for joint handling and mutual assistance at the time of emergency occurrences of major pollution incidents.

4.2.1 Objectives and Aims

Building an overall system for preparedness and response to occurrences of oil pollution in the sea, including the mapping of sensitive areas along the coastline, sources of risk of sea pollution, a policy of dealing with an incident of sea pollution, and listed details of the methods and means of handling a severe occurrence of sea pollution by a combination of forces of the relevant parties.

The program provides an answer to the following objectives:

- Definition of the organizational setup which includes all the relevant parties
- Identification and definition of the order of priorities for protection, cleaning, and the treatment of the coastline
- Definition of the operational principles for dealing with oil pollution of the sea and beaches along the coastline
- Defining the training that is necessary for the teams, field managers, and headquarters
- Determining a framework for practice drills of all those involved in dealing with sea pollution

The response levels for these definitions are presented in Table 2, while Fig. 8 shows the general principle of operation of the 3-tier response strategy in Israel.

The main scenarios for sea pollution incidents, to which the program relates to, are:

1. Scenario 1. A spillage during flow from an offshore oil terminal to the coast in any one of Israel's terminals (Haifa, Tel-Aviv, Ashdod, Ashkelon, Haifa, and Eilat)
2. Scenario 2. A ship emergency (a sinking, fire, beaching, or a collision) especially in respect of oil tankers along the Israeli coastline, which causes a spillage of oil into the sea
3. Scenario 3. A spillage mishap from a land-based source from an oil storage facility and which in situated close to the coast
4. Scenario 4. An oil spillage from a port complex (e.g., during the bunkering of ships)
5. Scenario 5. Oil pollution which approaches the Israel coastline and which originated outside Israel's territorial waters

4.3 Responsibilities of the Regulating Authorities for a Marine Oil Pollution

For as long as a sea-going vessel is involved in a sea pollution incident, the Administration of Shipping and Ports (MoT) are the commanding authority of the response system. The Marine Environment Protection Division (MEPD) in the Ministry of Environmental Protection will act as their deputy and will advise them. Resources will be allocated both for human life saving and vessel search and rescue operations first and foremost to combating of the oil pollution; protection of the environment will come in parallel but will be of a lesser focus until the declaration

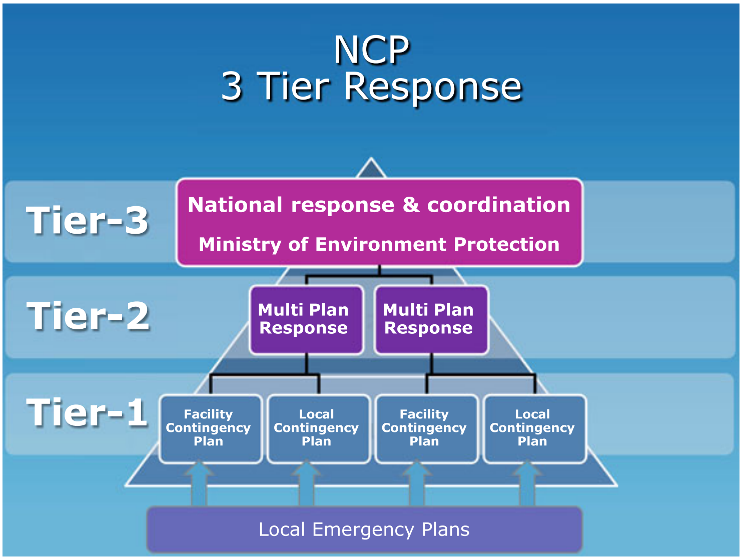
Table 2 Definitions – response levels according to the "TALMAT"

Tier 1 plan	Definition details
Local emergency plan (municipality) – Tier 1	The local emergency plan (LEP). The generally accepted name for TIER 1 programs, written for the response and cleanliness of polluted coastline and beaches from an oil spill. Local programs are the responsibility of the local foreshore authorities as well as bodies who are at risk of sustaining damage such as desalination installations and the IDF military camps
Facility emergency plan – Tier 1	A facility emergency plan is essentially the same as the LEP; however, it includes sea-based operations and capabilities. This plan is requested from installations who deal with oil transfer and use. The plan requests the necessary deployment of resources in relation to the facility's area of responsibility and on the extent of the activity and/or the potential pollution and the level of treatment deriving from them
Tier response level	Response details
Tier 1	A small occurrence of sea pollution or local in extent which can be dealt with by a local program operator (a plant and/or local protection program)
Tier 2	A medium-sized occurrence of sea pollution or interlocal in extent which is beyond the capability of being dealt with by a Tier 1 local program. Dealing with the event requires assistance from the operators of neighboring local programs (Tier 2a). If the source of the pollution is unknown, or where the pollution stems from a source lacking a treatment program, conduct of the event will be the responsibility of the MEPD (Tier 2b)
Tier 3	A major occurrence of sea pollution or of regional/national extent which requires the mobilization of national or international resources and which is handled by the national authority with the assistance of facility contingency plans and local protection programs and with the addition of international resources

that there are no humans at risk. The moment that dealing with the vessel is concluded and the incident has in essence become "environmental," command will be transferred to the Director of the MEPD, while the Head of the Administration of Shipping and Ports will act as his deputy and advisor. The time of the transfer of command will be decided by agreement between the incident manager and his deputy and will be documented in the same way as any other action.

4.4 Operational Command

A 24/7 Rescue Coordination Center (see Fig. 9) will be open and serve as a situation room to deal with the evolving event through all its phases and activities. The NCP of Israel makes use of the RCC's *Tier 3 operational command and its communication capabilities.*



NCP
3 Tier Response

Tier-3

National response & coordination
Ministry of Environment Protection

Tier-2

Multi Plan Response

Multi Plan Response

Tier-1

Facility Contingency Plan

Local Contingency Plan

Facility Contingency Plan

Local Contingency Plan

Local Emergency Plans

Fig. 8 NCP 3 3-tier response diagram. Source: Presentation by Fred Arzoine, Deputy Director, MEPD of Israel, 2014

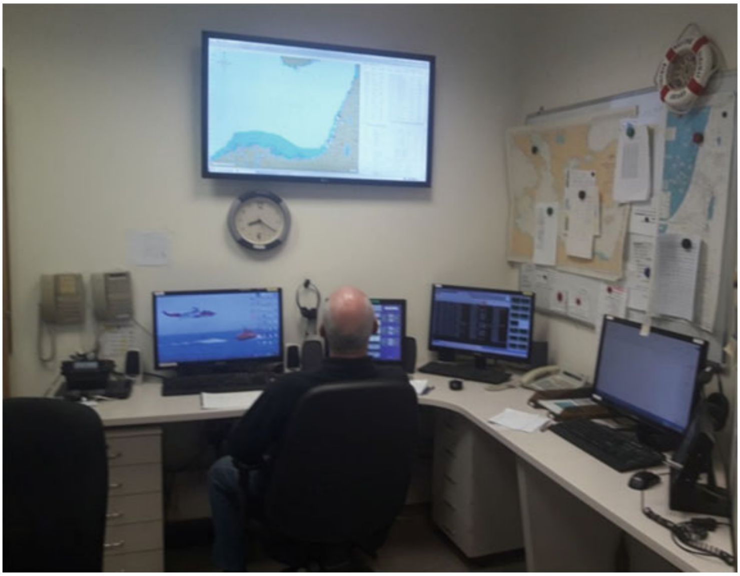


Fig. 9 Rescue Coordination Center (RCC) Haifa (formerly Haifa Radio 4XO). Source: Yoav Ratner, MEPD, Israel

4.5 Sensitive Areas and National Order of Priorities

ESI classifications for categories of beaches (according to morphological structure and vulnerability) are based on the US-NOAA classification [20] and are presented in Table 3. Table 4 then sets out the ecological socio-economic sensitivity for the various regions of Israel.

Table 3 Sensitive area classifications for beaches

Beach category	ESI index
Cliffs, bare rocks, exposed vertical walls made of concrete, iron, or wood (usually artificial structures)	1
Abrasion platforms or horizontal and bare rock surfaces created by the waves	2
Sandy beaches of light- to medium-sized granules (generally speaking with a moderate gradient)	3
A rough granule beach with a moderate to steep gradient or a beach combining sand, pebbles, gravel, and seashells	4
An uneven unusual beach with a mixture of sand and rocks to a varying degree or a horizontal and bare rock surface created by the waves or a noncontinuous rock surface that occasionally protrudes from the sea/sand	5
A course gravel cliff which is very frequently in contact with the water	6
A pebbled or gravel beach	6A
A breakwater which juts out into the open sea built from rocks, building waste materials, boulders, or artificial tetrapods	6b
Estuaries of streams and rivers (wet sand), mostly exposed to the open sea, “wet” sections of beaches or containing highly polluted water and rich in biota	7
Artificial protected anchorages or ports or protected rocky beaches that are not exposed to the open sea	8
Protected beaches of rare and natural value or of other special high sensitivity	9

Table 4 Ecological-socioeconomic sensitivity[a] classifications by region

Region	Weighted average grade (Scale of 1–10)	Rating[a]
Hadera + Netanya	8.82	6
Ashkelon	8.22	5
Haifa	8.12	4
Rosh Hanikra + Nahariya + Acre	6.44	3
Ashdod	4.32	2
Herzliya, Tel Aviv-Jaffa and the surrounding area	4.30	1

[a] Rating 6 = first priority for handling, rating 1 = last priority handling (from: “Analysis of Sensitivity for Dealing with Oil Pollution of Beaches” – April 2007 [22])

In a given geographical area, the handling order goes according to the following usages and facilities (in descending order of urgency):

1. Power stations
2. Declared nature reservoirs and sea turtles
3. Bathing beaches
4. Sea farming/fishing activity
5. Desalination plant/archeological site
6. Declared national parks
7. Port and river/stream spillage
8. Maritime center/maritime sports center, anchorage/marina, breakwater

Facility contingency plans are available in the following organizations:

- Eilat Ashkelon Oil Pipeline: EAPC (Ashkelon) and EAPC (Eilat Terminal)
- The Israel Electric Corporation: Haifa Power Station, Orot Rabin (Hadera) Power Station, Reading Power Station (Tel Aviv), Eshkol Power Station (Ashdod), and Rutenberg Power Station (Ashkelon)
- Oil and energy infrastructures: Kiryat Haim (Haifa) Connector Terminal and the Oil Port, the Haifa and Ashdod Oil Refineries, and the Port Companies of Haifa, Ashdod, and Eilat.[4]

Coastline municipalities with local emergency plans are:

1. Mate Asher
2. Nahariya
3. Acre
4. Kiryat Yam
5. Haifa
6. Hof Hacarmel
7. Tirat Hacarmel
8. Netanya
9. Herzliya
10. Hof Hasharon
11. Tel Aviv – Jaffa
12. Rishon Lezion
13. Bat Yam
14. Ashkelon
15. Hof Ashkelon
16. Eilat
17. Ashdod
18. Beer Tuvia

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[4] The preparatory structure within the Port Companies is in the jurisdiction of the Ministry of Transport and the Israeli Ports Company (the ports landlord company).

19. Gan Raveh
20. Jisr az-Zarqa
21. Hadera

A number of other organizations also take part in preparedness and response activities: IDF (the air force, the navy); the Nature Reserves Authority; the Weapons Development Authority (Rafael); Sea Water Desalination Plants; and Marinas (Acre, Herzliya, Tel Aviv, Jaffa, Ashkelon).

Figure 10 is taken from the unified sensitivity atlas of the Mediterranean coastline [21]. That map is part of the Tel Aviv Municipality Local Contingency Plan to deal with coastal oil pollution. The map lists the environmental sensitivity index of 11 grades, unique features of the area, waste storage places, command posts, and details needed in case of massive oil pollution of the coastline. Such maps exist for all local plans and for installations along the shore.

4.6 Oil Pollution Equipment in Israel

As the relevant international agreement suggests, a country would need to procure a certain quantity of oil pollution-combating equipment that will serve as an emergency stockpiles, both for local, national, and international cooperation and assistance. Israel operates the SVIVA 1 work and patrol boat, illustrated in Fig. 11.

To this end, Israel had purchased the following:

- 1,400 m open sea booms
- 1,000 m in-harbor booms
- 150 m seashore boom
- Four heavy duty open sea skimmers
- Seven skimmers for in-harbor waters
- 29 m^3 dispersants
- 17 m OCV SVIVA 2 for Eilat station
- 12 m workboat for Ashkelon station
- 10 m patrol and workboat for Eilat station

Table 5 shows the investment in oil-combating equipment that belongs to the government (Marine Environment Protection Division – Ministry of Environmental Protection).

The local and industrial bodies that were committed to have their contingency plans in place, according to the government decision in June 2008 that adopted the NCP (“TALMAT”), were also obliged into significant procurement processes, which are summarized below:

- 2,500 m open sea booms
- 6,000 m in-harbor booms
- 500 m seashore boom
- 41 m^3 dispersants

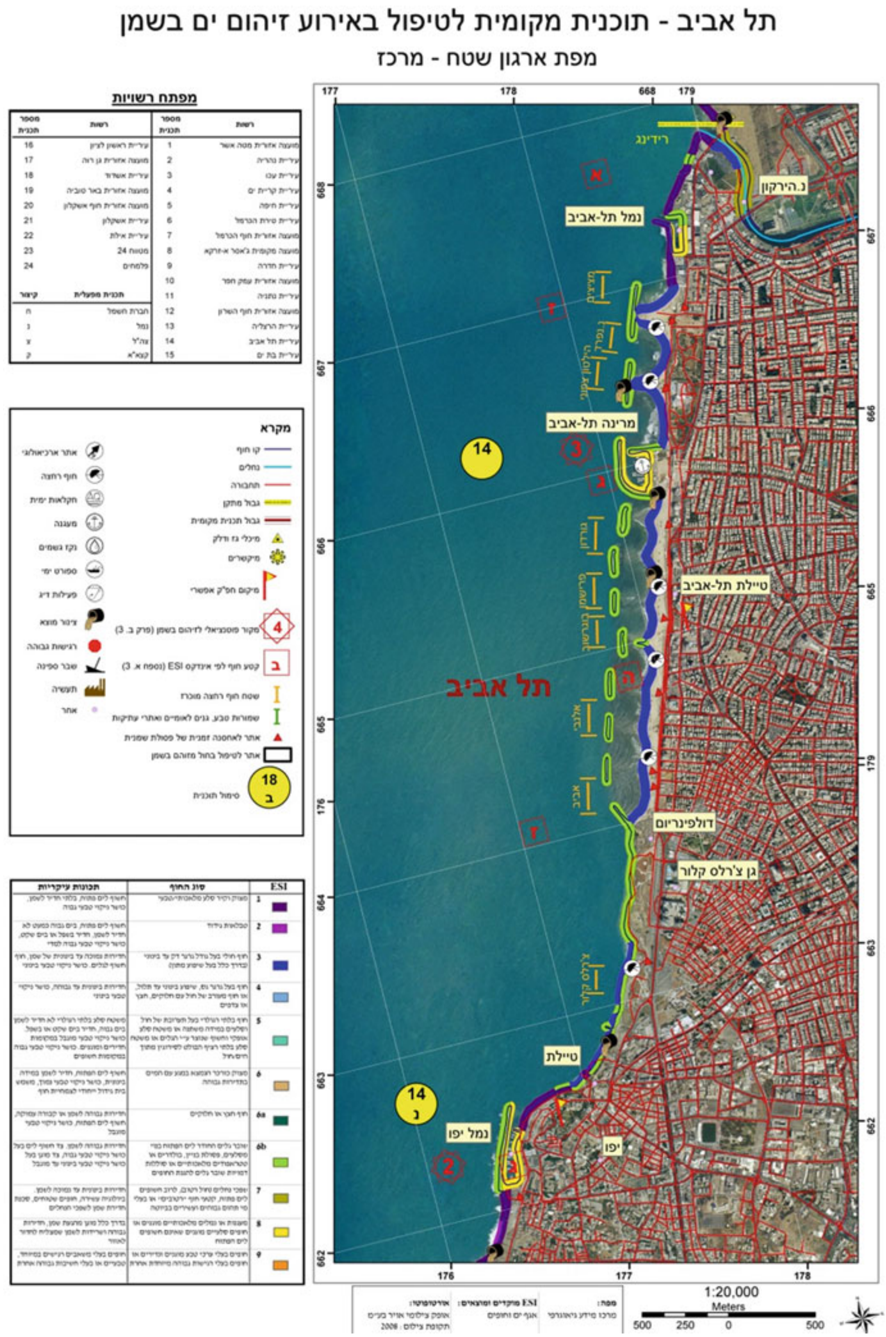

Fig. 10 Tel Aviv Municipality Local Contingency Plan area l setup and sensitivity map. Source: Local Emergency Plan of the City of Tel-Aviv, 2009

Fig. 11 SVIVA 1 – work and patrol boat. Source: Ran Amir, MEPD of Israel, 2008

Table 5 Total budget for construction of marine pollution prevention stations, Israel

Activity base	Investment (in USD)
Mediterranean Sea pollution prevention stations – Ashkelon, Haifa	2,245,000
Red Sea station – Eilat	2,050,000
Total	**4,295,000**

- 24 m OCV for Ashkelon station
- 39 m OCV and command ship (under operation agreement)
- building 2 new marine pollution prevention stations in Haifa and Ashkelon

Also, and perhaps even more important, three privately owned marine companies had realized that they as well may find business opportunities in joining the national preparedness efforts, and thus quite a significant investment was made, followed by signed contracts between the private sector entities, to put in place protection capabilities for any emergency oil pollution event. The investments summarized in Table 6 give the general scale.

Table 6 Total investments for marine oil pollution cleanup capability within the private sector

Institution/body	Investment (in USD) 2008–2015
Israeli Navy	75,000
EAPC	350,000
Haifa Port	62,000
Oil infrastructures	213,000
IEC	812,000
Private companies	
Ma'agan	1,375,000
Dankor	1,300,000
Gal yam	300,000
Total	**4,487,000**

5 Case Studies of Marine Oil Pollution in Israeli Waters

5.1 The Case of the Old Oil Pipelines in the Haifa Bay

In Haifa bay there were five 20–65-year-old crude oil pipelines, with a changing length of 1,500–3,000 m long. These pipelines were considered to be empty. However, during the summer of 2014, oil slicks were found on the northern beaches of Kiryat Haim (Haifa municipality). The leakage was found to be coming from one of the pipes. The local emergency plan of "Tashan" oil terminal was activated, putting an immediate seal on the leakages and beginning a long period of operations to empty the suspected pipelines and beach cleaning at the same time.

A survey was requested by the MEPD, and it was decided to remove all old pipelines. Figure 12 below shows the damaged pipe being taken out, while containment and oil-absorbing activities are taking place to minimize any leakages.

5.2 The Case of the Ship MSC PERLE

On the 19th of December 2010, the container ship MSC PERLE was docking in Haifa Port, and during deballasting operation, an estimated 35 m^3 of HFO were discharged to the waters, causing heavy pollution to ships and port facilities. Cleanup operations were done by the harbor master's response teams according to the local emergency plan of Haifa Port. The cleanup efforts took around 3 weeks. The ship's company and owner were fined after a criminal procedure and a court ruling, in the sum of 1 million ISH (around 250,000 USD). Figure 13 below illustrates how the oil slick in the port is being contained before being recovered.

Fig. 12 Containment and recovery of oil, Kiryat Haim beach, Haifa, Israel, 2014. Source: Nir Levinski, North Station Manager, MEPD of Israel

Fig. 13 Containment and adsorption of HFO, Haifa Port, 2010. Source: Ran Amir, MEPD, Israel

5.3 The Case of the Ship AVRAMIT

On the 24th of June, 2011, the MV AVRAMIT was anchoring at pilot point in the Red Sea, Eilat Port. For 2 days she discharged ballast water polluted with HFO, an estimated quantity of 15 m^3. The oil spill polluted large parts of the extremely

Fig. 14 MV AVRAMIT causing HFO pollution, Eilat Port, 2011. Source: Eilat Marine Pollution Prevention Station, MEPD, Israel

Fig. 15 Eilat Marine Pollution Station serving as “last frontier” to block and contain HFO pollution from MV AVRAMIT, 2012. Source: Eilat Marine Pollution Prevention Station, MEPD, Israel

vulnerable marine environment of Eilat with its unique coral reef assets. The cleanup took a week, involving Eilat municipality, MEPD marine pollution station, nature reserves authority, Eilat Port, and volunteers. The ship’s owner and captain were fined by 750,000 ISH (around 185,000 USD). Figures 14 and 15 show the oil in Eilat pier and contained at the coral beach, Eilat.

Fig. 16 Southern beaches of Israel polluted with tar after ship accident in the territorial waters of Egypt, 2005. Source: MEPD, Israel

5.4 The Case of Ships Collision South of the Border of Israel

On the night of the 4th of February, 2005, a collision between two marine vessels, one of them a tanker carrying light crude oil, occurred at the Mediterranean Sea, 12NM from Damietta, Egypt, causing a spill of oil at an estimated quantity of 1,500 m^3. Exact details are not in our possession; however, 5 days afterward the oil remains hit the coastlines of Gaza and southern part of Israel along some 100 km. Figure 16 shows the tar washed ashore. The NCP was activated involving all parts mainly the reconnaissance of the slick and preparedness for a full response. It was decided to leave the oil to naturally degrade ("do nothing").

