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Andrey G. Kostianoy *Editors*

Oil Pollution in the Mediterranean Sea: Part I

The International Context

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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; geo-ecology; 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 I: The International Context

Angela Carpenter and Andrey G. Kostianoy

Abstract This book (Part 1 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 chapters at an international level. The chapters consider various sources of oil entering the marine environment, activities such as numerical modeling of oil pollution in the Eastern and Western Mediterranean Basins, oil spill beaching probability assessment, and oil spill intervention activities. They also examine legislative measures in place to protect the marine environment of the Mediterranean from oil pollution, including the role of the Convention for the Protection of the Mediterranean Sea Against Pollution (Barcelona Convention, 1976) and its various protocols, in providing a framework under which nations across the region can work together to cooperate in preventing pollution from ships and from offshore exploration and exploitation activities or in the event of an emergency. The work of the Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea (REMPEC), established under the Barcelona Convention to enhance collaboration and cooperation between national contracting parties, is also examined, including its role in national contingency planning and oil pollution preparedness and response activities. The International Maritime Organization has a role in protecting the Mediterranean Sea and its various regions through the International Convention for the Prevention of Pollution from Ships and its Protocols (MARPOL 73/78 Convention) and sets limits on discharges of oil from ships, while the European Maritime Safety Agency supports oil spill detection activities through satellite surveillance across the region. This book

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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.

Keywords Barcelona Convention, EMSA, MARPOL Convention, Mediterranean Sea, Monitoring, Numerical modeling, Oil and gas exploration, Oil installations, Oil pollution, Oil spill preparedness, Oil spills, REMPEC, Shipping

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 [2]. The Mediterranean Basin is approximately 4,000 km from east to west and has a maximum width of 800 km [2]. Twenty-one countries border the Mediterranean; in alphabetical order, they are Albania, Algeria, Bosnia and Herzegovina, Croatia, Cyprus, Egypt, Greece, Israel, Italy, Lebanon, Libya, Malta, Monaco, Montenegro, Morocco, Slovenia, Spain, Syria, Tunisia, and Turkey [2].

The Mediterranean Sea is a relatively small, semi-enclosed sea, with limited exchange of water with the Atlantic Ocean and Black and Red Seas and is divided into two deep basins, the Western and Eastern Basins, which are further subdivided into a number of sub-basins [2] (see Fig. 1). The Western Basin has an area of

Fig. 1 The Mediterranean Basin and its waters. Source: UNEP-MAP – Barcelona Convention ([2], p. 19). Available at https://wedocs.unep.org/bitstream/handle/20.500.11822/364/sommcer_eng.pdf?sequence=4&isAllowed=y

approximately 0.9 million km^2 and includes within the Algerian-Balearic Basin, the Catalano-Balearic Sea, the Gulf of Lion, the Ligurian Sea, and the Tyrrhenian Basin [2]. At its western end is the 14-km-wide and 290-m-deep Strait of Gibraltar through which the Mediterranean Sea connects to the Atlantic Ocean [2]. Two large rivers drain into the Western Basin: the Ebro which has a drainage region covering the southern flanks of the Pyrenees and northern flanks of the Iberian Cordillera and flows into the Catalano-Balearic Sea and the Rhone, which has a drainage region covering the central Alps, Lake Geneva, and southeastern France and flows into the Gulf of Lion [2]. The Eastern Basin has an area of approximately 1.7 million km^2 and includes the Strait of Sicily, the Adriatic Sea, the Ionian Sea, the Levantine Basin, and the Aegean Sea [2]. It contains the deepest part of the Mediterranean, the Hellenic Trench, which runs from the western Peloponnese region of Greece to southeast of the island of Rhodes and which reaches a depth of 5,267 m off the Peloponnese [2].

The Mediterranean Sea faces multiple pressures and threats from human activities including threats to coastline stability and erosion resulting from population growth, the use of low-lying delta areas for dwellings, coastal modifications resulting in redistribution of sediments, and the construction of artificial coast areas in areas across the northern Mediterranean [2]. Other threats to the region include eutrophication, where inputs of dissolved nitrogen and phosphorus from wastewater, fertilizers, and sewage, for example, result in nutrient over-enrichment causing harmful algal blooms; the introduction of nonindigenous species entering the region through waterways such as the Suez Canal, being transported on the hulls of ships and in ballast water, and through aquaculture activities; marine litter; marine noise; and physical damage to the sea-floor from fishing, offshore construction, dredging, and rigs [2].