6 Summary and Conclusions

Israel's Ministry of Environmental Protection was assigned by the government in 1998 to be the national competent authority for the purpose of marine oil pollution preparedness and response planning, strategy, and implementation.

The legal national framework is quite firm and conclusive, derived from a set of international conventions. Currently, Israel is working on improving and adjusting its laws and regulations to give a full updated answer to new situations and technologies.

The National Contingency Plan ("TALMAT") was written and adopted according to a governmental decision on June 2008 and ever since is being implemented through all entities, including stockpiles and capacity building,

Fig. 17 An exercise in Ashkelon Port, deploying a sea boom. Source: MEPD, Israel

Fig. 18 An exercise in Haifa bay, dispersing oil with spraying aircraft, 2002. Source: MEPD, Israel

training exercises, and real cases of oil emergencies at the Mediterranean and Red seas including onshore response and cleanup operations. Lucky enough, to this date, no major pollution event had occurred. Bearing this in mind, it is clear to the decision makers that Israel must enhance its collaboration with other countries in the region in order to strengthen its preparedness and response capabilities.

Figures 17 and 18 show exercising boats of the EAPC in Ashkelon and a spraying aircraft in a dispersant spraying flyby.

References

1. International Maritime Organization (2017) International Convention on Oil Pollution Preparedness, Response and Co-operation (OPRC). http://www.imo.org/en/About/Conventions/ListOfConventions/Pages/International-Convention-on-Oil-Pollution-Preparedness,-Response-and-Co-operation-(OPRC).aspx
2. UNEP/MAP (1976) Convention for the Protection of the Mediterranean Sea against Pollution (Barcelona Convention). http://wedocs.unep.org/bitstream/id/53143/convention_eng.pdf. Accessed 4 Aug 2017
3. UNEP/MAP (undated) Protocol Concerning Cooperation in Preventing Pollution from Ships and, in Cases of Emergency, Combatting Pollution of the Mediterranean Sea. https://wedocs.unep.org/rest/bitstreams/2190/retrieve. Accessed 10 Aug 2017
4. International Maritime Organization (2017) International Convention on Civil Liability for Oil Pollution Damage (CLC). http://www.imo.org/en/About/Conventions/ListOfConventions/Pages/International-Convention-on-Civil-Liability-for-Oil-Pollution-Damage-%28CLC%29.aspx. Accessed 15 Aug 2017
5. International Maritime Organization (2017) International Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage (FUND). http://www.imo.org/en/About/Conventions/ListOfConventions/Pages/International-Convention-on-the-Establishment-of-an-International-Fund-for-Compensation-for-Oil-Pollution-Damage-%28FUND%29.aspx
6. IMO, the International Convention for the Prevention of Pollution from Ships (MARPOL). http://www.imo.org/en/about/conventions/listofconventions/pages/international-convention-for-the-prevention-of-pollution-from-ships-(marpol).aspx. Accessed 15 Aug 2017
7. REMPEC (1995) Sub-regional Contingency Plan for Preparedness and Response to Major Marine Pollution Incidents in the Mediterranean, June 1995. http://www.rempec.org/admin/store/wyswigImg/file/Information%20resources/Other%20Meetings-Activities/Contingency%20planning/Subregionals%20agreements%20and%20plans/Contplan-CEI.pdf
8. Paris MOU (2017) Paris Memorandum of Understanding on Port State Control – 40th Amendment Paris MOU, effective 1 July 2017. https://www.parismou.org/inspections-risk/library-faq/memorandum
9. Sviva.gov.il (1980) Prevention of Sea Water Pollution by Oil Ordinance [new version] 5740–1980. http://www.sviva.gov.il/English/Legislation/Documents/Seas%20and%20Coasts%20Laws%20and%20Regulations/PreventionOfSeawaterPollutionByOilOrdinance-NewVersion-1980.pdf
10. Sviva.gov.il (1983) Prevention of Sea Water Pollution by Oil Regulations (Marine Environment Protection Fee), 1983. http://www.sviva.gov.il/English/Legislation/Documents/Seas%20and%20Coasts%20Laws%20and%20Regulations/PreventionOfSeawaterPollutionByOilRegulations-MarineEnvironmentProtectionFee-1983.pdf
11. Sviva.gov.il (1968) Licensing of Businesses Law, 1968. http://www.sviva.gov.il/English/Legislation/Documents/Licensing%20of%20Businesses%20Laws%20and%20Regulations/LicensingOfBusinessesLaw1968-Excerpts.pdf
12. Sviva.gov.il (2000) Criminal Procedure Order Maintenance of Cleanliness, 2000. http://www.sviva.gov.il/English/Legislation/Documents/Maintenance%20of%20Cleanliness%20Laws%20and%20Regulations/CriminalProcedureOrder-TrialOption-MaintenanceOfCleanliness-2000.pdf
13. Sviva.gov.il (1990) Licensing of Businesses Regulations (Disposal of Hazardous Wastes), 1990. http://www.sviva.gov.il/English/Legislation/Documents/Licensing%20of%20Businesses%20Laws%20and%20Regulations/LicensingOfBusinessesRegulations-DisposalOfHazmatWaste-1990.pdf
14. Sviva.gov.il (1983) Prevention of Sea Pollution (Dumping of Waste) Law, 1983. http://www.sviva.gov.il/English/Legislation/Documents/Seas%20and%20Coasts%20Laws%20and%20Regulations/PreventionOfSeaPollution-DumpingOfWasteLaw-1983.pdf

15. Sviva.gov.il (1984) Maintenance of Cleanliness Law, 1984. http://www.sviva.gov.il/English/Legislation/Documents/Maintenance%20of%20Cleanliness%20Laws%20and%20Regulations/MaintenanceOfCleanlinessLaw1984.pdf
16. mfa.gov.il (1971) Ports Ordinance, 1971. Summary. http://mfa.gov.il/MFA/PressRoom/1998/Pages/Ports%20Ordinance%20-New%20Version–%201971.aspx
17. Sviva.gov.il (1975) Ports Ordinance Regulations (Loading and Discharging of Oil), 1975
18. Sviva.gov.il (2008) TALMAT (Israel's National Contingency Plan for Oil Pollution Preparedness and Response) Government Decision 3542, 5 June 2008
19. Sviva.gov.il (2007) Israel National Contingency Plan for Combating Marine Oil Pollution, 2007 ("TALMAT"). http://www.sviva.gov.il/English/env_topics/marineandcoastalenvironment/Documents/NatlContingencyPlanForPreparednessAndResponseToOilPollutionIncidents-July2007.pdf
20. US-NOAA, Office of Response and Restoration, environmental sensitivity index. https://response.restoration.noaa.gov/maps-and-spatial-data/environmental-sensitivity-index-esi-maps.html
21. Kerret D (2010) Marine pollution abatement on Israel's Mediterranean Coast – a story of palicy success. Tel Aviv University
22. Ministry of Environmental Protection (2006) Environmental sensitivity index atlas. Ministry of Environmental Protection (MoEP) http://www.sviva.gov.il/InfoServices/ReservoirInfo/DocLib2/Publications/P0101-P0200/P0130d.pdf (in Hebrew)
23. Ministry of Environmental Protection (2007) Marine quality: cleaner seas and coasts. Israel Environ Bull 32:8–13. http://www.sviva.gov.il/English/ResourcesandServices/Publications/Bulletin/Documents/Bulletin-Vol32-May2007.pdf
24. REMPEC. http://medgismar.rempec.org/

Oil Pollution in the Waters of Cyprus

George Kirkos, George Zodiatis, Loizos Loizides, and Marinos Ioannou

Abstract Cyprus is strategically located in the crossroad between three continents and accepts significant marine traffic within its maritime borders. The conflict of the oil transport activity and the high environmental and social capital of the North-Eastern Mediterranean renders the area with high risk for oil pollution. Only seven serious marine accidents have been recorded in the last decade but more than 1,000 possible oil spills were detected in the Levantine Basin through satellite observation systems. The potential increase of oil traffic in the area due to the hydrocarbon discoveries in the region between Israel, Egypt and Cyprus is likely to increase oil spill risks in the near future. To address oil pollution, Cyprus is implementing a National Contingency Plan (NCP) for Oil Pollution Combating where both the private and government sector contributes. Surveillance of accidental and operation oil spills is achieved by aerial and naval means as well as through satellite remote sensing monitoring and oil spill forecasting models. Cyprus has strong socio-economic bonds to the sea and a sensitive marine environmental heritage thus even a small oil spill can have significant environmental, social and economic impacts on the island. To avoid a marine pollution disaster, continuous improvement of the oil prevention and response capabilities of Cyprus is necessary. This can be achieved through investing in monitoring assets, technological innovation and forecasting models.

Keywords Aerial surveillance, Cyprus, Environmental impact, Legislation, Oil response, Oil spill, Oil spill modelling, Pollution, Satellite remote sensing

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Contents

1 Cyprus Oil Profile

Cyprus is the third largest island in the Mediterranean Sea, after the Italian islands of Sicily and Sardinia. It lies between latitudes 34° and 36°N, and longitudes 32° and 35°E and measures 240 km long from end to end, and 100 km wide at its widest point. It has a coastline of 770 km but only 290 km is under the control of the Republic of Cyprus.

Cyprus is strategically located in the north-eastern corner of the Mediterranean Basin at the crossroads of three continents and at the intersection of major international and regional shipping lines. Its location has made Cyprus a natural place of call for vessels sailing in and out of the Mediterranean region with some 100 different lines servicing Cyprus regularly, providing wide, regular and frequent connections between the island and the rest of the world [1].

Oil transport is a significant component of maritime transport within Cyprus' waters and it is expected to report considerable increase of its traffic over the coming years due to a number of factors such as the recent oil and gas discoveries in the Eastern Mediterranean Region (see Fig. 1). Also the widening and deepening of the Suez Canal could significantly increase traffic in the region and bring more traffic to Cyprus, which is likely to entice more oil product trans-shipment companies to its shores.

Currently, there is no oil or gas production in Cyprus and all fuel has to be imported. Oil consumption, in 2014, was about 59,000 bbl/day (Barrels/day). There are no oil refineries in Cyprus but there are two fuel unloading terminals, one at Dekelia and one at Vasilikos, the latter being an area that belongs to the Electricity Authority of Cyprus and serves its electricity production plants. The Dekelia terminal is a three buoys open sea berth, while the Vasilikos terminal is single point mooring. The average discharge rate of the Vasilikos terminal is 1,300 cubic meters per hour (cbm/h) of gas oil and 1,300 cbm/h of fuel oil. The Dekelia terminal has an average of 800–1,000 cbm/h. Both terminals can accommodate tankers of up to 50,000 Deadweight tonnage (DWT). More details are provided in Table 1.

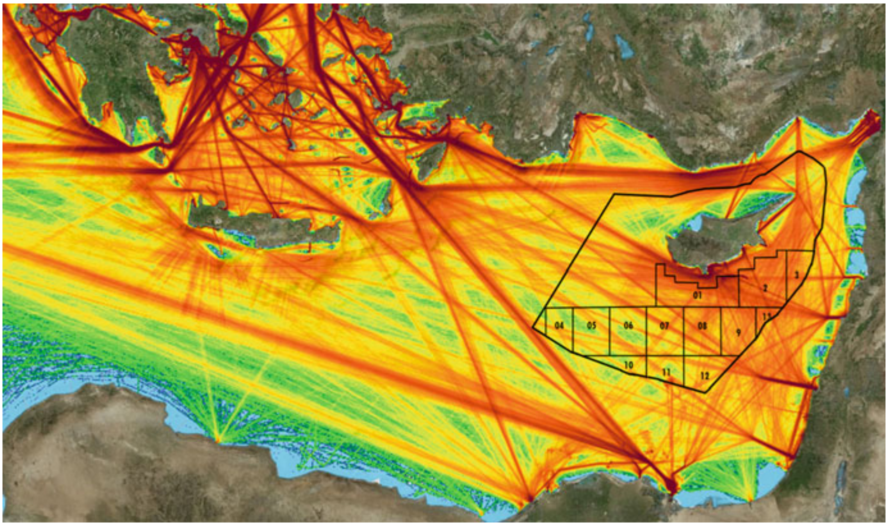

Fig. 1 Map of traffic intensity in the Levantine [2] with the exploration blocks in the EEZ of Cyprus

Table 1 Cyprus oil profile

General information	
Coastline (km)	770 (Under the Control of the Republic of Cyprus – 290 km)
Oil production bbl/day	0
Consumption bbl/day	59,000
Exportation bbl/day	0
Imports bbl/day	58,930
Oil refineries	
Larnaca oil refinery	Closed in 2004 and now imports of its petroleum products amount to 60,000 bbl/day
Oil terminals	
Dekelia (EAC) oil terminal	Three buoy open sea berths
	Max DWT: 50,000 tones
	Average charge rate: 800–1,000 cbm/h
Vasilikos EAC oil terminal	Single point mooring
	Average discharge rate:
	1,300 cbm/h gas oil
	1,500 cbm/h fuel oil

Source: Author's own work

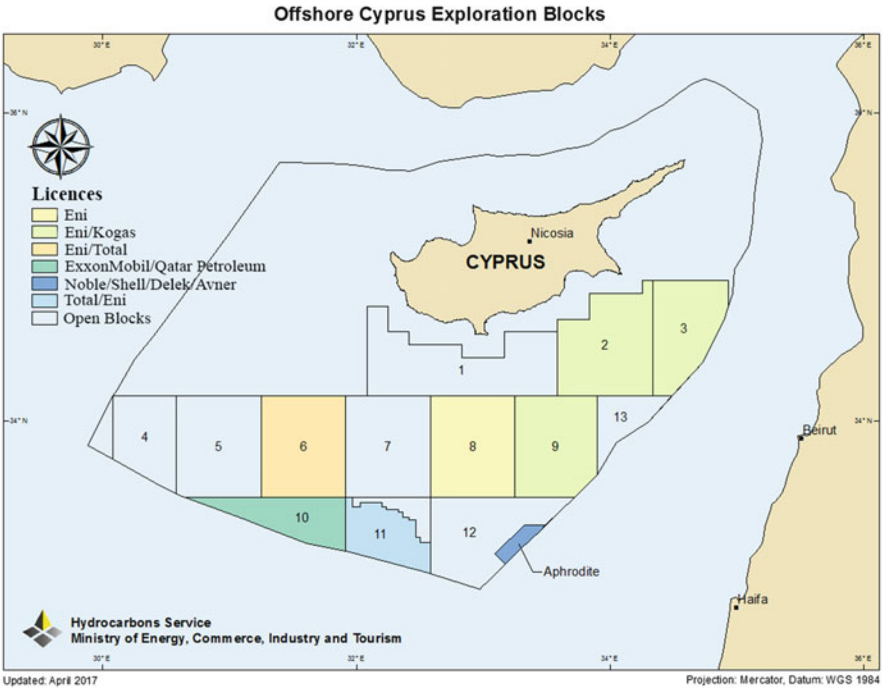

Fig. 2 Cyprus' exclusive economic zone (EEZ) blocks (MECIT Cyprus) [4]. Source: Ministry of Energy, Commerce, Industry, and Tourism of the Republic of Cyprus

However, a strong momentum is recently growing to develop Cyprus into a significant fuel hub in the region after the successful operation of the sophisticated oil storage terminal in Cyprus by Netherlands-based global oil terminal company VTTI. The terminal currently comprises 28 tanks and capacity of 544,000 m^3 and offers access to a deep water marine jetty as well as to road tanker loading facilities. An expansion is currently under evaluation and would create an additional 13 tanks and further capacity of 305,000 m^3 [3]. These developments match Cyprus' aspirations of becoming a regional fuel hub thanks to its strategic location, connecting Europe and the Black Sea with markets in the Middle East and Asia.

In 2011, Cyprus announced a world-class discovery of natural gas in its offshore exclusive economic zone (EEZ) block 12 – known as Aphrodite (see Fig. 2) with confirmed natural gas reserves of 4.54 trillion cubic feet (Tcf) with good prospects for more discoveries. Additionally, in 2015, a recent world-class discovery of 30 Tcf of natural gas was made in Egypt by ENI spurring on exploration in the Eastern Mediterranean (see Fig. 3). The discovery named Zohr is located just 6.5 km from the boundary of Cyprus' Block 11. These discoveries suggest a significant increase in oil and gas offshore exploration and production activities in the region offshore Cyprus in the near future.

Fig. 3 Oil and gas discoveries in the Eastern Mediterranean Levantine region (International Institute for Strategic Studies) [5]

2 Pollution Response Authorities and Their Roles

2.1 Organization of Pollution Response in Cyprus

2.1.1 National Contingency Plan

A National Contingency Plan (NCP) for oil spill response (OSR) for Cyprus was developed in 1987 and reviewed in 1997 and 2013. According to the NCP upon notification of an incident, the responsible authority for oil spill control and response at the national level will set up Emergency Response Centers (ERCs) to coordinate the spill response.

For major incidents requiring a national response or for those occasions which require the activation of sub-regional contingency arrangements, the ERC would be established at responsible authority's Headquarters. The Director would act as the National On-Scene Coordinator (NOSC) and will have the overall operational responsibility. The NOSC will be supported by a command team consisting of officers of the authority and any other individuals requested by the NOSC.

For minor incidents within the capability of local resources, the ERC would be established at local level and will be coordinated by an On-Scene Coordinator

Table 2 Cyprus anti-pollution equipment and materials

	Y/N	Quantity units
A. Materials and products		
1. Dispersants	Yes	10 tonnes
2. Sorbents	Yes	2,000 m
B. Equipment		
1. Anti-pollution vessel	Yes	5
2. Surveillance aircraft	No	
3. Aerial spraying aircraft	Yes	2
C. Booms		
1. Open sea booms	Yes	1,250 m
2. Harbour booms	Yes	400 m
3. Beach booms	No	
4. Sorbent booms	No	
D. Skimmers		
1. Mechanical		
2. Disc	Yes	10
3.Vaccum	Yes	1
4 Sorbent belt	Yes	40
E. Spraying units		
1. Beach (portable)	Yes	6 units
2. Boat mounted	Yes	2 sets
3. Beach cleaning units	No	
4. Pressure cleaner	Yes	4

Source: Author's own work

Table 3 Cyprus auxiliary anti-pollution equipment

	Y/N	Units
1. Pumps		
(i) Cargo transfer pumps	Yes	7
(ii) Heavy duty pumps	Yes	3
(iii) Underwater pumps	Yes	2
2. Oil/mixture container		
(i) Flexible-floating	No	
(ii) Flexible-onshore	Yes	6
(iii) Others	No	
3. Electricity generator	Yes	1

Source: Author's own work

(OSC). NOSC would monitor and provide assistance if requested and the situation would be regularly evaluated by the Executive Team. Operational teams, under the supervision of the OSC, may then be dispatched to respond at sea, undertake shoreline clean-up and the disposal of any recovered oil or oily waste and will be supported by a "Support Team" who will be responsible for the logistics. Under the terms of the NCP, the NOSC can request the assistance of other government departments, non-governmental organizations or industry should the need arise.

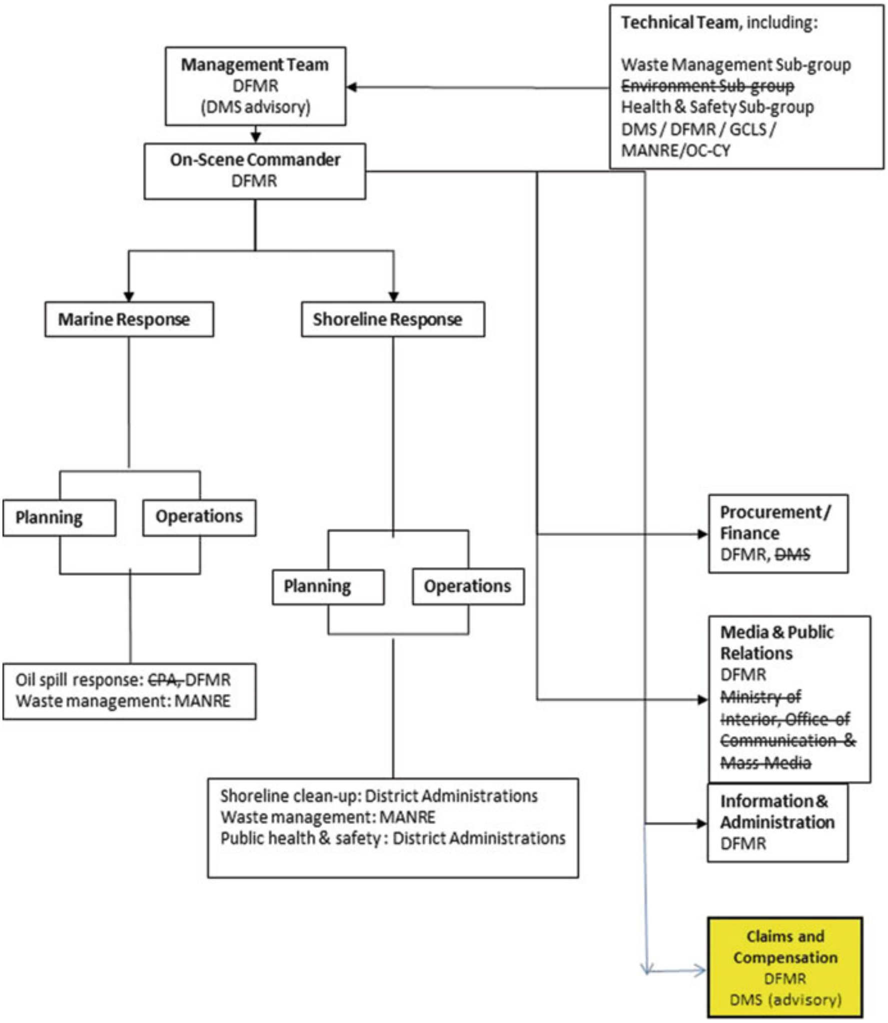

Fig. 4 TIER I response organigram [9]

Small spills occurring in one of the oil handling facilities would be combated with locally available resources under the surveillance of responsible authority [6]. If deemed necessary, the authority can activate the National Contingency Plan and if required enforce the Sub-regional Agreement between Cyprus, Israel and Egypt to combat oil spills.

In case of larger oil spills which cannot be dealt with using the national equipment and resources, the Department of Merchant Shipping is responsible for coordinating international and EU assistance. Also, the Department of Merchant Shipping will liaise with the European Maritime Safety Agency (EMSA) in order to contract oil recovery services. EMSA has a number of OSR vessels located around

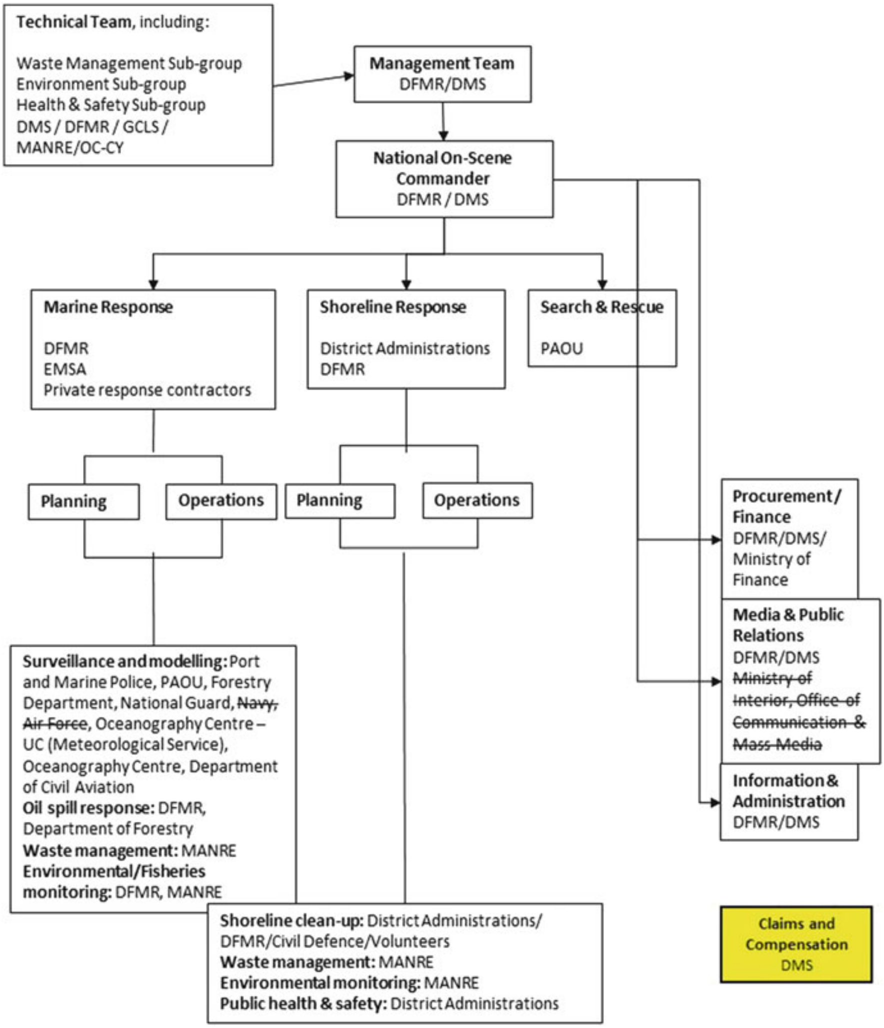

Fig. 5 TIER II response organigram [9]

the Mediterranean which can be made available to support clean-up activities, as necessary. Further specific information is available in this volume [7] and at the EMSA website [8] and could be used to discuss vessels located in the region including the oil tanker *Alexandria* located in Limassol. It is noted that the Republic of Cyprus does not own any specialized or dedicated anti-pollution vessels.

The recovery of oil is the first aim. The application of dispersants approved for use in EU countries is permitted in Cyprus only after authorization by the Director of the Department of Fisheries and Marine Research (DFMR).

Table 4 International conventions and protocols for the prevention control and combating of oil pollution from ships and their status

No.	Name of convention or protocol	Entered into force
1	International Convention for the prevention of pollution from ships, 1973 and modified by the protocol of 1978 (MARPOL 73/75) [10]	2 Nov. 1973
	Annex I/II – Regulations for the Prevention of Pollution by Oil/Regulations for the Control of Pollution by Noxious Liquid Substances in Bulk	02 Oct. 1983
	Annex III – Prevention of Pollution by Harmful Substances Carried by Sea in Packaged Form	01 Jul. 1992
	Annex IV – Prevention of Pollution by Sewage from Ships	31 Dec. 2001
	Annex V – Prevention of Pollution by Garbage from Ships	31 Dec. 1988
	Annex VI – Prevention of Air Pollution from Ships	19 May 2005
2	International Convention on Oil Pollution Preparedness Response and Cooperation (ORPC 1990)	13 May 1990
3	International Convention on Oil Pollution Preparedness Response and Cooperation (ORPC 1990) as amended in 2000 (OPRC/HNS 2000)	14 Jun. 2000
4	International Convention for the prevention of pollution of the sea by oil, 1954 and amended	12 May 1954
5	International Convention related to the intervention on the High Seas in cases of Oil Pollution causalities (Intervention 1969)	6 May 1975
6	1973 Protocol relating to Intervention on the High Seas causes of pollution by substances other than oil (Intervention 1973)	30 May 1983

2.1.2 Government Equipment

The National OSR equipment of the Republic of Cyprus is owned and managed by the DFMR. The main volume of OSR equipment and central stock is stored in Limassol, while smaller quantities are also distributed:

- In Limassol (Port of Limassol);
- In Vasilikos Power Plant;
- In Larnaca (regional stockpile);
- In Paralimni (Protaras – Golden Coast fishing shelter); and
- In Pafos (Pafos Harbour).

Limassol maintains also the national stockpile of oil spill dispersants but OSR from Limassol central stockpile may be transferred anywhere in Cyprus, while the Larnaca stored OSR is tasked to strengthen OSR operations between Larnaca and Famagusta.

A full description of equipment is shown in Tables 2 and 3.

Table 5 Conventions protocols related to oil pollution, prevention, control and combatting ratified by Cyprus

No.	Convention/protocol	Ratification
1	MARPOL 73/78	Yes
	Annex I/II	Yes
	Annex III	Yes
	Annex IV	Yes
	Annex V	Yes
	Annex VI	Yes
2	OPRC, 1990	No
3	OPRC/HNS 2000	No
4	INTERVENTION 1969	No
5	INTERVENTION 1973	No
6	CLC 1969	Yes
7	CLC Protocol, 1976	Yes
8	CLC Protocol, 1992	Yes
9	CLC Protocol, 2000	–
10	TANKERS PREVENTION	Yes
11	FUND 1971	Yes
12	FUND Protocol 1992	Yes
13	FUND Protocol 2003	No
14	Barcelona Convention 1976	Yes
15	Emergency Protocol 1976	Yes
16	Prevention and Emergency Protocol 2002	Yes
17	Offshore Protocol 1994	Yes

2.1.3 Private Sector

Several organizations are liable to assist DFMR in pollution response actions. These organizations include private organizations such as the electrical power stations and the cement factory and any other organization that maintains OSR equipment. Figures 4 and 5 present the organigram for OSR according to the NCP.

For the protection of the marine environment, there is generally an adequate number of International treaties, Conventions and Protocols for the prevention, control and combating of oil pollution. In addition, a number of related Regional Conventions and Protocols are in force for certain regional seas. The International Conventions and Protocols for the prevention, control and combating of oil pollution are shown in Table 4.

Cyprus is a participant in the majority of the conventions identified above. Table 5 shows which Conventions (and their Annexes) Cyprus has ratified.

3 Oil Pollution Monitoring Practice and Existing Systems

Oil Pollution Monitoring in Cyprus is achieved through a range of surveillance activities including: Aerial Surveillance, Naval Surveillance, and EMSA CleanSeaNet SAR images for oil spill forecasting. These are outlined below:

Aerial surveillance is achieved by the use of the Police Aviation Unit that assigns aircrafts or helicopters to monitor the areas where oil spill is reported or suspected and to verify the status of a reported oil spill. The Aerial Service is equipped with four helicopters: 2 × AgustaWestland AW139 and 2 × Bell 412 (Fig. 6).

Aerial surveillance is also carried out by the two dispersant spraying aircraft operated by the Air Unit of the Department of Forestry of MARDE (1 × AIRTRACTOR 802 and 1 × THRUSH 550) (Fig. 7).

Naval surveillance is implemented by the Marine Police and the vessels operated by DFMR. DFMR operates two multipurpose patrol vessels (located in Larnaca and Limassol ports) that can also carry dispersant spraying missions.

Oil spill forecasting in Cyprus is carried out using the well-established MEDSLIK oil spill and trajectory 3D model that predicts the transport, fate and weathering of oil spills and the movement of floating objects in the Mediterranean, the Black Sea and elsewhere. The MEDSLIK incorporates the evaporation, emulsification, viscosity changes, dispersion in water column, adhesion to coast and sedimentation [12].

The MEDSLIK oil spill and trajectory prediction system makes use of the Copernicus Med-MFC met-ocean data and of the Cyprus Coastal Ocean Forecasting and Observing System (CYCOFOS) downscaled forecasting products for operational application in the Cyprus waters and the Eastern Mediterranean Levantine

Fig. 6 H/C "AKRITAS" of Cyprus Police flies over Limassol's maritime area [11]

Fig. 7 “FOREST-ONE plane applies dispersants at sea” [11]

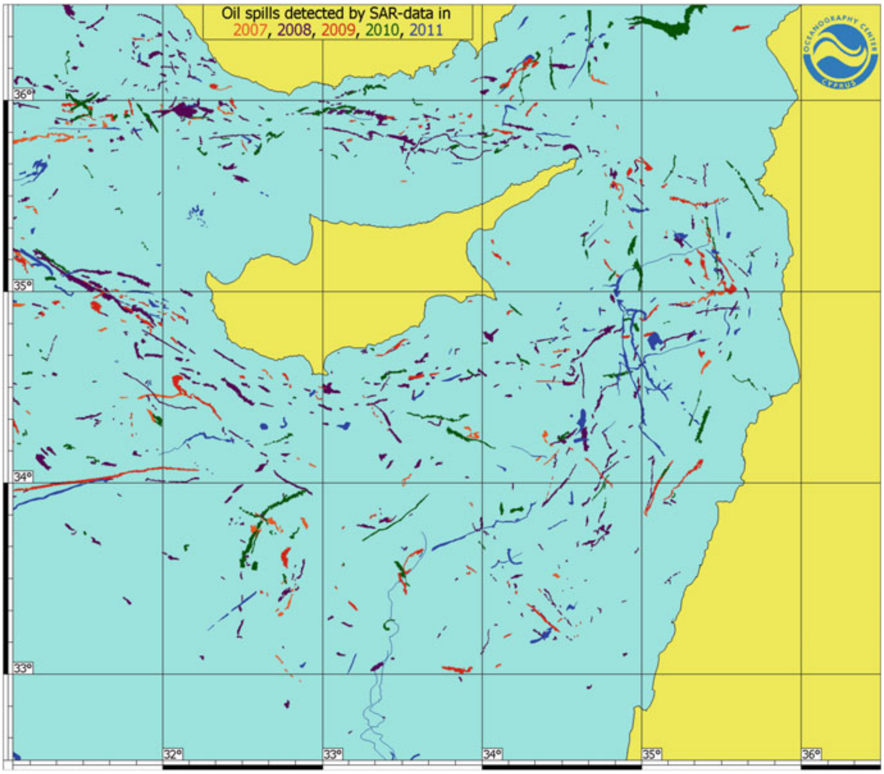

Fig. 8 Superposition of all the possible oil slicks observed in the Eastern Mediterranean NE Levantine Basin by SAR imagery during the period from 2007 to 2011 [13]

Basin. Advanced Synthetic Aperture Radar (ASAR) satellite remote sensing images from the European Space Agency (ESA) and EMSA CleanSeaNet (EMSA-CSN) [7] provide the means for routine monitoring of the southern European seas for the detection of illegal oil discharges. Figure 8 shows a composition of all the possible slicks detected in the Eastern Mediterranean NE Levantine Basin from satellite imagery over 5 years from 2007 to 2011, with the slicks for each year shown in a separate colour. During this period, more than 1,000 possible small or extended oil spills were detected in the NE Levantine Basin, mostly along the ships routes [13].

MEDSLIK coupled with the Copernicus Med-MFC met-ocean data, as well as with the CYCOFOS forecasting data with SAR images to provide backward and forward predictions for such satellite remotely observed oil slicks. MEDSLIK has the capability to plot the routes of the ships, provided by AIS and to compute the minimum distance that any ship path approaches to any backward position of the slick, thus assessing whether any ship would have been capable of causing the slick, assisting in this way the response agencies to implement the EC Directive 2005/35.

4 Amount of Oil Pollution

4.1 Maritime Accidents

According to the Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea (REMPEC) Accident database for the period 2004–2014, a total of seven marine accidents have been recorded in Cyprus waters, six of which occurred in the sea and one within the Limassol Port area.

The recorded accidents involved fires and explosions, ship collisions, grounding and other causes. Figure 9 presents the accident types recorded.

The main ship types involved in the accidents within Cyprus' waters were container carriers, bulk carriers, chemical tankers, oil tankers and general cargo ships. The Ship Type per Accident Type analysis is presented in Fig. 10.

Out of the recorded accidents, only two have resulted in oils spilled in the sea and specifically bunker fuel oil. The spilled quantities were relatively small since only 34 tons were reported spilled.

4.2 Oil Pollution Legislation

Cyprus is a State party to the major international instruments relating to the prevention and management of pollution. Specifically, it is a party to and has ratified the International Convention on Civil Liability for Oil Pollution Damage of 1969 ("CLC") and the 1992 Protocol amending the same (ratification Laws

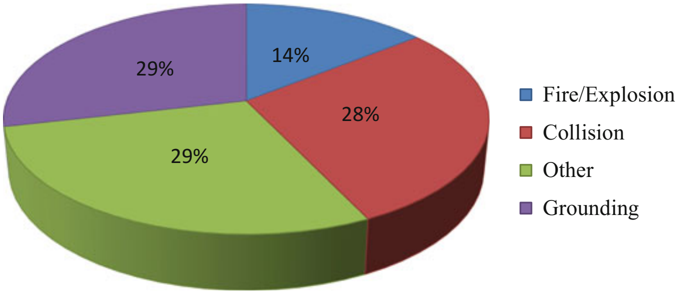

Fig. 9 Marine accident types for recorded accidents within Cyprus' waters (2004–2014)

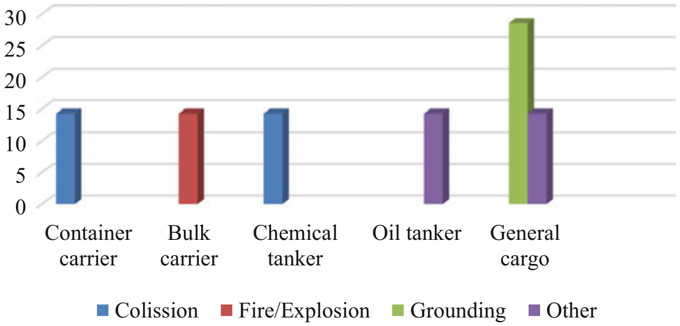

Fig. 10 Ship type per accident type (%) analysis within Cyprus's waters (2004–2014)

1989–2005) as well as the International Convention for the Establishment of an International Fund for Compensation for Oil Pollution Damage of 1971 and subsequent amendments (ratification laws 1989–1997). The liability regime under the said instruments has been extended to cover the "EEZ" of state parties.

Under the CLC liability regime, strict liability applies for ship owners. The right of the owner to limit liability can be removed by virtue of acts or omissions of the owner itself, with the burden of proving the ship owner's conduct being on the claimant.

Cyprus is also a party to the International Convention for the Prevention of Pollution from Ships, 1973 as modified by the Protocol of 1978 ("MARPOL 73/78") and its amendments, which has been ratified by virtue of the relevant Laws 1989–2005.

As regards the Mediterranean, Cyprus is a party to Convention for the Protection of the Mediterranean Sea Against Pollution and Connected Protocols and has ratified the same by virtue of Law of 1979 (Law 51/79) and amendments thereto by virtue of subsequent legislation (Laws 20(III)/2001 and Law 35(III)/2007, respectively). Cyprus is also a party to the Trilateral Agreement between Cyprus, Israel and Egypt for Cooperation in Combating Major Marine Pollution Incidents in the Mediterranean.

The duty to investigate marine accidents and incidents of Cyprus flagged ships all over the world and accidents and incidents of foreign flagged ships in the territorial waters of Cyprus vests with the Marine Accident Investigation Committee ("MAIC"), established under the Investigation of Marine Casualties and Incidents Law of 2012, Law 94(I)/2012 (transposing Directive 2009/18/EC of the European Parliament and the Council establishing the fundamental principles governing the investigation of accidents in the maritime transport sector [14]).

5 Impact on the Environment

Marine operations are a major source of pollution of surrounding areas due to discharges of waste and chemicals in the water. Special attention should be paid to oil spills as they can cause significant environmental damage and a negative effect on the economy. The effect could vary substantially depending on the size of the spill, its chemical characteristics, the oceanographic and meteorological conditions at the time and the effectiveness of spill response measures [15].

The sea and coastal area of Cyprus exhibits a rich marine environmental heritage due to the high level of biodiversity and endemism. It also provides socio-economically valuable natural wealth and services. These services largely maintain the economy and society of Cyprus.

Even a small oil spill in this ecologically sensitive area can have long-term impacts. The influence of an oil spill depends on the type and amount of toxics present in the petroleum product [16]. Large oil spills can be devastating to the marine environment. They kill fish, mammals, birds and their offspring, destroy plant life and reduce the food supply for organisms that survive and they also disrupt the structure and function of marine communities and ecosystems. Oil spill impacts can be far reaching not only for the environment but also for recreational activities, local industry, fisheries and marine life [17].

6 Way Forward

The North-Eastern Mediterranean where Cyprus is located is a confined water body that exhibits a congestion of conflicting uses. The dense marine traffic observed in Cyprus' waters increases the risk of operational and accidental oil pollution that would have devastating effects on the environment and the economy of the country. This makes the existence of a robust oil spill prevention and response system a necessity.

On a legal level, Cyprus has an adequate performance since it has ratified most relevant conventions and protocols. Improvements on an administrative level have been already initiated for the unification of, the currently fragmented, oil spill related authority and responsibilities under a single body.

Oil Pollution Monitoring in Cyprus is also subject to improvements by the investment in monitoring assets and in technological innovation and the use of data and images from the EMSA-CSN, as well as from REMPEC.

Aerial surveillance could be improved significantly by the admission of drones that could contribute in the increase in aerial surveillance range and duration while reducing costs.

Naval surveillance capabilities of Cyprus lack adequate long-range capability. Therefore, the addition of long-range patrol ships that will be able to navigate rough seas would significantly increase the naval surveillance capabilities.

Oil spill forecasting is at an advanced state in Cyprus using the well-established MEDSLIK oil spill model coupled with EMSA CSN satellite SAR data.