There are multiple sources of pollution entering the marine environment, including land-based sources (point-source and nonpoint-source), atmospheric deposition, riverine discharges, and marine activities including shipping, mining, and oil and gas exploration and exploitation [2]. Pollution includes organic matter entering coastal and marine waters from both domestic and industrial sources, with 37% of coastal settlements having inadequate or no wastewater treatment facilities for sewage in 2012 [2]. Heavy metals including lead, mercury, cadmium, zinc, and copper have been found in coastal sediments across the northern Mediterranean and have been linked to industrial and domestic waste discharges and to activities in harbors [2], while hazardous persistent organic pollutants (POPs) such as polychlorinated biphenyls (PCBs), dichloro-diphenyl-trichloroethanes (DDTs), and hexachlorobenzenes (HCBs) have also been found in northern areas ranging from Spain into and around the Adriatic (for HCBs very high levels were identified in Turkish waters in 2011) [2]. These substances were generally identified in the vicinity of industrial and urban areas and in the mouths of rivers such as Rhone and Ebro and offshore from ports such as Piraeus near Athens [2]. Maritime traffic is also a source of chemical compounds such as tributyltin (TBT) used in antifouling paints and polyaromatic hydrocarbons (PAHs) from oil discharges and accidental spills [2]. The latter are generally found in sediments near ports and industrial areas, and high levels have been linked to refineries, terminals, and ports [2].

Between 2000 and 2009, it was estimated that 4.2 thousand tonnes of oil was spilled in Western Mediterranean waters, 0.1 thousand in the Adriatic Sea, 5.5 thousand tonnes in the Central Mediterranean, and 19.2 thousand tonnes in the Eastern Mediterranean [2]. In the case of the Eastern Mediterranean, 13,000 tonnes originated from an incident at the Jiyeh power plant in Lebanon in July 2006 [3]. In the case of the Western Mediterranean, the major oil spill from the *MV Haven* in April 1991 off Genoa resulted in a spill of 144,000 tonnes of oil, making it the fifth largest oil spill recorded since 1967 [4]. In 2017 it was noted that the rate of accidents has gone down in the Mediterranean despite an increase in shipping traffic, and it was concluded that the international regulatory framework, both through the IMO and regional cooperation activities, has had a positive impact on reducing accidents [5]. Despite this, however, it was considered that the risk of spills from oil tankers and also vessels transporting hazardous noxious substances (HNS) cannot be completely eliminated, while illicit spills continue to occur and require ongoing monitoring to identify the source of such spills [5]. Even as this volume was underway, and a chapter on shipping and oil transportation in the Mediterranean Sea had been completed [6], a spill occurred in Greek waters in September 10, 2017, where the *Agia Zoni II* tanker was wrecked and subsequently sank near the port of Piraeus and off the coast of Salamina, Greece [7]. The oil tanker was carrying fuel oil and marine gas oil, the vast majority of which was contained and removed using oil spill cleanup units [8], but an estimated 700 tonnes of oil were spilled as a result of this accident [6].

The majority of oil and gas exploration activities have occurred in the Eastern Mediterranean Basin, including along the northern and central Italian coasts of the Adriatic Sea where there were approximately 90 offshore platforms in 2007 [9], while there have been major natural gas finds in the waters of Israel [10, 11], exploration activities taking place off the coast of Cyprus [12], and new exploration activities planned in Greek waters in the coming years [13]. Oil and gas exploration activities pose a threat to the marine environment, the seabed, and sea-bottom habitats and species [14], and oil contamination can persist in the marine environment for many years, depending on the oil type, the location of a spill, and the area in which the contamination occurs [15, 16]. In the Western Mediterranean, Algeria is one of the top three oil producers in Africa and is a potential source of oil pollution on the southern shore of the Western Basin of the Mediterranean Sea since it has six coastal terminals for the export of petroleum products, together with five oil refineries (three in coastal cities), located along its coastline [17]. Between 1988 and 1997, some 22,563 tonnes of oil entered the Mediterranean Sea annually from coastal refinery effluent sources. Of this, it was estimated that around 2,971 tonnes per year came from Algerian coastal refineries (the largest volume for an individual country) [18].