References

1. Cyprus Business & Investment Opportunities Yearbook (2011)
2. www.marinetraffic.com. Accessed May 2017
3. VTTI Cyprus. http://www.vtti.com/terminals/vttv-cyprus. Accessed May 2016
4. Ministry of Energy, Commerce, Industry and Tourism of Republic of Cyprus (n.d.) http://www.mcit.gov.cy/mcit/. Accessed May 2017
5. International Institute for Strategic Studies (n.d.) https://www.iiss.org/. Accessed Mar 2016
6. ITOPF (2012) A summary of oil spill response arrangements & resources worldwide – country profile. ITOPF
7. Carpenter A (2016) European Maritime Safety Agency activities in the Mediterranean Sea. In: Carpenter A, Kostianoy AG (eds) Oil pollution in the Mediterranean Sea, part I – the international context. The handbook of environmental chemistry. Springer, Heidelberg. Doi: 10.1007/698_2016_1
8. European Marine Safety Agency (n.d.) http://www.emsa.europa.eu/csn-menu.html. Accessed May 2016
9. Ministry of Agriculture, Natural Resources and Environment (2011) The National Contingency Plan for Oil Pollution Combatting of Cyprus. Nicosia
10. International Maritime Organization (n.d.) www.imo.org/en/About/Conventions/ListOfConventions/Pages/International-Convention-for-the-Prevention-of-Pollution-from-Ships-%28MARPOL%29.aspx. Accessed May 2016
11. Attas N (2012) Report “NIRIIS 2012” – Cyprus oil pollution response exercise, Limassol. 25–26 Sept 2012
12. De Dominicis M, Pinardi N, Zodiatis G, Lardner R (2013) MEDSLIK-II, a Lagrangian marine surface oil spill model for short-term forecasting – part 1: theory. Geosci Model Dev 6:1851–1869. doi:10.5194/gmd-6-1851-2013
13. Zodiatis G, Lardner R, Solovyov D, Panayidou X, De Dominicis M (2012) Predictions for oil slicks detected from satellite images using MyOcean forecasting data. Ocean Sci 8:1105–1115
14. Cyprus Shipping Law Review – 2015 (2015) International Comprative Legal Guides. http://www.iclg.co.uk/practice-areas/shipping-law/shipping-2015/cyprus. Accessed Apr 2016

15. Ministry of Commerce, I. a. (2008) Strategic Environmental Assessment (SEA) concerning hydrocarbon activities within the exclusive economic zone of the Republic of Cyprus
16. Stoyanov S (n.d.) Water pollution and waste management in port areas. University of Chemical Technology and Metallurgy, Sofia
17. National Research Council (2003) Oil in the sea III: inputs, fates, and effects. National Academies Press, Washington, DC. Doi: 10.17226/10388. Accessed May 2017. https://www.nap.edu/catalog/10388/oil-in-the-sea-iii-inputs-fates-and-effects

Oil Pollution in the Waters of Algeria

Aicha Benmecheta and Lotfi Belkhir

Abstract As one of the three top oil producers in Africa, with a coastline of 1,644 km along the Mediterranean south shore, Algeria is a major stakeholder in the oil pollution in the Western Basin of the Mediterranean Sea. In this chapter, we review the major sources and levels of pollution from the three largest oil export terminals of Algeria, which also combine major oil refineries, including the largest refinery in Africa, and their potential impact on the overall pollution of the Mediterranean waters and beyond.

Keywords Algeria oil pollution, Algiers oil terminal, Arzew refinery, Hydrocarbon pollution in the Mediterranean Sea, Oil pollution, Skikda oil terminal, Skikda refinery

Contents

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1 Introduction

Algeria is the largest country on the African continent, and with a coastline of 1,644 km, it holds the lion's share of the southern shore of the Western Basin of the Mediterranean Sea. Algeria is also the top producer of natural gas in Africa, the second largest natural gas supplier to Europe, after Russia, and is among the top three petroleum producers in Africa. Algeria is also estimated to hold the third largest reserve of shale gas in the world [1]. In 2015, the country produced about 1.7 million barrels per day (bpd) of total petroleum products, with roughly a 2:1 split between crude oil and refined petroleum products. Also, more than 75% of this production was exported by sea through oil tankers. Algeria does not currently have any transcontinental export oil pipelines allowing it to export directly to its northern Mediterranean neighbors.

Algeria uses six coastal terminals for the export of its petroleum products conveniently distributed throughout its long coastline and which are located, going from west to east, in Oran, Arzew, Algiers, Bejaia, Skikda, and Annaba. Also, Algeria has five oil refineries with a total capacity of 652,500 bpd, three of which, Skikda (352,700 bpd), Algiers (63,400 bpd), and Arzew (58,500 bpd), are in coastline cities, while the other two are in the Saharan cities of Hassi Messaoud (163,500 bpd) and Adrar (14,400 bpd). The Skikda refinery is ranked no. 1 in Africa and no. 3 in the world and processes more oil than all the other four refineries combined. It's estimated that about 76% of Algerian crude oil is exported to Europe with the remainder sent to the Americas (17%) and Asia and Oceania (7%) [1]. Clearly, these facts make Algeria a very significant stakeholder and player in the oil pollution of the Mediterranean Basin, and the impact of its near and onshore oil operations is a subject deserving a careful assessment. We count in those operations two major sources of oil pollution to the Mediterranean Sea:

1. The first comes from the traffic of oil tankers at the six export terminals, through illegal discharges, tank cleaning, runoffs, etc. It's estimated that 35% of the oil that enters into the sea waters in general is due to tanker traffic and other sea shipping operations [2].
2. The second and perhaps more important source of water pollution coming from Algerian petroleum operations is the three oil refineries in Skikda, Arzew, and Algiers in order of importance (see Fig. 1).

To precisely assess the oil pollution level in the Mediterranean Sea, it would have been extremely helpful to have some direct estimates of the input of oil from the different sources in the Mediterranean. This unfortunately is not practically

Fig. 1 The three major sources of hydrocarbon pollution in the Algerian Mediterranean Basin. *Source*: Adapted from Google Earth

possible, mainly due to the lack of appropriate statistics from the different countries as well as to the lack of coherent monitoring figures on oil in the area. Instead, we will have to rely on some specific and rigorous field studies that have shed valuable insight on this serious problem.

Oil refinery effluents contain many different chemicals at different concentrations including ammonia, sulfides, phenol, and hydrocarbons. The exact composition cannot however be generalized as it depends on the refinery and which units are in operation at any specific time. It is therefore difficult to predict what effects the effluent may have on the environment. Toxicity tests have shown that most refinery effluents are toxic but to varying extents. Some species are more sensitive and the toxicity may vary throughout the life cycle. Sublethal tests have found that not only can the effluents be lethal but also they can often have sublethal effects on growth and reproduction. Field studies have shown that oil refinery effluents often have an impact on the fauna, which is usually restricted to the area close to the outfall [3].

In this chapter, we will offer a state-of-the-art review of the most extensive studies of the impact of Algerian hydrocarbon on Mediterranean waters, originating from either the near-shore refinery activities or the oil exports. Since much of the data collected and the studies conducted were made on sites, such as Skikda, Algiers, and Arzew which serve as both export terminals and refinery sites, it is quite difficult to determine for certain the specific source of that pollution.

The rest of this chapter will consist primarily of Sect. 2 which will describe in fair details the most recent and thorough studies of the oil pollution levels in each of the three sites, namely, Skikda, Arzew, and Algiers. Each site will be the subject of its own study and hence its own section. The methods used, which consist of in-field studies as well as remote sensing using satellite imagery, will also be described in fair details. In the final subsection of Sect. 2, we will discuss the important and serious consequences of the findings from these various studies.

2 State of Pollution in Algerian Waters and Major Sources and Culprits

The Mediterranean Sea has the notable peculiarity of having a water deficit, which, notwithstanding the impact of mesoscale eddy currents that can cause regional and global dispersion of pollutants, tends to prevent any outflows of surface waters through the Strait of Gibraltar into the Atlantic Ocean. This, in essence, makes the level of hydrocarbons in the Western Basin one of the highest in the world. This also raises the fear of seeing an increased level of less biodegradable pollutants, such as organochlorines and other surfactants, lead to the progressive degradation of the pelagic and offshore ecosystems [4]. Also, the high level of near-shore hydrocarbon pollution is further aggravated by the lack of significant tides, which limits significantly the dilution and diffusion of those pollutants across larger areas and their faster biodegradation.

The main sources of oil pollution in Algeria waters are the effluents of the on-shore refineries and the various discharges and runoffs from the oil export terminals. We focus in this section on the state of pollution of near-shore Algerian waters in the vicinities of Skikda, Arzew, and Oran. All of three cities serve as export terminals as well as host major refineries.

2.1 Skikda Bay

2.1.1 Level of Contamination

Skikda bay is located in the east-northern part of Algeria, about 470 km east of the capital Algiers. The area is in contact with an enormous petrochemical industrial complex, where raw petroleum and refined hydrocarbon products contaminate the surrounding areas via atmospheric pollution as well as effluents, which are dumped into seawaters. An important study conducted by Boutefnouchet, Bouzerna, and Chettibi helped establish the effects of these pollutants and waste disposal on the vicinity of the bay [5].

Several samples were taken at six (6) different sites along the bay and the outfall pipes of the industrial complex (see Fig. 2).

Several chemical analyses were made to analyze the concentrations of hydrocarbons, CO_2, Ca^{+2}, and Mg^{+2}, chlorides and phosphates, and the alkalinity present into the samples. Table 1 shows a summary of the results on all six (6) sites and compares them with their clean water counterparts. As can be seen from the data, all of the six sites show very elevated levels of contamination in most of the chemicals (to the exception of phosphates) as compared with clean water. This level of pollution is attributed mostly to the effluent dumping from the petrochemical complex [5].

Fig. 2 Studied littoral zone of Skikda bay (Algeria): (1) Fishing port located at the Stora Gulf. (2) Ancient port located in the center of the town. (3) New port located at the entry of the industrial zone. (4) Effluents dumping from the petrochemical complex of Skikda. (5) Ben Mhidi Bathing station. (6) The Marsa Platanes. *Source*: [5]

Table 1 Different chemical constituents expressed in ppm and corresponding to six different sampling points

Site	1	2	3	4	5	6	Clean water
Hydrocarbons	10	10	19	188	2	260	10^{-2}
CO_2	10^4	10^3	1,340	1,200	700	1,400	N/A
M-Alkalinity	550	625	123	147.5	122.5	165	50
Total hardness	5,000	5,500	5,280	4,660	5,000	4,860	50
pH	8.7	8.7	8.5	8.8	8	8.9	6.5–8.5
Cl^-	2,492	2,279	3,227	3,582	>24,000	3,339	250
Po_4^{-3}	0.01	0.014	<0.02	<0.02	<0.02	<0.02	0.025
T (°C)	28	28	26	28	26	28	N/A
COD (chemical oxygen demand)	4.24	6.72	5.36	8.4	4.5	9.6	N/A

2.1.2 Cleaning and Biodegradation of Oil Pollutants

Another notable study also by Boutefnouchet et al. looked at the biodegradation process of pollutants as a function of time in the Skikda bay [6]. In this study, the researchers sought to identify and assess the effectiveness of selected

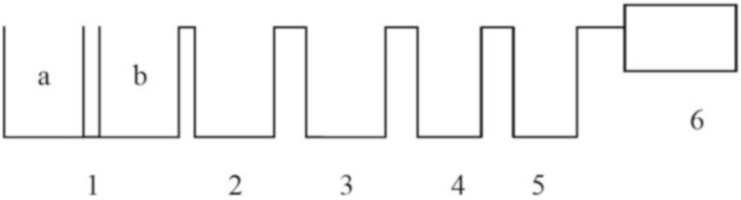

Fig. 3 Schematics of the various basins of the Skikda refinery effluent treatment unit. Basin 1 (*a*) and (*b*) are used for the screening of big chunks; basin 2 is primarily for decantation and scraping off of the precipitated elements; basin 3 is used for the flocculation of the effluents; basin 4 is the microbiological basin where the biodegradation of the effluents starts using microorganisms solutions, aided with proper oxygenation and clean water source; basin 5 is a secondary decantation basin; and finally basin 6 is a sand filter

microorganisms for the cleaning and prevention of pollution by biological means, as a potential mitigating solution to the elevated level of pollution they previously uncovered.

In addition to the study of the biodegradation within the natural contaminated environment at some specific sites shown in Fig. 2, they also studied the biodegradation rate at the level of the effluent distillation and treatment unit of the Skikda refinery. The unit is composed of six (6) separate basins as shown in Fig. 3.

The researchers collected four (4) separate microbial populations and named them as follows: (1) PMA from basin 4 (Fig. 2); (2) PMB from the contaminated ground of the refinery; (3) PMC from uncontaminated position 3 (Fig. 2) corresponding to the new port located at the entry of the industrial zone; and (4) PMD from position 4 (Fig. 2) corresponding to the dumping site from the petrochemical complex. Each of the four (4) microbial populations was found to have its own distinctive composition. The effectiveness of these four (4) mixtures on the biodegradation of the same type of hydrocarbon (NAFTA B form of petrol from Hassi Messaoud oil wells), using the same conditions of oxygenation and clean seawater, was then evaluated as a function of time from 0 to 21 days.

Figure 4a shows the time evolution of the hydrocarbon biodegradation as a function of time over a 21-day period. Note that the biodegradation curves for PMA, PMB, and PMC all seem to achieve a 93% reduction in hydrocarbon, while PMD achieved a 98% reduction. All populations seem to exhibit a rate-limiting behavior as expected from these kinds of processes. The researchers also measured the CO_2 production by these bacterial populations during the degradation process.

Figure 4b shows the emissions curve as a function of time during the 21-day period. Again, the PMD population shows a significantly higher CO_2 emission level, confirming its more potent efficiency at biodegrading the hydrocarbon. Finally, we remind the reader that the PMD population was collected from the position (4) in Fig. 2, which corresponds to the effluent dumping from the petrochemical complex of Skikda. This is also the same position that shows the second highest level of hydrocarbon contamination (188 ppm) across all the six (6) sites that were assessed and shown in Table 1. In other words, despite the apparent

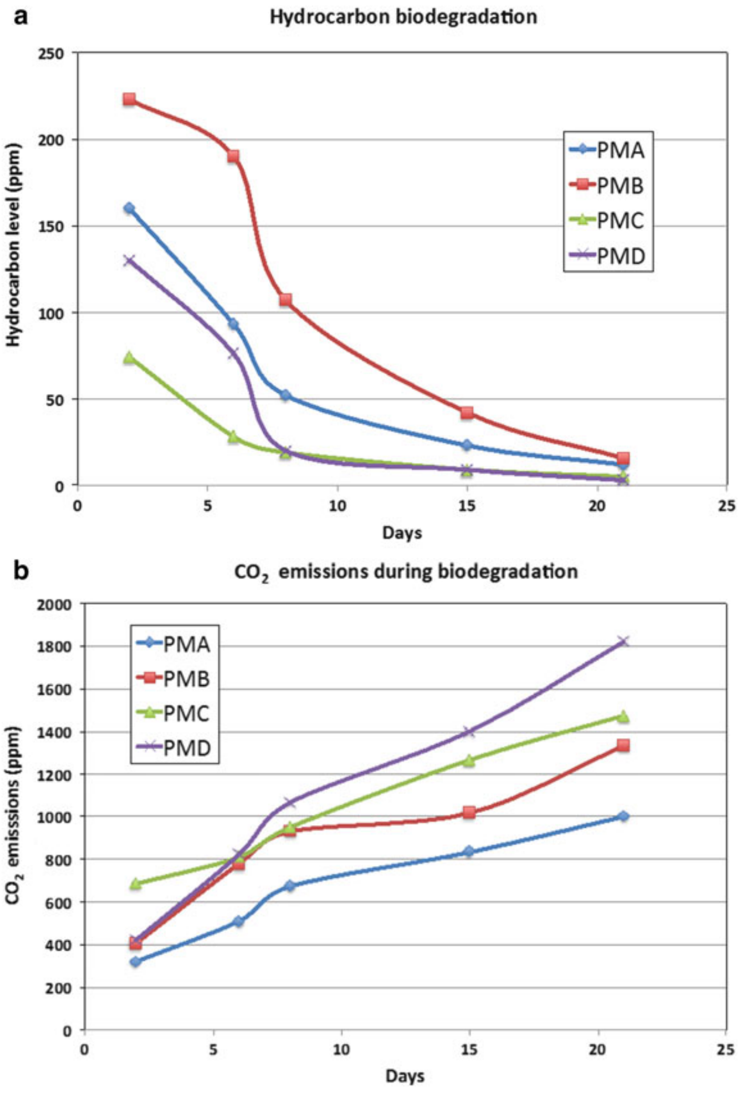

Fig. 4 (**a**) Hydrocarbon biodegradation for four different bacterial populations as a function of time over a 21-day period. (**b**) CO_2 emissions for four different bacterial populations as a function of time over a 21-day period

effectiveness of the PMD bacterial population in biodegrading the hydrocarbon from the effluents, there is nonetheless a very elevated level of contamination that is still present.

Dates	15/07/2003	17/11/2003	02/12/2003	07/12/2003	16/12/2003	22/12/2003
Sites	1,2,3,4,5	6,7,8,9	10,11,12,13,14	15,16,17,18,19,20	21,22,23,24,25,26	27,28,29,30,31,32

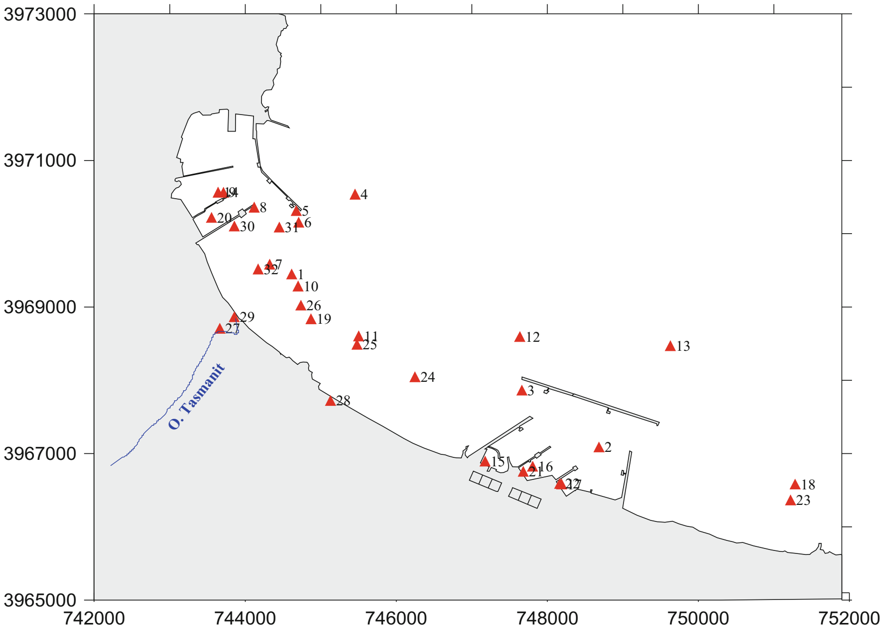

Fig. 5 Dates and sites of seawater samples taken from the Arzew Bay

2.2 *Arzew Bay*

Arzew Bay is situated in the northwestern part of Algeria and is about 400 km west of the capital Algiers. In other words, it's almost equally distant to the Skikda bay from Algiers and on the opposite, western side of the country.

Some of the most pertinent work on the assessment of hydrocarbon pollution in Arzew Bay was led primarily by Benmecheta and her team in 2005 [7]. The assessment was done using both extensive in situ sample collection and analysis combined with remote sensing assessment using satellite imaging.

Benmecheta conducted a sample analysis on the Arzew bay from thirty-two (32) separate sites on six (6) different days over a period of spanning July–Dec 2003. The selected sites and timeline are shown in Fig. 5. The samples were all collected at 1-meter vertical depth from the water surface and were carefully protected in airtight bottles lined with aluminum foil pre-washed in carbon tetrachloride to prevent any oxidation. Also, to prevent any spurious postharvesting microbial activity, the researchers acidified the samples that were not immediately analyzed to a pH <3 with a solution of hydrochloric acid (HCl).

The assessment of the hydrocarbon (HC) content in the samples was conducted using the UV/Vis (ultraviolet–visible) spectroscopy to measure their absorptance

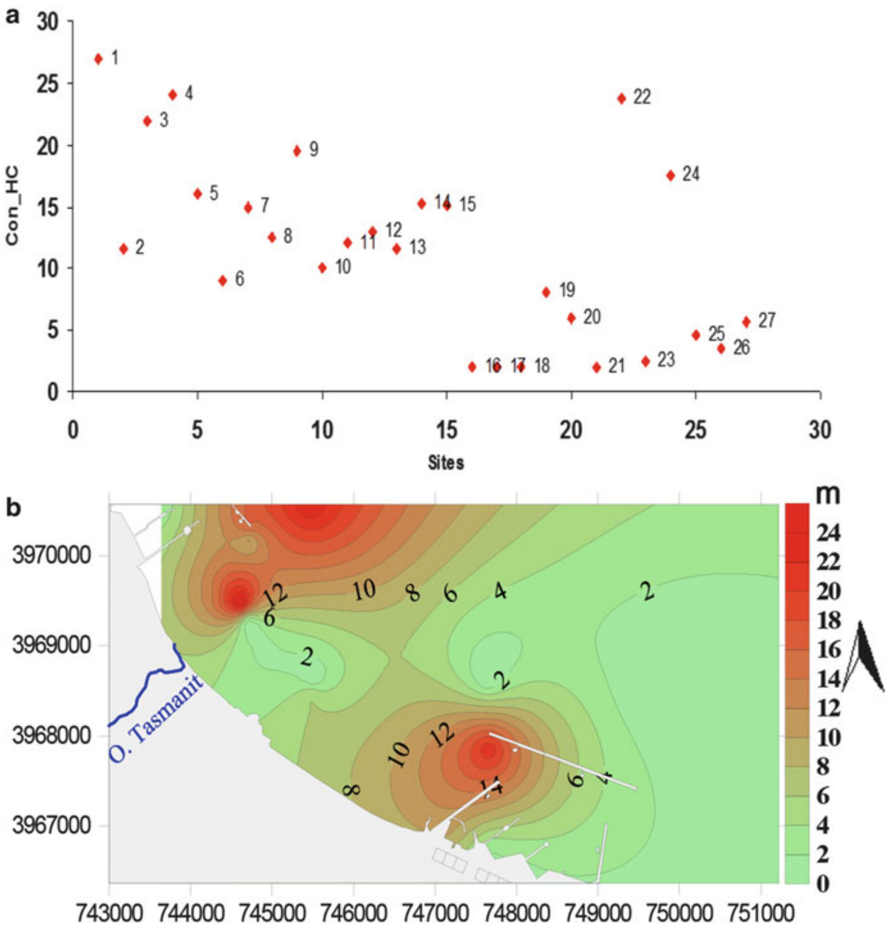

Fig. 6 (**a**) HC pollution content for each of the 32 sampled sites in Arzew Bay. (**b**) HC content per location showing the dispersion gradient of the pollution

spectrum in a chloroform solvent. The HC content in mg/l (equivalent to ppm) was obtained with the reading of the 400 nm wavelength. The key results of the study were as follows:

- The highest values of HC content tended to be localized around (1) site 1 which is the direct recipient of the effluent discharges from the large petroleum and gas-processing complex at Arzew which flow through Ouadi Tasmanit (Tasmanit river shown in blue in Fig. 5) and (2) from sites 4, 5, and 9 and sites 2, 22, and 24 which fall in the oil tankers areas on the western and eastern sides, respectively (see Fig. 6a).
- There was a high level of variability of the HC pollution over time and over space on a relatively small scale, as shown in Fig. 6b, with HC content ranging from 2 mg/l to a maximum of 27 mg/l.

- The effect of dilution is very strong, suggesting a very rapid dispersion of the pollution in the neighboring regions and beyond.
- When taking into account the dispersion effects, these levels of sea pollution are consistent with the levels of hydrocarbon concentration (90–180 mg/kg) in surface sediments originating from the Arzew shores, as reported in [8].

2.3 Algiers Bay

Last but not least in our review of the pollution levels in the Algeria seas is the review of the Bay of Algiers, the capital and largest city of Algeria. The most comprehensive study of this bay was done by Houma-Bachari in her Ph.D. thesis [8]. Figure 7 shows the location of the beautiful Bay of Algiers along with some unfortunate images of the pollution and effluents entering that bay on an ongoing basis.

Bachari's study is characterized by the fact that she relied almost exclusively on the remote sensing techniques of satellite imaging to study the level of pollution of the Bay of Algiers, along with another pertinent regions such as the Bays of Bousmail, El Djamila, and Zemmouri. This allowed her to assess the pollution level on a much larger area, but at the same time restricted her to rely on proxy metrics such as turbidity and suspended matter (SM), rather than a direct assessment of the hydrocarbon levels as was done in the field studies conducted in the bays of Arzew and Skikda. Figure 8 shows a SPOT satellite imagery in three XS spectral channels (often referred to as SPOTXS images) of the variation of suspended matter in the Algiers Bay (10 April 2009).

Figure 9 shows the level of turbidity at the surface of the Bay of Algiers on the NTU (nephelometric turbidity units) scale. Turbidity was found to vary from 80 to 116 NTU at the water surface. The highest values were registered at the Port of Algiers and El-Harrach, while the lowest were near El Hamma. This is quite consistent with the fact that both Oued El-Harrach (River of El-Harrach) and the Port d'Alger are by far the two largest sources of effluents in the region.

In addition to the turbidity measurement using satellite imagery, Bachari and her team conducted three in situ campaigns to measure the amount of suspended matter (SM) at several depth levels across the whole bay and calibrate their remote sensing data. Table 2 shows the mean and standard deviations of the SM levels measured in campaigns 1 and 2. The two campaigns are conducted about 1 month apart and were characterized by very similar weather conditions, such as temperature, wind, and sea current speeds.

Notice in Table 2 the large difference in the SM levels between campaign 1 and campaign 2, which shows a level of SM more than 4.5 times larger than the campaign 1 level. This high variability in sea surface pollution is believed to be due to the rapid dispersion that is characteristic of the powerful sea currents of the Mediterranean Sea as explained below.

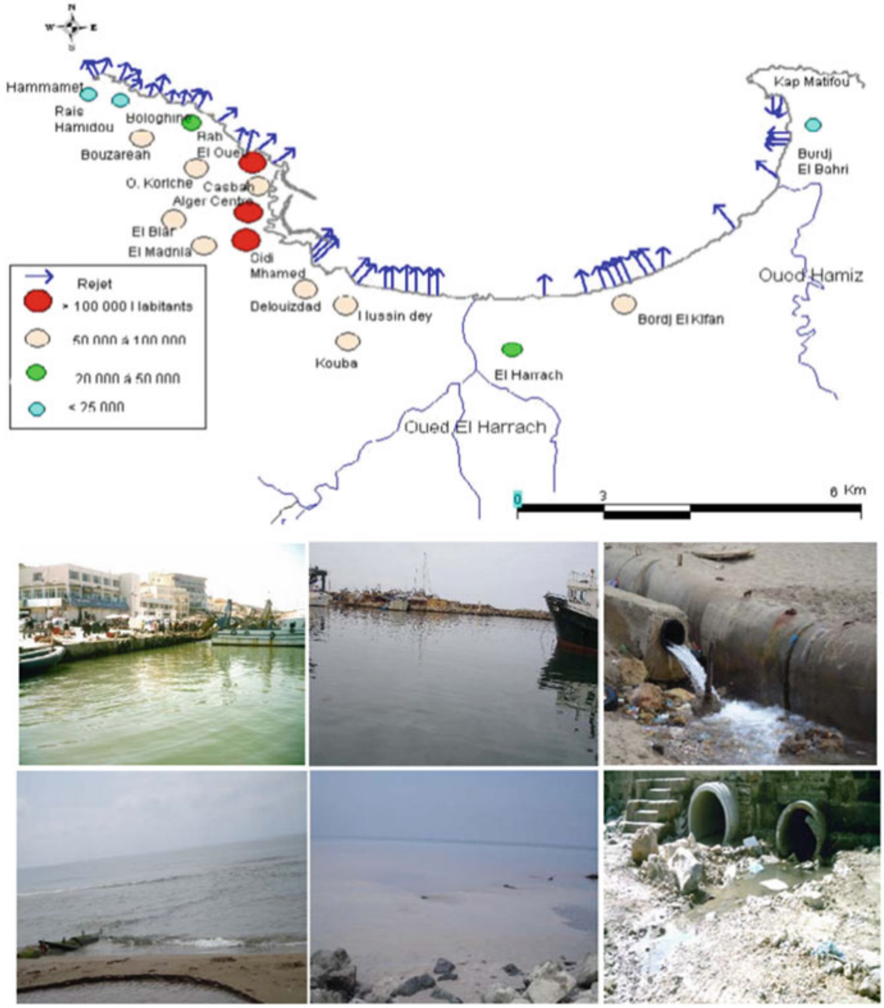

Fig. 7 Schematic of Algiers Bay showing (*blue arrows*) the main sources pollution and effluents, along with some sample pictures of those pollution sources (Courtesy of Houma-Bachari [8])

2.4 Dispersion of Pollution

We have seen from the above review of the HC pollution levels in the bays of Skikda, Arzew, and finally Algiers that the levels of HC and suspended matters range from about 30 mg/L in the Bay of Arzew to more than 250 mg/L in the Bay of Skikda and vary from 20 to 95 mg/L in the Bay of Algiers. Notwithstanding the fact that all these values are unacceptably high, what is even more disturbing is the degree of variability of these pollution levels, which is indicative of the dispersion effect of this pollution on both a regional and even global level.

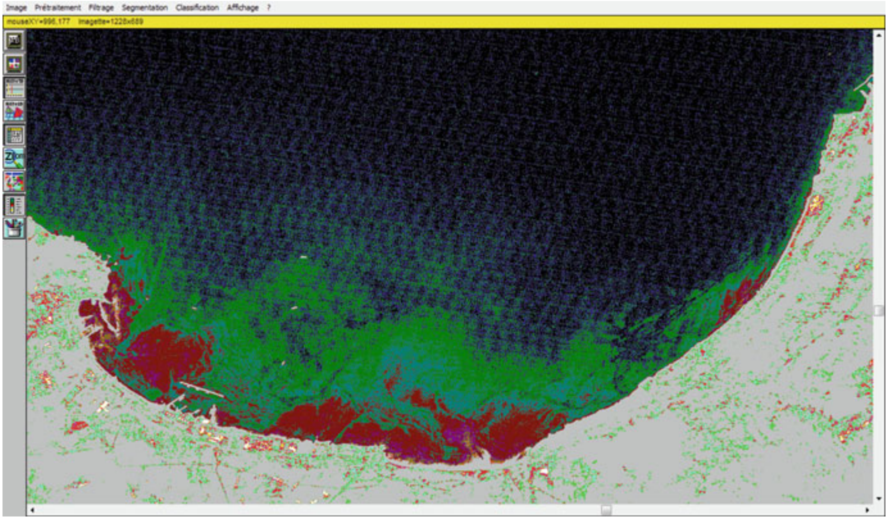

Fig. 8 Variation of suspended matter on a SPOTXS satellite image made of the Algiers Bay (10 April 2009) [9]

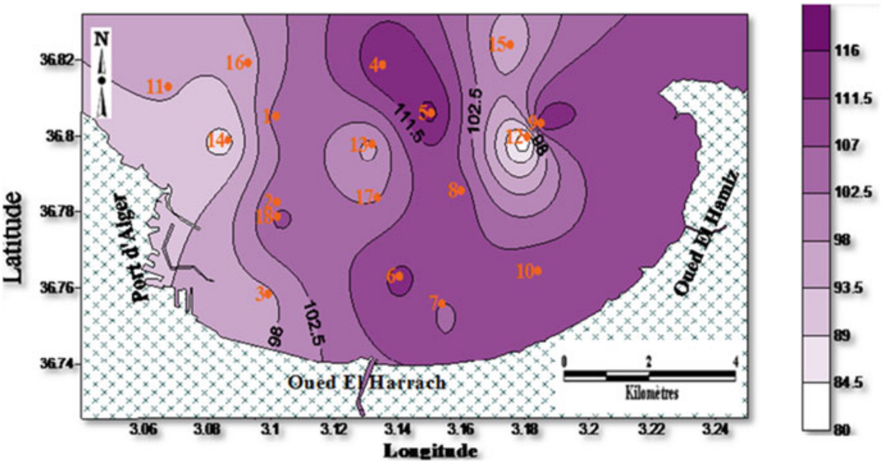

Fig. 9 Turbidity map in the Bay of Algiers (Courtesy of Bachari [8])

The water circulation in the Mediterranean Basin is known to cause regional dispersion of pollution [10]. Also, Arzew Bay is less than 300 nautical miles away from the Strait of Gibraltar and the Atlantic Ocean. Furthermore, the Algerian Current is one of the most energetic flows in the Mediterranean Basin. One branch of this current reaches the coast and returns to the western direction (Fig. 10). This current is formed by a series of mesoscale eddy currents at different scales. The buoys, released upstream and across a coastal meander between 0°E and 1°E

Table 2 Suspended matter measured at or near the surface level of the sea across the Bay of Algiers during two separate campaigns

Suspended matter (SM) (mg/L at 1 m below surface)			
Campaign 1 (March 2009)		Campaign 2 (April 2009)	
Mean	Std deviation	Mean	Std deviation
19.71	5.92	94.76	6.85

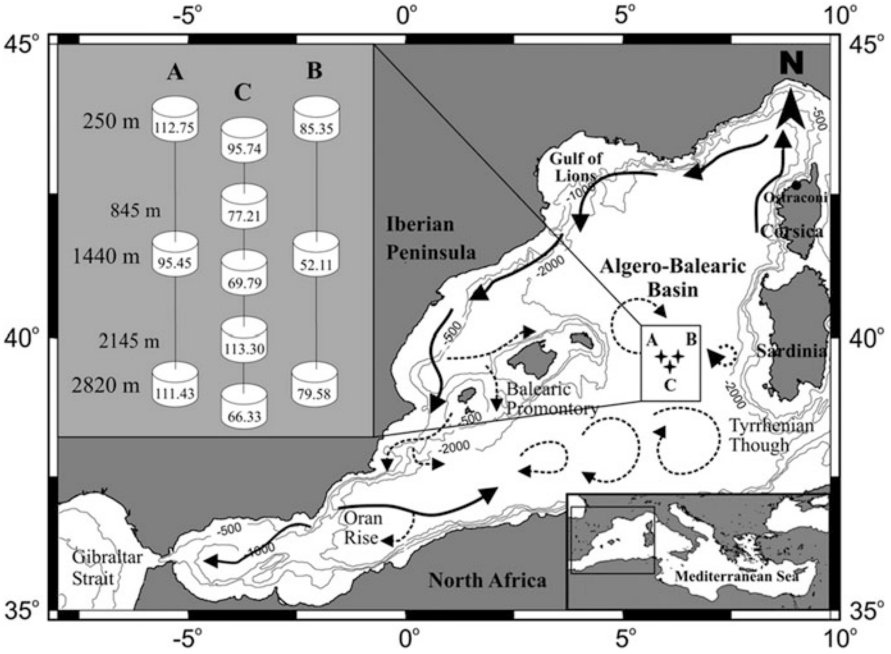

Fig. 10 Surface water circulation in the Western Mediterranean Basin [11]

longitude, were followed for 3 months and found to travel an average speed of 14 cm/s (0.5 km/h) showing high energetic fluctuations related to several mesoscale eddies. More specifically, these are equivalent to 66 km in four (4) days along the zonal component and about 26 km in two (2) days along the meridional component [12]. This surface current is the main factor of dispersion of pollutants, such as HC, mercury, and others, to other coastal areas in western Algeria and beyond [13].

3 Oil Pollution Preparedness and Response

Algeria is a bona fide member of the Barcelona Convention (ratified in February 1981) and REMPEC (Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea) and is one of the seventeen (17) countries out of the twenty-one (21) coastal countries surrounding the Mediterranean Basin that received approval from REMPEC for its National Contingent Plan [14].

REMPEC has provided its assistance since its establishment in 1976 in the field of national systems for preparedness for and response to marine pollution, to the competent national authorities of Algeria among fourteen (14) other Mediterranean countries. In addition to assisting individual coastal country in developing their contingency plans, REMPEC has also been involved since 1992 in the development of subregional systems for preparedness and response to major marine pollution incidents. Such subregional arrangements, called sub-regional contingency plans (SRCP), for mutual assistance in case of marine pollution emergencies significantly extend the spill response capacities of individual countries by providing a mechanism for pooling resources and jointly conducting response operations.

The first SRCP was in the South-Western part of the Mediterranean and included Algeria, Morocco, and Tunisia. It has been financed by the International Maritime Organization (IMO) and developed by REMPEC, in close cooperation with the national authorities of these three countries and signed in Algiers on 20 June 2005. The agreement and the plan entered into force on 19 May 2011 [15].

Separately from REMPEC, Algeria also ratified a National Contingency Plan with the International Tanker Owners Pollution Federation (ITOPF) effective 1994 [16]. This plan requires the three marine districts of Alger, Oran, and Jijel to maintain a response plan for combating pollution at sea and on shore and local authorities to have suitable arrangements in place. These are overseen by a national committee presided over by the Minister of the Environment. A review of the National Contingency Plan is under way; this will include arrangements for HNS response (Information as of May 2011).

In the event of an incident, command is allocated according to the size of the spill. The Minister of the Environment will assume control at a national level. At a regional level, command is assumed by the commander of the relevant marine district. Local authorities have a responsibility for minor incidents. The coast guard has operational responsibility for response at sea. The relevant administrative districts are in charge of cleanup on shore. In practice, Civil Protection Units under the Ministry of Defense will undertake any shoreline cleanup [15].

Finally, in June 2000, Algeria successfully completed an Oil Pollution Management Project funded by the World Bank's Global Environment Trust Fund [17]. The primary objectives of the project were to reduce the quantity of petroleum hydrocarbons entering the international waters of the Mediterranean and to comply with MARPOL 7 3/78 Convention requirements. The project also achieved, among other objectives, development of a comprehensive and integrated system for the management of oil pollution caused by marine sources, thus ensuring commonality of approaches and methodologies, promoting exchange of information and coordination, enhancing monitoring capability among the countries in the region for preventing and combating oil pollution, and improving the quality of the marine environment.

These objectives were successfully attained and deemed to be appropriate and in line with the government's international commitment to monitor compliance with international conventions related to marine pollution. They were clear and realistic with regard to national policies and regional agreements (Union du Maghreb Arabe-UMA agreement) [17].

To this date, there are no records of any major spills or pollution incidents that were caused by either an oil tanker or any one of the three major refineries studied in this chapter.

4 Conclusion

We have given in this chapter a succinct yet fairly thorough review of the current state of hydrocarbon pollution in the Algerian waters of the Mediterranean Basin. In particular, we have reviewed the most recent and pertinent field and remote sensing studies conducted on the three largest sources of oil pollutions of the Algeria sea waters, namely, the ports of Skikda, Arzew, and Algiers. We have found that the pollution levels are in all cases very significant and range from 30 mg/L in the Arzew waters to more than 250 mg/L in some spots of the Skikda Bay and vary from 20 to 95 mg/L in the Algiers Bay.

Perhaps even more disturbing than the actual levels at any particular spot is the very high level of dispersion of those HC pollutants across the whole Mediterranean Sea and even beyond into the Atlantic Ocean through the Gibraltar Strait, and this despite the fact that the Mediterranean Basin has a water deficit that limits the outflow to the Atlantic Ocean. Indeed, the Algerian Current is driven by highly energetic mesoscale surface currents in the Mediterranean Basin, which are known to cause regional dispersion of pollution.

References

1. US Energy Information Administration (2016) Country analysis brief: Algeria. Report, March 2016. https://www.eia.gov/beta/international/analysis_includes/countries_long/Algeria/algeria.pdf. Accessed 31 May 2016
2. World Ocean Review (2015) Oil pollution of marine habitats. http://worldoceanreview.com/en/wor-1/pollution/oil/. Accessed 31 May 2016
3. Wake H (2005) Oil refineries: a review of their ecological impacts on the aquatic environment, Estuar Coast Shelf Sci 62(1):131–140
4. Peres J (1978) Vulnerabilite des Ecosystemes Mediterraneens a la Pollution. Ocean Manage 3 (3):205–217
5. Boutefnouchet N, Bouzerna N, Chettibi H (2005) Assessment of the petrochemical industry pollution on the Skikda Bay, Algeria. Int J Environ Res Public Health 2(3):463–468
6. Boutefnouchet N, Bouzerna N, Chettibi H (2006) Biodégradation des hydrocarbures en eau de mer: Cas de Naphta B. Sci Study Res 7(2):1582–1595

7. Benmechta A (2005) Hydrocarbon pollution in Bay of Arzew. Master's thesis, National Center of Space Techniques, Oran, Algeria
8. Houma FB (2009) Modélisation et cartographie de la pollution marine et de la bathymétrie à partir de l'imagerie satellitaire. Ph.D. thesis, Paris Est
9. Houma F, Samir B, Bachari N, Rabah B (2013) Contribution of satellite measurements to the modeling and monitoring of the quality of coastal seawater, perspectives in water pollution. In: Ahmad I, Ahmad Dar M (eds) InTech. doi:10.5772/53375. Available from: http://www.intechopen.com/books/perspectives-in-water-pollution/contribution-of-satellite-measurements-to-the-modeling-and-monitoring-of-the-quality-of-coastal-seaw. Accessed 22 June 2016
10. Millot C, Taupier-Letag I (2005) Circulation in the Mediterranean Sea. The handbook of environmental chemistry, volume 5: water pollution, pp 1–30
11. Zúñiga D, Calafat A, Heussner S, Miserocchi S, Sanchez-Vidal A, Garcia-Orellana J, Canals M, Sánchez-Cabeza JA, Carbonne J, Delsaut N, Saragoni G, 2008 (2008) Compositional and temporal evolution of particle fluxes in the open Algero–Balearic basin (Western Mediterranean). J Mar Syst 70(1–2):196–214
12. Salas J, Garcıa L, Font J (2001) Statistical analysis of the surface circulation in the Algerian Current using Lagrangian buoys. J Mar Syst 29(1–4):69–85
13. Bouchentouf S, Tabet D, Ramdani M (2013) Mercury pollution in beachrocks from the Arzew gulf (West of Algeria). Travaux de l'Institut Scientifique, Rabat, Série Zoologie 49(1–5)
14. REMPEC. http://www.rempec.org/index.asp. Accessed 22 June 2016
15. REMPEC. http://www.rempec.org/rempec.asp?theIDS=2_86&theName=RESPONSE&theID=9&daChk=1&pgType=1. Accessed 22 June 2016
16. ITOPF. http://www.itopf.com/knowledge-resources/countries-regions/countries/algeria/. Accessed 22 June 2016
17. World Bank (2000) Implementation completion report (28607; 28650) on a grant from the global environment trust fund to the democratic and popular republic of Algeria for an oil pollution management project. Report No: 20557, 12 June 2000. http://www.thegef.org/gef/sites/thegef.org/files/gef_prj_docs/GEFProjectDocuments/M&E/Documents%20and%20data/DatabaseContent/TE/2000/WB%20IW/68%20Oil%20Pollution%20Management%20Project_Algeria.pdf. Accessed 22 June 2016

Conclusions for Part II: National Case Studies

Angela Carpenter and Andrey G. Kostianoy

Abstract This book (Part II of a volume on “Oil Pollution in the Mediterranean Sea”) has presented a review of knowledge on oil pollution in the Mediterranean Sea, through a series of national and regional case studies. Those chapters have used a range of data on oil extraction and production activities, oil transportation, satellite technology, aerial surveillance, and in situ monitoring, for example, to present a picture of trends in oil pollution in various areas of the region over many years. A range of legislative measures are in place to protect the marine environment of the region, including the Convention for the Protection of the Mediterranean Sea Against Pollution (Barcelona Convention, 1976) and its Protocols. The Mediterranean Sea and its various regions, such as the Adriatic Sea, have special status for the prevention of pollution by oil from ships under International Convention for the Prevention of Pollution from Ships and its Protocols (MARPOL 73/78 Convention). National Contingency Planning (NCP) and other activities take place under the aegis of the Regional Marine Pollution Emergency Response Centre for the Mediterranean Region (REMPEC), through which countries in the region can work together to cooperate in preventing pollution from ships, for example, and work together to combat pollution in the event of an emergency. NCP and oil pollution preparedness and response activities are discussed within a number of the national case studies. By bringing together the work of scientists, legal and policy experts, academic researchers, and specialists in various fields relating to marine environmental protection, satellite monitoring, oil pollution, and the Mediterranean Sea, these national case studies present a picture of oil pollution

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from a range of sources (shipping – accidental, operational, and illegal), offshore oil and gas exploration and exploitation, and coastal refineries, to present a picture of the current situation in the Mediterranean Sea.