There are in place a range of standards for oil pollution from both shipping and oil and gas exploration and exploitation in the region. 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, 1994) sets out standards for the disposal of oil and oily waste from oil and gas installations in the region [19]. This is one of a number of Protocols to the 1976 *Convention for the Protection of the Mediterranean Sea Against Pollution* (Barcelona Convention) [20], other Protocols to which include the *Protocol for the Protection of the Mediterranean Sea against Pollution from Land-Based Sources and Activities* (LBS Protocol) [21] and the *Protocol on the Prevention of Pollution of the Mediterranean Sea by Transboundary Movements of Hazardous Wastes and their Disposal* (Hazardous Waste Protocol) [22].

The Convention and its Protocols, together with the work of the Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea, a body established to support Mediterranean coastal states in combatting oil pollution and dealing with its consequences, are discussed in this volume, as are the roles of the European Maritime Safety Agency in monitoring and protecting the region through satellite surveillance and provision of oil spill cleanup resources and the role of the International Maritime Organization and the *International Convention for the Prevention of Pollution from Ships* (MARPOL Convention) [23], under Annex I on Oily Wastes, of which the Mediterranean Sea has special status which establishes strict limits on the volume of oil that can be legally discharged[1] which the Adriatic Sea holds Particularly Sensitive Sea Area (PSSA) status, with even tighter restrictions than for the rest of the Mediterranean.

Other chapters appearing in this volume include the history, sources, and volumes of oil pollution in the Mediterranean; an examination of shipping and oil transportation and the hazards that are presented by pipelines and tankers and an examination of oil and gas production activities that have, and continue, to take place in the region; a discussion on oil spill intervention measures at international, regional, and national levels (including intervention planning); oil spill beaching probability through the use of maps and simulations to provide vulnerability analysis and risk assessment in the Mediterranean; an overview of EU, nationally and regionally funded oil spill response projects that contribute to protecting valuable marine ecosystems; a summary of major oil spill numerical predictions in the Eastern Mediterranean, including application of oil spill models to real-life oil pollution accidents and spills; and a chapter on oil spill numerical modeling in the Western Mediterranean for over 15 years and using a range of different ocean and atmospheric forecasting models.

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.

This two-part volume follows on from earlier volumes in the Handbook of Environmental Chemistry Series which examined oil pollution in the Baltic Sea [24] and in the North Sea [25], and, following on from this Mediterranean volume,

[1]For further details on these limits, see http://www.imo.org/en/OurWork/Environment/SpecialAreasUnderMARPOL/Pages/Default.aspx.

plans are already in place for a volume on "Oil Pollution in the Black Sea" which will be presented in two parts. Part I of this volume on the Mediterranean Sea contains 15 chapters including the 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, and includes 10 national case study chapters presenting and covering 9 Mediterranean countries (in the case of Italy, there are two chapters, one excluding and one covering Italian waters within the Adriatic Sea). It was not possible to include, in Part II, a chapter from every state bordering the Mediterranean Sea, due to geopolitical problems in the region (particularly in the east and along the North African coast). However, many of the chapters in Part I do include material that covers the entire Mediterranean Sea and its basins and sub-basins.

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.

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History, Sources and Volumes of Oil Pollution in the Mediterranean Sea

Andrey G. Kostianoy and Angela Carpenter

Abstract This chapter presents a brief review of history, sources and volumes of oil pollution in the Mediterranean Sea. Historical records show 16 major oil spills occurred between May 1966 and September 2017 and resulted in oil spills ranging between 6,000 and 144,000 tonnes; the largest spill came from the *MT Haven* tanker after an explosion on board on April 11, 1991. Sources of oil pollution are typical for other seas and include shipping, oil and gas platforms, ports and oil terminals, land-based sources, military conflicts, natural oil seeps and even atmospheric inputs. Shipping activities are the main cause for oil pollution in the Mediterranean Sea while oil and gas production and exploration are not so important, unlike in the Gulf of Mexico or the Caspian Sea. If we exclude major oil spill accidents from ships, which are very rare events in the Mediterranean, different expert reports and estimates provide total volumes of oil pollution ranging from 1,600 to 1,000,000 tonnes per year. The 625 times difference in values means that we still do not know the real volume of oil pollution entering the Mediterranean Sea and this is a big problem that should be addressed.