Keywords Aerial surveillance, Barcelona Convention, European Union, MARPOL Convention, Mediterranean Quality Status Report, Mediterranean Sea, National contingency plan, Oil installations, Oil pollution, Oil pollution preparedness and response, Oil spill monitoring, REMPEC, Satellite monitoring, Shipping

Contents

The Mediterranean Sea lies between Europe to the north, Asia to the east, and Africa to the south. It is one of the most highly valued seas in the world, with coastal habitats including brackish water lagoons, estuaries, coastal plains, wetlands, rocky shore, and sea grass meadows, for example [1]. In 2010 around 472 million people lived in Mediterranean countries, mainly concentrated near the coasts of the western Mediterranean, the western shore of the Adriatic Sea, the eastern shore of the Aegean-Levantine region, and the Nile Delta [2]. The population of the region is forecast to grow to 572 million by 2030, which will increase the environmental pressures facing the region from demand for water and energy, waste generation, degradation of habitats, and impacts on coastlines, for example [2].

The Mediterranean Sea is one of the busiest in the world with around 20% of shipping trade and 10% of world container traffic moving through it and around 200 million passenger movements annually [2], while major shipping routes are dominated by crude oil shipments coming from the eastern Black Sea, from Northern Egypt, and from the Persian Gulf (via the Suez Canal) [3]. This contributes to environmental impacts including CO_2 emissions, oil pollution, and marine litter [2], while oil and gas production activities generate waste and the release of pollutants into the atmosphere [4]. There are oil and gas reserves located in Algeria, Cyprus, Egypt, Israel, Italy, Lebanon, Libya, and Syria, with offshore exploration and exploitation activities taking place, particularly in the eastern Mediterranean [4], together with coastal refineries in Italian Adriatic waters and in Algeria, for example. Figure 1 illustrates total oil and gas production by country between 1990 and 2015, with the upper black line showing the total for all countries.

The majority of countries bordering the northern Mediterranean Sea are EU member states (Spain, France, Italy, Slovenia, Croatia, and Greece) and, together with the island states of Cyprus and Malta, they are subject to European Union (EU) legislation relating to marine pollution. However, the Principality of Monaco, a sovereign city state on the French Riviera, together with many countries in the Adriatic (Bosnia and Herzegovina, Montenegro, and Albania), in the eastern Mediterranean (Turkey, Syria, Lebanon, and Israel), and on the North African coast (Egypt, Libya, Tunisia, Algeria, and Morocco), is not subject to such legislation.

In order to protect the marine environment at a regional level, the United Nations Environment Programme (UNEP) established a Regional Seas Programme in 1974.

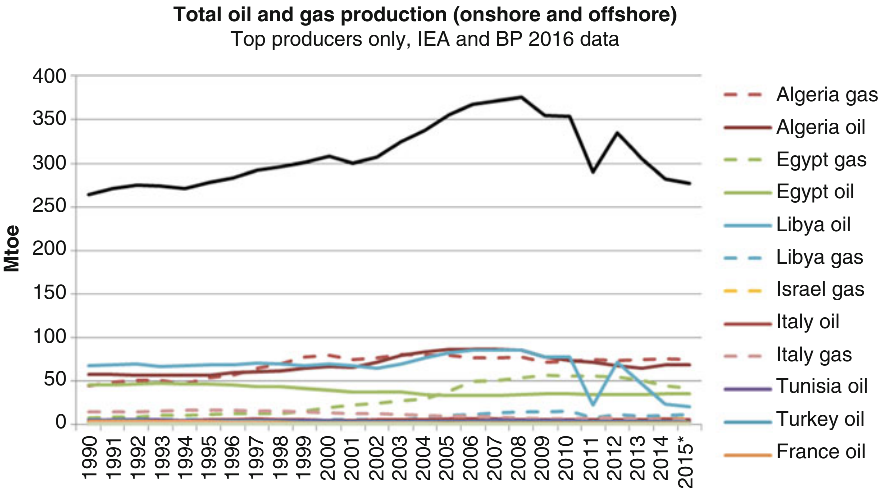

Fig. 1 Total oil and gas production (onshore and offshore) in the Mediterranean Sea region. Source: UNEP (2017) Mediterranean Quality Status Report [4]

In 1975 the Mediterranean Region adopted an action plan (MAP) which focused on marine pollution control and which was approved by 16 Mediterranean countries together with the European Community (now EU) [5]. Subsequently, the Convention for the Protection of the Mediterranean Sea Against Pollution (Barcelona Convention) was adopted in 1976 in order to protect the marine environment across the whole region [6], and Contracting Parties (CPs) to the Barcelona Convention include all 21 Mediterranean coastal states together with the European Union. The Barcelona Convention has a range of protocols relating to dumping of pollutants from ships and aircraft, pollution from land-based sources, and pollution from offshore exploration and exploitation, for example. Figure 2 sets out the current status of ratification of the Convention and its Protocols which provide a legislative framework under which countries in the region can work together to prevent, combat, or eliminate oil pollution from all sources.

Also in 1976, a Regional Oil Combatting Centre (ROCC) was established to help Mediterranean coastal states cooperate in combatting oil pollution and also deal with marine pollution emergencies. The ROCC was renamed as the Regional Marine Pollution Emergency Response Centre in the Mediterranean Region (REMPEC) in 1989 [7]. Based in Valetta on the island of Malta, it has assisted countries across the Mediterranean by, for example, helping 15 CPs to draft and adopt National Marine Pollution Contingency Plans, helped groups of countries to develop subregional agreements on pollution preparedness and response, and helped countries strengthen national legislation on the enforcement of the International Convention for the Prevention of Pollution from Ships (MARPOL Convention) [8] to illustrate just some of its activities over more than four decades.

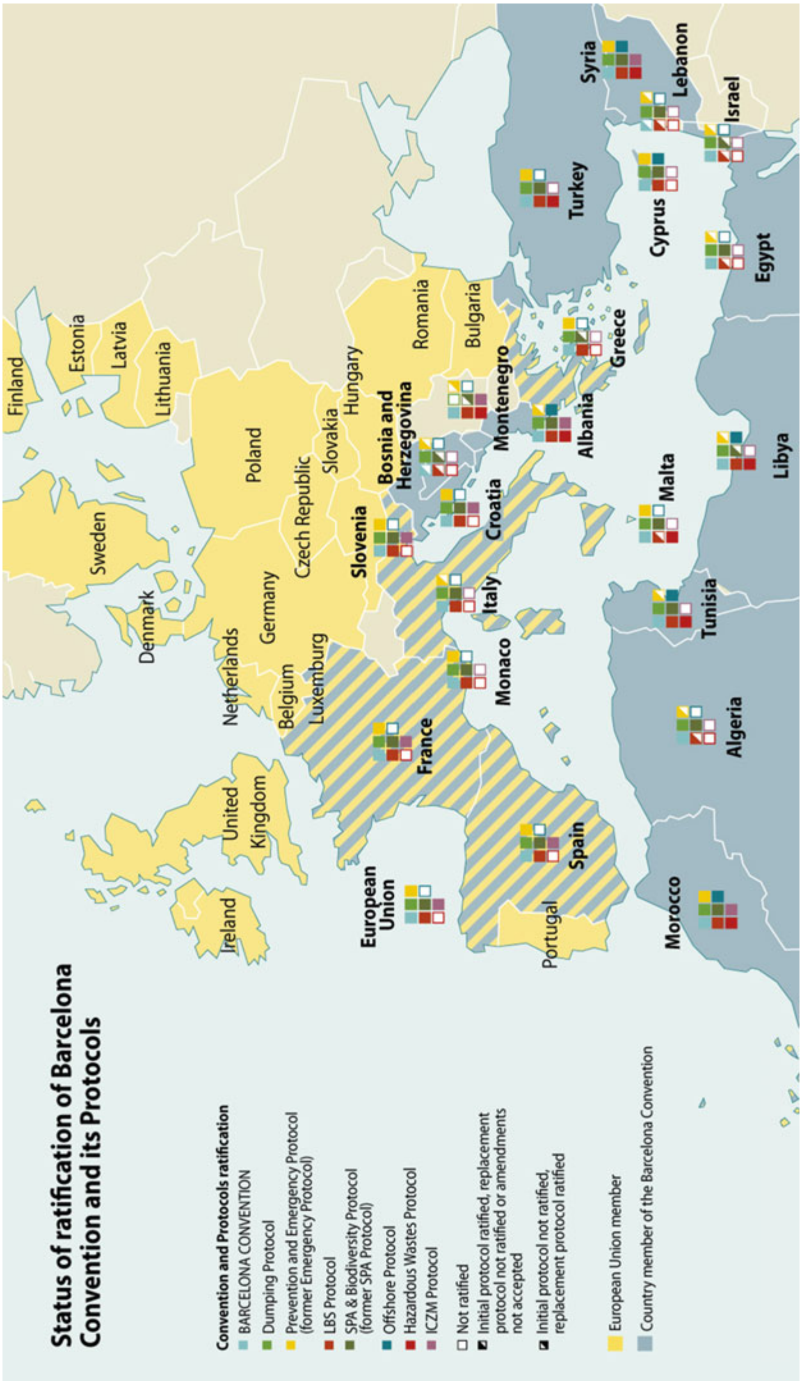

Fig. 2 Map showing status of ratification of the Barcelona Convention and its protocols. Source: GRID Arendal. Available at: https://www.grida.no/resources/5911; UNEP Mediterranean Action Plan (MAP)

While the roles of various bodies at different levels (regional, international, EU) as they relate to oil pollution in the Mediterranean Sea are covered in Part I (the International Context) of this volume [9–13], the focus of Part II is on national case studies from around the region.

This book contains ten chapters on "national activities," written by experts and practitioners covering Spain, France, Italy, the Adriatic coast of Italy, Slovenia, Croatia, Turkey, Israel, Cyprus, and Algeria [14–23].

Spain has one of the longest coastlines in Europe (approximately 8,000 km) including its Atlantic coast and Mediterranean Sea coast. Spain also has territories in the Atlantic Ocean (the Canary Islands) and the Mediterranean Sea (the Balearic Islands of Mallorca, Minorca, Ibiza, and Formentera). Spanish territorial waters, at approximately 1.5 million km^2, are around three times as large as its land area (just over 500,000 km^2). Spain, the largest country in Southern Europe and second largest European country, also has two cities located on the African mainland (Ceuta and Melila), giving it a land border with Morocco, and Spanish territory also includes several small islands in the Alboran Sea off the coast of Africa. Spain's Mediterranean coastline has an abundance of beaches, and its most ecologically valuable locations are its coastal wetlands, dunes, small islands and islets, and some areas of seabed [14]. The Balearic Islands have a long, rugged coastline, with beaches in small inlets and lagoons, for example, and a wide range of ecologically important environments [14]. Spanish coastal waters in the Mediterranean also have significant socio-economic importance through activities including tourism, fisheries, and aquaculture, with the mainland Mediterranean coast, Canary Islands, and Balearic Islands receiving 85% of all foreign tourists and 60% of domestic tourists in Spain [14]. As a result of tourism, increasing amounts of energy from oil and gas are supplied by sea, while sea trade contributes to economic prosperity in the region [14].

Approximately106,000 vessels pass through, or cross, the Strait of Gibraltar each year, posing a risk of oil or other pollution from accidents (structural damage, grounding or sinking of vessels) or operational discharges (e.g. during fuel transfer) [14]. While a large number of major oil spills occurred in Spanish waters over the last half century, including the *Urquiola*, *Aegean Sea*, *Khark 5*, and *Prestige* oil spills (numbers 10, 15, 17, and 20 in Table 1 showing the world's top 20 oil spills), no major oil spill has occurred in Spanish Mediterranean waters and only one in the Mediterranean as a whole (the 1991 *Haven* oil spill off Genoa). However, a number of pollution incidents have occurred in Spanish ports, resulting in small discharges of oil products in the inner waters of harbours, generally resulting from cargo handling, bunkering, or oil transfer operations [14]. There are eight harbours that are major load and discharge centres for oil products and which hold oil terminals of coastal refineries [14], together with two offshore oil rigs 45 km off the coast of Tarragona Province (north-east Spain), with a pipeline leading to a refinery in Tarragona, and a refinery in Murcia Province, also on the Mediterranean coast [25]. Approximately one pollution incident from rigs has occurred each year between 2006 and 2015, including all Spanish waters [14].

Table 1 World 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	***MT 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

Source: ITOPF [24]

Note: Quantities rounded to the nearest thousand tonnes. Spills in bold occurred in the Mediterranean Sea

Marine pollution prevention, preparedness, and response are the responsibility of a number of different authorities in Spain, including the Spanish Maritime Safety Agency (SASEMAR), for example, which is the national body providing search and rescue, maritime traffic control, and pollution prevention and response services, while 20 Maritime Rescue Coordination Centres (MRCCs) are responsible for operational coordination of pollution incidents [14]. The National Rescue and Pollution Response (NPRP) Investment Plan provides the necessary resources to deal with pollution incidents, and SASEMAR owns a maritime fleet of 73 vessels and an aerial fleet of 3 aircraft and 11 helicopters [14]. Maritime units perform mechanical recovery of oil on the sea surface, and a number of vessels are equipped for towing, search and rescue, and oil spill response purposes [14]. SASEMAR aircraft operate for approximately 1,200 h/year for pollution control activities, around half of all surveillance activities taking place at night, and this is supported by EMSA CleanSeaNet (CSN) remote sensing surveillance [26].

There has been a declining trend over 5 years for spills and vessels being caught "red-handed" illegally discharging bilge waters, for example [14], and oil spill forecasting and identification activities provide evidence to support enforcement activities [14]. Those activities include participating in annual Bonn-OSINet (oil spill identification network of experts within the Bonn Agreement) activities [27]. Spain therefore has a solid system for oil pollution prevention and response, a clear regulatory framework, and bilateral and regional operational plans established with neighbouring coastal states. These, together with investment action plans, aerial and satellite surveillance, and oil forecasting, source identification, and sampling systems, mean that Spanish authorities are able to respond to the medium and small oil spills occurring in Spanish waters while at the same time enhancing maritime safety in order to reduce shipping accidents [14].

France has a coastline of around 4,853 km including all of its overseas regions and territories (including French Guiana and islands in the Atlantic, Pacific, and Indian Oceans). Metropolitan France has a coastline of 3,427 km and is bounded by the Mediterranean Sea, Atlantic Ocean, English Channel, and North Sea [28]. Metropolitan France includes the island of Corsica in the Mediterranean and, with the inclusion of all its overseas departments and territories, possesses the second largest exclusive economic zone in the world covering more than 11 million km^2 [28]. The French Mediterranean coastline includes the French Riviera (Côte d'Azur) along the southeast corner of France (where it meets up with the Italian Riviera), an area that is a hotspot for tourism in the northern Mediterranean basin [15]. The French city of Marseille is also located on the Mediterranean coast, in Provence, and is the second largest city in France, Marseille is the sixth largest port in the EU (largest in the Mediterranean), and approximately 80 million tons of freight passed through the port of Marseilles in 2015 [29]. There are a small number of oil refineries located along the coast of Provence including at Fos-sur-Mer and Lavera, for example [30]. While operational spills from shipping take place weekly or even daily on some heavy traffic routes (an average of 330 spills per year during the years 2000–2009 in French Mediterranean waters; 115 spills in 2012), these spills are generally less than 10 m^3 of oil, and there has never been a major oil spill in French Mediterranean waters [15]. The Côte d'Azur was, however, impacted by the 1991 *MT Haven* oil spill, when partially burnt oil from that spill was carried to the region through prevailing winds, waves, and the Ligurian current, with an estimated 10,000 tons of oil drifting into French waters [15].

The French system of oil spill prevention and response involves public services and institutions under the French Marine Pollution Organization (POLMAR). POLMAR partners include three maritime préfectures (covering the Mediterranean, Atlantic, and the Channel and North Sea), the mayors of communes or prefects of départements impacted by a pollution incident, and CEDRE (the "Centre de documentation, de recherche et d'expérimentations sur la pollution accidentelle des eaux") which provides an advisory service in the event of an incident. It also involves a number of French ministries together with Meteo-France which deals with slick drift prediction modelling [15]. The French system also involves an annual "at-sea" response exercise organised by each maritime préfecture, together with other organisations, while CEDRE holds regularly updated manuals setting out information and recommendations for dealing with an emergency at sea (Polmar-sea) and on the coastline (Polmar-land) [15]. The response strategy in dealing with accidental spills has, since 2000, been that ship owners are required to pump and recover highly toxic pollutants (including crude oil and heavy fuel oil) from shipwrecks, and to release low toxicity pollutants under controlled conditions, at their own expense [15].

Operational spills as part of a ship's normal operation, whether resulting from a human decision, human error, or a technical failure, are generally illegal within the Mediterranean Sea given its special status under the MARPOL Convention [8][1], and in 2001 a law on operational spills established a court in Marseilles (together with two courts on the Atlantic side of France) to deal with legal aspects of operational pollution [15]. As soon as any spill occurs, a response plan is activated to mobilise at-sea detection, satellite and aerial observations, and slick drift modelling to predict the path of a spill and determine priorities for pollution response [15]. Statistics for the years 2000–2015 covering both the Atlantic and Mediterranean shows that 67% of spills identified by Marine Pollution Reports (POLREP) were oil, of which only one tenth could be linked to a source [15]. While it was only in 2003 that the Mediterranean maritime préfecture started arresting and prosecuting ships suspected of illegal operational spills these prosecutions, this has, in combination with surveillance activities, led to a reduction in the number of operational spills in French waters [15]. Through joint exercises conducted through bilateral agreements under the Barcelona Convention [6] and participation in the activities of REMPEC [7], France is a major regional player in cooperation to deal with oil pollution in the Mediterranean [15].

Italy is surrounded by the Adriatic Sea in the east, the Ionian Sea in the southeast, the Tyrrhenian Sea in the southwest, and the Ligurian Sea in the northwest [16], and its land border with France is the meeting point of the French and Italian Riviera. Italy has a coastline of 7,600 km, and its territory includes the islands of Sardinia and Sicily, together with a number of smaller islands. Around 30% of the Italian population of around 60 million people live in 646 coastal towns [16]. Large volumes of crude oil are transported by tanker to Italy from the Middle East and Russia, while tanker trades represent around 60% of trade between littoral states in the Mediterranean, with the main Italian discharge ports being Trieste in the Adriatic, Augusta in the Ionian, and Genoa in the Ligurian Seas [16]. There are offshore oilfields south of Sicily and in the Adriatic Sea [16, Fig. 8] with 139 offshore installations, 119 of which are production platforms, 8 support platforms, and 9 non-production platforms, together with 13 subsea wellheads [16] and around 14 oil refineries in Italy (many located on the coastline) [30]. Although oil pollution risk is high, there has been only one major oil spill in Italian waters, that of the

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[1] The Mediterranean Sea is a special zone under MARPOL, with strict limits on the volume of oil that can be legally discharged. See http://www.imo.org/en/OurWork/Environment/SpecialAreasUnderMARPOL/Pages/Default.aspx.

MT Haven off Genoa in 1991. As noted previously, around 144,000 tonnes of crude oil was spilled in that accident, some of which was transported as far as the Côte d'Azur of France on the prevailing currents.

Italy's pollution response activities fall under the direction of the Ministry of Environment at the strategic level, the Coast Guard branch of the Italian Navy for operational activities at national and local levels, and the Civil Protection Department in the event of a large and catastrophic event. The response system has three levels: (1) for small spills far from the coast incidents, (2) for small or medium oil spills in coastal or protected areas, and (3) for large oil spills requiring resources in addition to those available from the Ministry of Environment, with Level 2 and 3 spills over 100 m^3 being reported to the regional centre [16]. The Italian Coast Guard has around 600 vessels spread across 100 harbours to deal with a range of incidents and has access to a large number of vessels available from a contracting company to participate in spill cleanup activities [16]. The Italian Coast Guard also has a fleet of aircraft equipped with sensors (including side-looking airborne radar; SLAR) to detect pollution at sea [16]. In recent years, much of Italian oil pollution monitoring has included satellite imagery, partly provided by COSMO-SkyMed data and partly by EMSA CSN data.

Italy has been involved in a range of remote sensing programmes including some with the European Space Agency and NASA [16]. Its largest investment has been in space systems for earth observation and COSMO-SkyMed; a constellation of four SAR satellites, together with ground-based activities, provides data for risk management, civil and defence needs, and marine monitoring (including monitoring for oil pollution) [16]. Oil spill monitoring is the main focus of the Italian chapter [16] which considers a range of issues associated with the use of SAR for operational use of satellite imagery. It considers the history of Italy's contribution to such operational use and a range of benefits to be gained from it which include acting against oil pollution, helping to identify offenders, monitoring oil rigs and offshore pipelines, detecting natural seeps, and search and rescue operations [16]. Images of potential oil spills can be sent to the Ministry of Environment and the Coast Guard from the Matera Remote Sensing Centre, which assists them in identifying vessels responsible for pollution and, where necessary, taking operational measures to deal with and mitigate the effects of such pollution [16]. The Italian National (Marine Pollution) Contingency Plan, a requirement of Article 4 of the Barcelona Convention [6, 11], supported by REMPEC [12] has been developed over time to include the use of satellite and other new technologies, and this approach is considered to discourage operational oil spills which represent the major source of pollution in Italian waters [16].

Three chapters examine oil pollution in the Adriatic Sea subbasin of the Mediterranean [17–19]. The Adriatic Sea lies is a semi-enclosed water body occupying the northern part of the Mediterranean central basin and lying between the Apennine Peninsula of Southern Europe in the west and the Balkan Peninsula in the east [31]. It measures around 770 km from southwest to northeast and has a width of between 93 and 248 km and a coastline of 3,707 km (6,200 km with the addition of all the approximately 1,300 islands, mostly along the eastern shores of the Adriatic)

[31]. There are six states with a coastline on the Adriatic – Italy in the west, with a coastline of 1,249 km, and (from north to south on the Balkan Peninsula) Slovenia (coastline of 47 km), Croatia (1,777 km), Bosnia and Herzegovina (23 km), Montenegro (298 km), and Albania (362 km) in the east (see Fig. 3) [31].

The Adriatic Sea is a home to 7,000 species of flora and fauna, including around 750 species of algae, a range of gastropods and molluscs, and more than 400 species and sub-species of fish [31]. The region is highly productive for fisheries and is an important area for tourism in the region, with a range of historic locations (including underwater cities and major archaeological sites on land), seaside resorts and beaches, and many on- and in-water activities (e.g. diving, windsurfing, yachting, leisure fishing) [31]. The region has a population of more than 3.5 million people living in coastal areas. The Adriatic has 15 marine protected areas (4 in Italy, 7 in Croatia, 3 in Slovenia, and 1 in Albania) [31] where human activities are restricted in order to protect the natural and cultural resources of the region. There are around

Fig. 3 The Adriatic Sea (http://www.worldatlas.com/aatlas/infopage/adracsea.gif)

100 oil and gas platforms in the Adriatic along the coast of Emilia-Romagna (Italy), together with a number of liquefied natural gas terminals [31]. Platforms and rigs are allowed to discharge higher concentrations of oil in water (monthly average concentration of 40 parts per million (ppm) and a single incident maximum of 100 ppm) than is the case for shipping under MARPOL Special Area status, where any visible and/or detectable oil spills (deemed to be above the 15 ppm) are illegal [17].

Between 70 and 80 million tons of crude oil, petroleum products and liquid chemical cargos are transported within the Adriatic Sea each year [17], and there are 19 Adriatic Sea ports that handle more than a million tons of cargo per year: the largest cargo port is located in Trieste in Italy; the largest passenger port is Split in Croatia [31]. The main ports handling crude oil are Trieste (41 million tons discharged in 2015); Venice in Italy (10 million tons imported in 2015); Omišalj, north-west of the island of Krk in Croatia (between 7 and 9 million tons in 2015); and the Port of Koper in Slovenia (more than 3 million tons in 2015) [17]. Large vessel traffic is dense and likely to continue to grow in volume, resulting in the constant threat of both operational and accidental pollution.

A system using satellite images to detect pollution and backtrack it to its source has been developed in the region to minimise ship-generated pollution [17]. Despite the use of satellite surveillance systems and aerial surveillance, illegal discharging and dumping by commercial vessels remain commonplace [17], and the frequency of accidental spills in the Adriatic is estimated to be more than five times higher than the world average [17]. 174 accidents occurred between 1995 and 2005 of which only 8 spills exceeded 10 m^3 quantity of oil released: the largest of these was the *MT Baba Gurgur* spill in February 1989 which released 100 m^3 [17]. Operational pollution, for example, as a result of tank washing by oil tankers, is far more common and in breach of the discharge limits set out for the region [17]. Around 100–200 commercial vessels sail in the Adriatic at any given time, and it is estimated that 7–10 of those vessels are polluting [17]. Between 1999 and 2004, there were 1,049 possible oil spills identified in the Adriatic from ERS-1 and ERS-2 SAR satellite images [17]. Between 2005 and 2006, the AESOP (Aerial and Satellite Surveillance of Operational Pollution in the Adriatic Sea) Project was developed to test the capability of providing satellite near real-time operations for marine oil pollution and monitoring shipping routes in the region [17]. Sixty-six possible spills were detected in the Adriatic in the summer of 2005 from 69 images, with a response activated by the Italian Coast Guard to deal with a significant operational release on 25 August 2005 off San Cataldo Point in Puglia in the southern Adriatic [17]. In September 2005 three slicks (out of four) were successfully connected with potential polluters [17]. AESOP was a predecessor of the EMSA CSN service established in 2007 [26], a service which has confirmed that oil is still illicitly discharged across all European seas and which detected 250 probable oil spills in the Adriatic Sea between 2011 and 2015 [17].

Despite the frequency of detections by satellite imagery (including EMSA CSN and images from the new sensor Sentinel-1), and subsequent confirmation using surveillance vessels and aircraft, it can be concluded that oil pollution is much reduced from levels in the early 2000s, with just under 3,000 m^3 being discharged each year [17]. Case studies are presented on pollution from shipping and from rigs in the Adriatic Sea to illustrate how pollution has been successfully attributed to the polluter [17], At the same time, it is necessary to model marine seeps from six crude oil seeps in the Adriatic Sea (natural springs where liquid and gaseous hydrocarbons leak from underground oil and gas accumulations) to ensure that natural seepages are not attributed to human activities [17]. Pollution can also come from other sources including fishing activities (e.g. oil in bilge water or leaks from hydraulic systems on board) and from land-based sources entering the marine environment through rivers and streams, and there are also ten wrecks in the northern Adriatic Sea that pose a potential pollution threat due to the nature of their cargos and bunker fuel oil left on board [17]. As a result of advances in satellite imagery and aerial surveillance, for example, there has been some reduction in oil pollution; the Adriatic Sea still faces the threat of pollution from a range of sources [17]. That threat is seen as posing a significant threat to the Slovenian coast, its environment as a particularly sensitive shallow sea, and Slovenia cultural heritage sites [18].

While the Slovenian coast is only 46.6 km long, with several bays and peninsulas, its 180 km^2 shallow sea area is the location of two salt pans, mussel and fish farms, has a wide variety of marine flora and fauna, and contains five marine protected areas including nature reserves and natural monuments [18]. An area of particular concern and high vulnerability is the Secovlje salt pans in the Bay of Piran [18]. Much of the salt pans are below sea level and are protected by embankments; a risk is posed to millennia of heritage in the event of an oil spill occurring at the same time as elevated sea levels, high tides, and strong winds from the southwest [18]. In addition, there are 36 areas with cultural remains which already face danger from fishing trawlers and anchoring procedures and which would be at serious risk of permanent damage in the event of a major oil pollution incident [18]. Hazard identification and analysis are therefore very important in the region in order to identify all the potential or likely hazards of an oil or chemical spill and determine the sensitivity of an area to such an incident (including factors such as type of coast, presence of natural resources, amenity values, etc.) [18].

A high level of preparedness and response would be necessary to deal with marine pollution in Slovenian waters, and a subregional contingency plan has been drawn up between Italy, Croatia, and Slovenia, has been presented to the Barcelona Convention, and is awaiting final adoption [32]. Slovenia has also established a simulation-based oil spill crisis management centre which provides training, acts as an active centre in the event of a real emergency, and this has already been used in such cases [18]. Vessel traffic surveillance, metocean buoys, and high-frequency radar have been installed to help cooperation between the three countries if the subregional contingency plan is activated [18], while Traffic Separation Schemes are in use in the Adriatic Sea as a whole. Slovenian waters host the majority of shipping traffic in the Adriatic in the port of Koper which receives around 6,000 vessels/year, with around 45 million tons (out of total traffic of 70 million tons) being crude oil, its derivatives, and liquid chemical cargos [18]. Commercial maritime traffic in the northern Adriatic (through Koper, Trieste, Venice, Ravenna, and Rijeka) grew by 7% per year between 1990 and 2013, while Koper has seen an average annual growth of 8% between 2010 and 2015 for cargo throughput (nearly 16% yearly for container growth), with dredging and pier extension leading to larger vessels being able to operate in the port, and 93 cases of oil pollution took place in the port of Koper between 2007 and 2015 (about one third of all cases of pollution) [18].

While there have been a number of explosions/serious fires and collisions on ships operating in the Gulf of Venice/northern Adriatic, there were only two incidents causing serious pollution between 1985 and 2008: the release of 90 m^3 of bunker oil from the *Ledenice* in 1983 at the Izola Shipyard and a spill of >10 m^3 of sludge or bunker oil from an unknown source in the Bay of Koper in 1990, with oil spreading beyond Slovenian waters into the Gulf of Trieste [18]. A range of accidents have taken place including the grounding of a 220-m-long fully loaded Chinese bulk carrier which ran aground in fog, but fortunately did not release any pollution, for example [18]. No operational spill has occurred in Slovenian territorial waters, although some have been close enough to pose a risk, including the 6 August 2008 case of an operational discharge of oil which resulted in a 2 NM long and 1/2 NM wide oil slick and tar balls being discovered along the Istrian Coast and just outside the Bay of Piran, near to the Secovlje salt pans [18]. While measures were taken to deal with the spill, it was not considered to pose a threat to the Italian or Slovenian coasts, and so they were not informed of the incident. However, following a violent storm, oil came ashore around Savudrija Cape [18]. HF radars and satellite images were used in this case to hindcast and to progressively simulate this incident; these can provide valuable tools both in predicting where a spill will spread to and for polluter identification [18]. This is particularly important in an area of high natural and cultural risk in the event of a catastrophic spill, particularly with more and larger ships operating in the north-eastern Adriatic Sea [18].

Croatia, with around one million people living around its coasts and islands, has an economy that is dependent on tourism, fisheries, aquaculture, shipping, and marinas, for example [19]. Croatia has a number of marine protected areas, national parks, special reserves, and areas of ecological significance in its waters, while the EU’s Natura 2000 ecological network includes 16.4% of Croatia’s marine area (5,205 km^2) [19]. Aquaculture ponds are located in many coastal areas and on the southern sides of many Adriatic islands, making them vulnerable to oil and other pollution from shipping traffic such as tankers and cargo ships; the main transport routes used by those ships are crossed by fishing vessels and also cruise ships [19]. Oil exploration activities are also being conducted by Croatia, Albania, and Montenegro, and this will pose a risk of pollution if oil deposits are located in the eastern Adriatic [19]. However, Croatia has a number of undefined marine borders with Montenegro and with Bosnia and Herzegovina, and agreement is still pending with Slovenia for the marine border by the Bay of Piran, and this has implications for protection of the marine area, for search and rescue activities, and for exploration and exploitation of underwater oil and gas reserves [19].

SAR has been used for operational oil spill detection and monitoring in the region for many years, and a high number of images have been analysed to identify oil slicks from natural, accidental, and intentional sources [19]. Examples of oil slicks identified from Envisat and Radarsat-1 satellites for the period 2003–2016 have been examined to identify the main causes of oil pollution (size, shape, and prevailing locations) in the Adriatic Sea (Envisat images were available from ESA and Radarsat-1 through a pilot project with Russian collaboration with the Canadian Space Agency) [19]. The main sources of oil pollution are identified as routine tank-washing operations and illegal discharges, generally coming from small vessels and fishing boats, and either being caused by accidents or by dumping of oily wastes [19]. Slicks/spills of between 9 and 108 km^2 have been identified in SAR images, potentially from routine tank-washing operations and illegal discharges, and most of these oil spills were intentionally released during night, since they were detected on SAR images acquired during morning passes of the satellites [19]. These spills are generally located in the open sea at the boundary between Italian and Croatian waters and along the main shipping routes [19]. Although AIS vessel tracking can be used to potentially identify the source of such pollution, it is not possible to use this information as evidence for a prosecution in court [19]. The use of continuous SAR observations has, however, contributed new knowledge on oil pollution in the Adriatic including size of slicks, time and seasonal data, and identification of new and previously unknown sources in the region [19].

At the easternmost part of the Mediterranean Sea are the waters of Turkey in the north Levantine sub-basin, where the Mediterranean and Black Seas are connected via the Turkish Straits System, an extremely busy natural channel for national and international maritime traffic [20]. Turkish waters are under heavy use by petroleum tankers from Russia and the Middle East, and these pose a threat to the Turkish coastline, along which there are many harbours, marinas, and coastal facilities [20]. There are also two refineries on Turkey’s eastern Mediterranean coast (at Îzmir and in Ïskenderun), together with the Baku-Tbilisi-Ceyhan (BTC) pipeline passes which passes through Ïskenderun City, which also pose a high pollution risk in the region [20]. At a national level, there are two Turkish ministries with responsibility for pollution response, the Ministry of Transport Maritime Affairs and Communication (TM-TMAC) and the Ministry of Environment and Urbanization (TM-EU), which are regulated under national legislation for the protection of the seas from oil and other harmful substances pollution, for example [33]. Contingency plans for coastal facilities, together with regional and national contingency plans (NCP) have been prepared by TM-EU, which include the roles of other ministries, regional governments, NGOs, and experts [20]. Preparedness activities are carried out and coordinated by TM-TMAC, while emergency response facilities are based on a three-tier approach: Tier 1, small-scale pollution from coastal facilities and ships; Tier 2, middle-sized pollution events; and Tier 3, large-scale pollution requiring national capabilities [20]. The Regional and National Emergency Action Plans are in place to deal with oil spills and other hazardous substances, and an emergency response centre is located in Antalya, and a GIS-based decision support system (YAKAMOS) is in place for decision-makers to determine the best course of action during a pollution incident [20]. Natural protected areas, important cultural areas, habitats of species such as monk seal and sea turtle, and important economic areas (fisheries, tourism areas, beaches, industrial facilities, etc.) have been identified, and the risks from accidents analysed on the basis of factors including maritime traffic levels, previous accidents, importance of the coastline, etc. have been determined [20]. There are also ten stockpiles of equipment in various locations to deal with the impacts of a pollution incident [20]. Regional exercises are carried out twice yearly for coastal facilities, and there is a national exercise every 3 years to ensure that representatives of the various organisations and institutions are familiar with how to deal with a pollution incident under the contingency plans [20]. City-based contingency plans are in place for seven cities located on the southeast Mediterranean Sea and the Aegean Sea coasts, and guidelines based on contingency plans include information on response systems and cleanup methods, the use of dispersants in emergency situations, and communication among teams and the public in emergency situations, for example [20].

Aerial surveillance by aircraft or helicopter is regularly undertaken by the Turkish Coast Guard, and satellite-based remote sensing systems are also used to identify pollution, with EMSA CSN [26] providing access to satellite images [20]. However, there have been no significant accidents resulting in marine pollution in Turkish waters, although there have been a number of accidents for Turkish flagged and foreign flagged ships in Turkish coastal waters [20]. There is also the risk of operational discharges from vessels operating in the two refineries and the many harbours and marinas around the Turkish coastline [20]. Strict laws are in place to penalise polluters for environmental damage caused by oil pollution at loading facilities, with reduced penalties if the polluter deals with cleaning up a spill; accidental spill and clean-up costs are also controlled under Turkish environmental law [20]. While Turkey does face the risk of a marine pollution incident (accidental or operational) due to the high density of shipping traffic, it has in place the infrastructure and contingency plans necessary to deal with pollution from oil and petroleum-related products [20] and at the regional level can call upon REMPEC through its 24/7 Centre to assist in the case of an emergency (as can all contracting parties to REMPEC) [7].

Israel has territorial waters of 2,264 km^2, a total marine area (EEZ plus territorial waters) of 30,000 km^2, and 195 km of coastline on the eastern Mediterranean Sea (and 14 km of coast on the Gulf of Aqaba in the Red Sea) [21]. Israel's marine area contains marine and coastal nature reserves, five major desalination plants for the production of drinking water, three major electric power stations, two main commercial ports, leisure locations, and fishing areas and developing aquaculture grounds, while 70% of Israel's population lives within 15 km of the Mediterranean coastline, where the country's main economic, commercial, and tourist activities are also located [21]. Israel receives all its liquid and solid fuels (oil and gas) through its coastal ports and oil terminals [21]. Around 10 million tons of crude oil and 4 million tons of oil products are imported annually, offloaded from ocean-going vessels into onshore terminals; and about 2 million tons of oil products are exported annually [21]. There are two crude oil open sea terminals at Haifa and Ashkelon, two product terminals at Hadera and Ashdod, and two product terminals within closed ports at Haifa Port and Kishon Port [21]. Shipping activities within ports produce relatively frequent small to medium oil pollution incidents, often the result of de-ballasting, bunkering, small-scale collisions and from onshore oil facilities [21]. Two offshore gas production platforms in Israel's EEZ are connected by marine pipelines to coastal facilities, and Israel also has significant offshore oil and gas exploration and exploitation activities taking place in the Levantine Basin, which includes the EEZs of Israel, Egypt, and parts of Cyprus [21]. The Karish and Tanin gas fields are estimated to contain around 2.7 trillion ft^3 (Tcf) of natural gas and 41 million barrels of oil equivalent (Mboe) of light hydrocarbon liquids [34]. The Leviathan natural gas project in offshore Israeli waters is estimated to hold 22 Tcf of gross recoverable natural gas resources and should be delivering gas ashore by the end of 2019 [35]. All findings are in ultra-deep water of 1.5 km depth or more, and there is the potential to find oil reservoirs beneath the gas fields [21]. Due to prevailing winds and currents in the eastern Mediterranean basin, almost oil spills tend to drift to the eastern Mediterranean coastline, posing a threat to Sinai, Gaza, Israel, Lebanon, and Syria [21]. For example, in February 2005, a collision between two vessels 12 nautical miles off Damietta, Egypt, resulted in a spill of around 1,500 m^3 which, after 5 days, washed ashore on the coastlines of Gaza and southern Israel for around 100 km [21].