Keywords Aerial surveillance, Mediterranean Sea, Oil installations, Oil pollution, Oil seeps, Oil terminals, Ports, Satellite monitoring, Shipping

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1 Introduction

Historically, the Mediterranean was a centre of European civilization. Since the times of Ancient Egypt, Rome and Greece, the Mediterranean Sea has connected the countries of Southern Europe, Africa and Near East by shipping routes which played a major role in the development of trade and international relations between countries, unfortunately including numerous wars. Today, maritime transport in the Mediterranean is a strong economic sector, with 15% of global shipping activity by number of calls (10% by vessel deadweight) and around 18% of global crude oil shipments taking place in the region [1]. The extensive maritime transport of large quantities of crude oil comes (a) from the Middle East to ports in Europe and North America via the Suez Canal, (b) between the Mediterranean and the Red Sea, (c) through the Strait of Gibraltar and (d) between the Black Sea and the Mediterranean through the Turkish Straits. For example, in 2006 crude oil loaded and discharged at Mediterranean ports amounted to 220 and 255 million tonnes, respectively [2].

Intensive shipping activities in the Mediterranean pose a potential danger to the marine environment due to oil pollution which may arise due to different reasons. In the pre-industrial era when the main fleet was still under sail and the internal combustion engine was not yet invented, we can speculate that the only source for oil pollution in the Mediterranean Sea was natural seepages from the bottom. This is a natural factor which is related to the presence of petroleum and gas deposits found in geological formations beneath the Earth's surface or bottom of the seas, and its intensity is related to seismic activity which is, in turn, related to tectonics of the lithospheric plates.

By the mid-nineteenth century, the shipping industry was in transition from sail-powered boats to steam-powered boats and from wood construction to an ever-increasing metal construction. Since the 1910s diesel engines have been used in ships, and their number has increased significantly. While there is no evidence of oil pollution in the Mediterranean at the beginning of the twentieth century, this lack of evidence does not mean that ship technologies at the time were available to prevent oil pollution from ships; we can only speculate that this is because there are no records on oil pollution available for these times. It is evident however that WWI and

WWII added to oil pollution of the Mediterranean significantly because several thousands of ships and submarines were sunk and aircraft shot down over the sea.

Records on accidents from ships and related oil pollution in the Mediterranean appeared during the 1960s, and it is clear that major incidents with oil spills larger than 6,000 tonnes occurred almost yearly until 1981. Since then significant progress in technologies of ship construction, operation and routing resulted in a sharp decrease of a frequency of accidents with ships in the Mediterranean. After 1981 there were only four major accidents, unfortunately including the biggest ever oil spill in the region of 144,000 tonnes resulting from the *MV Haven* accident off Genoa, Italy. Unfortunately, operational oil spills of a size of about 1–10 tonnes released by ships of different types occur almost daily in different parts of the sea, and these remain a major oil pollution problem for the Mediterranean as their number may reach 1,500–2,500 every year. Finally, the Mediterranean Sea faces a new problem which is a recent intensification of oil and gas development in the Eastern Mediterranean. In the coming years, potential oil pollution from these new sources should also be taken into account.

This chapter presents a brief review of history, sources and volumes of oil pollution in the Mediterranean Sea.

2 History of Oil Pollution in the Mediterranean Sea

If we look on the list of the world's top 180 major (over 6,000 tonnes) oil spills since the early 1960s, the first serious incident in the Mediterranean Sea was on 15 May 1966 with the *Fina Norvege* and resulted in 6,000 tonnes oil spilled close to Sardinia, Italy. On 1 November 1970, an incident with the *Marlena* resulted in 15,000 tonnes oil spilled near Sicily, Italy. The next incident occurred on 11 June 1972 with the *Trader* and resulted in a 37,000 tonnes oil spill. Then, on 25 April 1976 came the next serious incident which was with the *Ellen Conway* which resulted in 31,000 tonnes oil spill close to the Port of Arzew, Algeria. On 30 June 1976 was the *Al Dammam* spill with 15,000 tonnes oil spilled close to Agioi Theodoroi, Greece. The following year, on 10 August 1977, a serious incident occurred with the *URSS 1* in the Bosporus Strait and resulted in a 20,000 tonnes oil spill. On 25 December 1978 came the *Kosmas M.* spill when 10,000 tonnes of oil was spilled close to Asbas, Antalya, Turkey. The following year, on 2 March 1979, an incident occurred with the *Messiniaki Frontis* and resulted in a spill of 16,000 tonnes of oil close to Crete, Greece [3].

A more serious incident was with the *MT Independența* ("Independence"), a large Romanian crude oil carrier which on November 15, 1979 collided with a Greek freighter at the southern entrance of Bosphorus Strait, Turkey, and exploded. She caught fire and grounded. Almost all of the tanker's crew members died. It was estimated that 30,000 tons of crude oil burned and that the remaining 64,000 tons spilled into the sea. The *Independența* burned for weeks, causing heavy air and sea pollution in the Istanbul City area and the Sea of Marmara [3].