Protection of Israel's seas and coasts from pollution, together with the demands of urbanisation, industrialisation, and tourism, for example, is a national priority, and Israel has in place a legal framework to deal with oil pollution, derived from international agreements including the International Convention on Oil Pollution Preparedness, Response and Cooperation (OPRC 1990) [36], the Barcelona Convention [6], REMPEC [7], and MARPOL [8]. There is also a subregional plan for preparedness and response between Israel, Egypt, and Cyprus, established in 1995 within the framework of the Barcelona Convention and with the assistance of the EU, to facilitate mutual assistance and cooperation in mobilising equipment to deal with pollution that threatens their coastlines or territorial waters [21]. A trilateral subregional contingency plan between Greece, Cyprus, and Israel is also being developed [21]. A range of national laws are in place to prepare for, respond to, and combat all sources of pollution to the marine environment and in particular oil pollution [21]. The Marine Environmental Protection Division (MEPD) of Israel's Ministry of Environmental Protection (MoEP) is the national competent authority for oil pollution preparedness and response and is funded by the Marine Pollution Prevention Fund (created in 1983) under which ships pay fines for non-compliance and fees are levied on sea-going tankers used to import oil into Israel [21]. The MEPD has jurisdiction and oversight for all aspects of marine protection including accidental and emergency oil and chemical spills from ships and terminals, pollution from land-based sources, and dumping of waste at sea [21]. Enforcement and monitoring activities are conducted by professional inspectors using a range of equipment, aided by aerial surveillance, and inspections cover vessels and oil tankers calling to Israel's ports, offshore installations handling oil, industrial plants, and wastewater plants [21]. The NCP for preparedness and response to incidents of pollution of the sea (TALMAT) [37] was approved in 2008 and provides a structure for dealing with oil spill response in the case of spills up to 4,000 tons of oil; larger spills are deal with either through subregional conventions or at a wider level under international conventions [21]. TALMAT requires local emergency plans at the municipality level or facility level and for pollution ranging from Tier 1 (small spills that can be dealt with locally) to Tier 3 (major pollution incidents requiring mobilisation of national or international resources) [21]. There are a large number of facilities requiring contingency plans, together with coastal municipalities with local emergency plans, and a range of organisations take part in preparedness and response activities including Israeli Defence Forces (air and navy), for example, while a 24/7 Rescue Coordination Centre assists with pollution incidents, and a wide range of equipment (booms and skimmers, dispersants, workboats, and patrol boats) are available for use in such incidents [21]. Israel is, therefore, prepared in the event of a pollution incident taking place but considers that enhanced collaboration with other countries in the region is vital to strengthen its preparedness and response capabilities [21].

Cyprus, located in the north-eastern corner of the Mediterranean basin, is the third largest island in the Mediterranean Sea after the islands of Sicily and Sardinia off Italy. Cyprus measures some 240 km from end to end and is 100 km wide at its' widest point, and has a coastline of 770 km, 290 km of which is under the control of the Republic of Cyprus.[2] The economy of Cyprus is heavily dependent on its marine environment for tourism and has established six marine Natura 2000 sites and has in place measures to monitor and protect species such as the Mediterranean monk seal and marine turtles and to monitor sea caves [38]. The sea and coastal areas have a rich marine environmental heritage and a high level of biodiversity, making it susceptible to long-term problems from even a small spill in an ecologically sensitive area [22]. In 2013 significant offshore natural gas deposits were identified in the Aphrodite gas field in its EEZ, to the south of the island, within the Levantine Basin [39]. A range of gas fields, including Israel's Tamar and Leviathan fields and Egypt's Zohr field, have been discovered within that basin (see Fig. 4) [40]. The Aphrodite field has confirmed natural gas reserves of 4.54 Tcf and the potential for further discoveries [22]. The Cyprus government is seeking to move away from its energy dependence on imported petroleum towards domestically produced natural gas from the Aphrodite field, although tensions between the Republic of Cyprus and Turkey concerning the limits of the EEZ may pose problems for the development of Cyprus's mineral fuel reserves [39]. Cyprus is also looking to develop as a mineral fuel hub for the region, and there is a large oil storage terminal based in the south of the island with 28 tanks and a capacity of 544,000 m^3, having access to a deep water marine jetty, and with expansion plans currently under evaluation [41].

An NCP for oil spill response was developed by Cyprus in 1987 and subsequently reviewed in 1997 and 2013. As with other NCPs in the Mediterranean, in the event of a major incident, an Emergency Response Centre will be established to coordinate any spill response, including cooperation at subregional level if required [22]. Cyprus

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[2] The northern part of Cyprus is under the control of the self-declared Turkish Republic of Cyprus (36% of the island); a UN buffer zone covers a further 4% (see https://en.wikipedia.org/wiki/Cyprus). The Sovereign Base Areas of Akrotiri (in the south of Cyprus) and Dhekelia (in the south east) remain under British control (see https://en.wikipedia.org/wiki/Outline_of_Akrotiri_and_Dhekelia).

Fig. 4 Oil and gas discoveries in the eastern Mediterranean Levantine region (International Institute for Strategic Studies) [40]

has, as noted previously, a subregional agreement with Israel and Egypt to combat oil spills and is developing a trilateral agreement with Greece and Israel [21]. Out of seven marine accidents recorded in Cyprus waters (according to the REMPEC Accident database 2004–2014), only two resulted in very small amounts of oil being spilled at sea [22]. A wide range of anti pollution equipment and materials are available for use in the event of a pollution incident, including dispersants, booms, skimmers, and spraying units, stockpiled at various locations on the island [22]. While the Republic of Cyprus does not own any anti pollution vessels, it does have access to them with the Department of Merchant Shipping being responsible for liaising with EMSA to contract oil recovery services including use of EMSA oil spill response vessels located around the Mediterranean; one such vessel is based at Limassol [42]. The Department for Fisheries and Maritime Research (DFMR) is the body responsible for authorising the use of dispersants. Cyprus participates in the majority of international conventions and their annexes including MARPOL [8] and OPRC [36], for example, together with the Barcelona Convention [6] and various protocols of that convention [11]. The Police Aviation Unit conducts aerial surveillance activities, while the Marine Police, in conjunction with the DFMR, conducts at-sea surveillance and can also carry out dispersant spraying missions. Surveillance activities are supplemented by the use of EMSA CSN, while a range of data sources and tools are used to monitor the region and to forecast the transport, fate, and weathering of oil spills [22]. However, it is considered that aerial surveillance could be significantly improved, potentially through the use of drones, and that long-range patrol ships could also significantly improve the naval surveillance capabilities of Cyprus.

The final national case study in Part II is that of Algeria on the North African coast [23]. As noted previously, it was not possible to obtain chapters relating to Egypt, Libya, Tunisia, or Morocco. Algeria has a coastline of 1,644 km along the Mediterranean south coast and has six coastal terminals for the export of petroleum products located at Oran, Arzew, Algiers, Bejaia, Skikda, and Annaba (from west to east) [23]. It also has five oil refineries with a total capacity of 652,000 bpd, three of which are in coastal cities (at Skikda, the largest oil refinery in Africa and third largest in the world, and in Algiers and Arzew) [23]. Algeria is the top natural gas producer in Africa, has the third largest shale gas reserve in the world, and produced about 1.7 million bpd of total petroleum products in 2015 [23]. Seventy-five percent of its petroleum and petroleum products are exported by sea in oil tankers, operating out of its six coastal terminals, and it is estimated that 35% of oil that enters the sea is due to this tanker traffic (including from illegal discharges, tanker cleaning, and run-offs) [23]. Water pollution also comes from the three refineries [23]. Studies have been undertaken in the Bays of Skikda, Arzew, and Algiers using field studies and remote sensing using satellite imagery to determine oil pollution levels in each of those locations [23] with high values of hydrocarbon pollution levels being found in each of those Bays [23]. Due to its location in the Mediterranean basin, and the energetic flow of the Algerian Current [43], hydrocarbons, mercury, and other pollutants can be dispersed to coastal areas in western Algeria, and beyond, and sites have been studied using in-field and satellite monitoring techniques [44].

Algeria is a party to the Barcelona Convention [6] and REMPEC [7], has received approval from REMPEC for its NCP, and has a subregional contingency plan with Morocco and Tunisia, the first to be signed in the southwestern part of the Mediterranean in June 2005 (it entered into force in May 2011) [23]. Algeria has also ratified an NCP with the International Tanker Owners Pollution Federation (ITOPF) in 1994, which covers the marine districts of Alger, Oran, and Jijel, and is overseen by the national committee led by the Ministry of the Environment [23]. These, and other plans in place at local national and regional levels, mean that Algeria has in place a range of measures to prevent and combat oil pollution and to improve the quality of the marine environment [23]. Despite the potential risks from high volumes of oil tanker traffic, and pollution in effluents from coastal refineries, there have been no major oil spills or pollution incidents in Algerian waters [23]. However, pollution levels are high in the three bays of Skikda, Arzew, and Algiers, with levels up to 250 mg/L in some locations in Skikda Bay and up to 95 mg/L in Algiers Bay. With the high level of dispersion of such pollutants across the whole of the Mediterranean, and also through the Strait of Gibraltar into the Atlantic Ocean, the monitoring of these Bays and the refineries and coastal terminals within them is clearly important [23].

Overall, it can be concluded that levels of oil pollution in the Mediterranean Sea have, from the standpoint of the individual national cases, improved significantly over recent years, particularly as there have been only a very small number of oil spills from ships over the last few years. However, the September 2017 spill from the shipwreck of the *Agia Zoni II* tanker, near the port of Piraeus and off the coast of Salamina, Greece [45], illustrates that accidents cannot be considered a thing of the past and that countries need to maintain their readiness to deal with such incidents in a timely manner. Smaller operational spills also remain an issue, as highlighted in many of the chapters in this volume, and action to prevent such spills (including illegal spills) is also vital. Aerial and satellite surveillance activities provide one way of monitoring for such spills and potentially hindcasting them to their source. Oil (and less so gas) production in both the western and eastern Mediterranean, and in the Adriatic Sea, also pose a threat, and here also monitoring is vital to ensure that standards are met and any spills are dealt with promptly.

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References

1. UNEP (2017) Mediterranean 2017 Quality Status Report. Environmental characteristics. https://www.medqsr.org/environmental-characteristics. Accessed June 2018
2. UNEP (2017) Mediterranean 2017 Quality Status Report. Socio-economic characteristics. https://www.medqsr.org/socioeconomic-characteristics. Accessed June 2018
3. UNEP (2017) Mediterranean 2017 Quality Status Report. Maritime transport. https://www.medqsr.org/maritime-transport. Accessed June 2018
4. UNEP (2017) Mediterranean 2017 Quality Status Report. Energy, gas and oil exploration and exploitation, mining and manufacturing. https://www.medqsr.org/energy-gas-and-oil-exploration-and-exploitation-mining-and-manufacturing. Accessed June 2018
5. UNEP (n.d.) The Mediterranean Action Plan. http://www.unep.org/regionalseas/mediterranean. Accessed June 2018
6. UNEP (1976) Convention for the Protection of the Mediterranean Sea Against Pollution (Barcelona Convention). http://wedocs.unep.org/bitstream/id/53143/convention_eng.pdf. Accessed June 2018
7. REMPEC (n.d.) About REMPEC – Mandate (webpage). http://rempec.org/rempec.asp?theIDS=1_91&theName=ABOUT_REMPEC&theID=6&daChk=1&pgType=1. Accessed June 2018
8. International Maritime Organization (2015) International Convention for the Prevention of Pollution from Ships, 1973, as modified by the protocol of 1978 (MARPOL 73/78). IMO, London. http://www.imo.org/About/Conventions/ListOfConventions/Pages/International-Convention-for-the-Prevention-of-Pollution-from-Ships-(MARPOL).aspx. Accessed June 2018
9. Bellefontaine N, Donner P, Johansson T (2016) Oil spill intervention in the Mediterranean Sea. In: Carpenter A, Kostianoy AG (eds) Oil pollution in the Mediterranean Sea: part I – the international context. The handbook of environmental chemistry. Springer, Berlin. https://doi.org/10.1007/698_2016_36

10. Hildebrand L, Bellefontaine N, Johansson T (2016) International maritime organization and oil pollution in the Mediterranean Sea. In: Carpenter A, Kostianoy AG (eds) Oil pollution in the Mediterranean Sea: part I – the international context. The handbook of environmental chemistry. Springer, Berlin. https://doi.org/10.1007/698_2016_19
11. Carpenter A, Johansson T (2017) The Barcelona Convention and it role in oil pollution prevention. In: Carpenter A, Kostianoy AG (eds) Oil pollution in the Mediterranean Sea: part I – the international context. The handbook of environmental chemistry. Springer, Berlin. https://doi.org/10.1007/698_2017_168
12. Carpenter A, Donner P, Johansson T (2017) REMPEC – regional strategy for the prevention of and response to marine pollution from ships. In: Carpenter A, Kostianoy AG (eds) Oil pollution in the Mediterranean Sea: part I – the international context. The handbook of environmental chemistry. Springer, Berlin. https://doi.org/10.1007/698_2017_169
13. Carpenter A (2016) EMSA activities in the Mediterranean Sea. In: Carpenter A, Kostianoy AG (eds) Oil pollution in the Mediterranean Sea: part I – the international context. The handbook of environmental chemistry. Springer, Berlin. https://doi.org/10.1007/698_2016_18
14. de la Torre L, Albaigés J (2016) Oil pollution in Spanish waters. In: Carpenter A, Kostianoy AG (eds) Oil pollution in the Mediterranean Sea: part II – national case studies. The handbook of environmental chemistry. Springer, Berlin. https://doi.org/10.1007/698_2016_103
15. Girin M, Daniel P (2017) Oil pollution in French waters. In: Carpenter A, Kostianoy AG (eds) Oil pollution in the Mediterranean Sea: part II – national case studies. The handbook of environmental chemistry. Springer, Berlin. https://doi.org/10.1007/698_2017_4
16. Nichiro F, Grieco G, Migliaccio M, Nicolosi PDM (2016) Oil Spill monitoring in the Italian waters: COSMO-SkyMed role and contribution. In: Carpenter A, Kostianoy AG (eds) Oil pollution in the Mediterranean Sea: part II – national case studies. The handbook of environmental chemistry. Springer, Berlin. https://doi.org/10.1007/698_2016_115
17. Perkovic M, Harsch R, Ferraro G (2016) Oil spills in the Adriatic Sea. In: Carpenter A, Kostianoy AG (eds) Oil pollution in the Mediterranean Sea: part II – national case studies. The handbook of environmental chemistry. Springer, Berlin. https://doi.org/10.1007/698_2016_53
18. Perkovic M, Hribar U, Harsch R (2016) Oil pollution in Slovenian waters: the threat to the Slovene Coast, possible negative influences of shipping on an environment and its cultural heritage. In: Carpenter A, Kostianoy AG (eds) Oil pollution in the Mediterranean Sea: part II – national case studies. The handbook of environmental chemistry. Springer, Berlin. https://doi.org/10.1007/698_2016_112
19. Morović M, Ivanov A, Olć M (2016) Mapping of oil slicks in the Adriatic Sea: Croatia case study. In: Carpenter A, Kostianoy AG (eds) Oil pollution in the Mediterranean Sea: part II – national case studies. The handbook of environmental chemistry. Springer, Berlin. https://doi.org/10.1007/698_2016_38
20. Karakoç FT, Ediger D, Günay AS (2016) Oil pollution in Turkish waters of the Mediterranean Sea. In: Carpenter A, Kostianoy AG (eds) Oil pollution in the Mediterranean Sea: part II – national case studies. The handbook of environmental chemistry. Springer, Berlin. https://doi.org/10.1007/698_2016_100
21. Amir R (2017) Oil pollution in the marine waters of Israel. In: Carpenter A, Kostianoy AG (eds) Oil pollution in the Mediterranean Sea: part II – national case studies. The handbook of environmental chemistry. Springer, Berlin. https://doi.org/10.1007/698_2017_101
22. Kirkos G, Zodiatis G, Loizides L, Ioannou M (2017) Oil pollution in the waters of Cyprus. In: Carpenter A, Kostianoy AG (eds) Oil pollution in the Mediterranean Sea: part II – national case studies. The handbook of environmental chemistry. Springer, Berlin. https://doi.org/10.1007/698_2017_49
23. Benmecheta A, Belkhir L (2016) Oil pollution in the waters of Algeria. In: Carpenter A, Kostianoy AG (eds) Oil pollution in the Mediterranean Sea: part II – national case studies. The handbook of environmental chemistry. Springer, Berlin. https://doi.org/10.1007/698_2016_57

24. ITOPF (2015) Oil tanker spill statistics 2014. International Tanker Owners Pollution Federation Limited (ITOPF), London. http://www.itopf.com/fileadmin/data/Documents/Company_Lit/Oil_Spill_Stats_2014FINALlowres.pdf. Accessed June 2018
25. Soto-Viruet Y (2016) The Mineral Industry of Spain. United States Geological Service (USGS) 2013 Minerals Yearbook: Spain [Advance Release], March 2016. https://minerals.usgs.gov/minerals/pubs/country/2013/myb3-2013-sp.pdf. Accessed June 2018
26. European Maritime Safety Agency (EMSA) (2014) The CleanSeaNet service: taking measures to detect and deter marine pollution. EMSA, Lisbon. http://emsa.europa.eu/publications/information-leaflets-and-brochures/item/2123-the-cleanseanet-service.html. Accessed June 2018
27. Dahlmann G, Kienhuis P (2015) Oil spill sampling and the Bonn-oil spill identification network: a common method for oil spill identification. In: Carpenter A (ed) Oil pollution in the North Sea. Springer, Cham, pp 237–254
28. Wikipedia (2018) France. Wikipedia page at 10 June 2018. https://en.wikipedia.org/wiki/France. Accessed June 2018
29. Eurostat (2017) Top 20 EU ports for maritime freight, 2015 (thousand tonnes) RYB17.png. http://ec.europa.eu/eurostat/statistics-explained/index.php?title=File:Top_20_EU_ports_for_maritime_freight,_2015_(thousand_tonnes)_RYB17.png. Accessed June 2018
30. Perez AA (2016) The Mineral Industry of France. USGS 2013 Minerals Yearbook: France [Advance Release], March 2016. https://minerals.usgs.gov/minerals/pubs/country/2013/myb3-2013-fr.pdf. Accessed June 2018
31. Zonn IS, Kostianoy AG (2016) The Adriatic Sea. In: Joksimović A et al (eds) The Boka Kotorska Bay environment. The handbook of environmental chemistry, vol 54. Springer, Berlin, pp 19–42. https://doi.org/10.1007/698_2016_42
32. Sub-Regional Contingency Plan for Prevention of, Preparedness for and Response to Major Marine Pollution Incidents in the Adriatic Sea (2005) Portoroz, 9 Nov, pp 1–44
33. Law (2005) Law on marine environment pollution from oil and other harmful substances and emergency response and damages compensation. Official Newspaper No. 5312, 3 Mar 2005, Issue 25752 (in Turkish)
34. Offshore Technology (2017) Israel approves Karish and Tanin gas field developments. Article dated 30 Aug 2017. http://www.offshore-technology.com/news/newsisrael-government-approves-karish-and-tanin-gas-fields-development-plan-5913574/. Accessed June 2018
35. Offshore Technology (2017) Noble energy to develop leviathan natural gas project in offshore Israel. Article dated 28 Feb 2017. http://www.offshore-technology.com/news/newsnoble-energy-approves-offshore-leviathan-project-development-5749312/. Accessed June 2018
36. International Maritime Organization (2017) International Convention on Oil Pollution Preparedness, Response and Co-operation (OPRC). http://www.imo.org/en/About/Conventions/ListOfConventions/Pages/International-Convention-on-Oil-Pollution-Preparedness,-Responseand-Co-operation-(OPRC).aspx. Accessed June 2018
37. Sviva.gov.il (2007) Israel national contingency plan for combating marine oil pollution, 2007 ("TALMAT"). http://www.sviva.gov.il/English/env_topics/marineandcoastalenvironment/Documents/NatlContingencyPlanForPreparednessAndResponseToOilPollutionIncidents-July2007.pdf. Accessed June 2018
38. European Environment Agency (2015) Cyprus country briefing – the European environment – state and outlook 2015, 18 Feb 2015. https://www.eea.europa.eu/soer-2015/countries/cyprus. Accessed June 2018
39. Hastorun S (2015) The Mineral Industry of Cyprus. United States Geological Service (USGS) 2013 Minerals Yearbook: Spain [Advance Release], August 2015. https://minerals.usgs.gov/minerals/pubs/country/2013/myb3-2013-cy.pdf. Accessed June 2018
40. European Parliment Direcorate-General for External Politics (2017). Energy: a shaping factor for regional stability in the Eastern Mediterranean. http://www.europarl.europa.eu/RegData/etudes/STUD/2017/578044/EXPO_STU(2017)578044_EN.pdf. Accessed Aug 2018
41. VTTI Cyprus (n.d.) http://www.vtti.com/terminals/vttv-cyprus. Accessed June 2018
42. EMSA (n.d.) Oil Spill response services. http://www.emsa.europa.eu/oil-spill-response.oil-recovery-vessels.html. Accessed June 2018

43. Salas J, Garcıa L, Font J (2001) Statistical analysis of the surface circulation in the Algerian current using Lagrangian buoys. J Mar Syst 29(1–4):69–85
44. Bouchentouf S, Tabet D, Ramdani M (2013) Mercury pollution in beachrocks from the Arzew gulf (West of Algeria). Travaux de l'Institut Scientifique, Rabat, Série Zoologie 49(1–5)
45. World Maritime News (2018) ITOPF: two large oil spills reported in 2017. Article posted 22 Jan 2018. https://worldmaritimenews.nom/archives/241402/itopf-two-large-oil-spills-reported-in-2017/. Accessed June 2018

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A. Carpenter and A. G. Kostianoy (eds.), *Oil Pollution in the Mediterranean Sea: Part II - National Case Studies*, Hdb Env Chem (2018) 84: 287–292,
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