The following year another serious incident happened with the *Irenes Serenade* in Navarino Bay, Greece, on 23 February 1980, where 100,000 tonnes of oil was spilled to the sea. This incident was ranked number 9 out of the world's top 20 with the *Atlantic Empress* spill (1979, off Tobago, West Indies, 287,000 tonnes) in first place [4].

Then on 29 December 1980, a spill of 37,000 tonnes resulted from an incident with the *Juan Antonio Lavalleja* which grounded during a storm close to the Port of Arzew, Algeria [3].

Other incidents occurring in the Mediterranean include a spill of 18,000 tonnes from the *Cavo Cambanos* on 29 March 1981 close to Corsica and a spill of around 12,200 tonnes of heavy fuel oil and slops from a collision between the oil/bulk/ore carrier *Sea Spirit* and the LPG carrier *Hesperus* west of Gibraltar in 1990 [5]. While that incident took place outside the Mediterranean Sea, oil entered the region carried by winds and currents, presenting a serious threat to the coasts and waters of Spain, Morocco and Algeria [6].

In April 1991 off Genoa, Italy, the *MV Haven* (Fig. 1), the biggest oil spill ever recorded in the Mediterranean, was one of only two of the 20 top largest oil spills occurring globally since the late 1960s. In this case 144,000 tonnes of oil was spilled in the sea (number 5 out of the top 20) (see Table 2 in [4, 7]).

In 2000, incident with *Castor* off Nador, Morocco, due to structural failure in storm conditions resulted in a gasoline spill of 9,900 tonnes [8].

Fig. 1 *MT Haven* tanker after explosion on April 11, 1991, off the coast of Genoa, Italy (http://www.takepart.com/photos/worlds-worst-oil-spills/10-mt-haven-tanker-oil-spill)

In July 2006, along the coast of Lebanon, between 15,000 and 30,000 tonnes of heavy fuel oil was spilled into the sea after the Jiyeh power plant be bombed by the Israeli Air Force on July 14 and 15, during the 2006 Israel-Lebanon conflict. A 10 km-wide oil spill covered 170 km of coastline, killed fish and threatened the habitat of endangered green sea turtles [9–11].

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 [12]. The vast majority of oil on board was contained through the deployment of oil spill clean-up units [13], and the volume of oil spilled was estimated at between 700 and 2,500 tonnes [12].

More cases of oil pollution in the Mediterranean Sea can be found [8, 14, 15], but they are much smaller and have a size ranging from 50 to 2,000 tonnes.

3 Sources of Oil Pollution in the Mediterranean Sea

Different expert reports and publications provide quite different assessment of oil pollution sources and their share in total volumes of oil coming to the sea or ocean. Very often it is difficult to compare these shares because there is no consensus between them. For example, The US National Research Council (NRC) Report "Oil in the Sea III: Inputs, Fates, and Effects" [16] developed a new methodology for estimating petroleum inputs to the sea from both natural and human sources. Oil inputs from human activities are categorized as those that originate from (1) petroleum extraction, exploration and production activities; (2) petroleum transportation, including tanker spills; and (3) petroleum use, including runoff from highways and discharges from recreational vehicles.

The NRC report shows that although the public often associate oil in the ocean with tanker accidents, natural seeps are the largest source of oil in the sea, accounting for about 60% of the total in North American waters and 45% worldwide. Historically, oil and gas exploration, petroleum production and transportation-related spills have been significant sources of oil in the oceans. New technologies have reduced oil pollution from ships and platforms. During the past decades, improved production technology and safety training of personnel have dramatically reduced both blowouts and daily operational oil spills. Today, accidental spills from platforms represent only about 1% of petroleum discharged in North American waters, for example, and about 3% worldwide [16].

Although the amount of oil transported over the oceans continues to rise, transportation-related spills have gone down. Most tankers now have double hulls or segregated tank arrangements that dramatically reduce spillage. Transportation spills now account for less than 4% of the total petroleum released in North American waters and less than 13% worldwide [16].

The conclusion of the NRC report was surprising to many: oil from individual cars and boats, lawn mowers, jet skis, marine vessels and airplanes contributes the most oil pollution to the ocean. This includes land runoff from oil slicks on urban roads and hydrocarbons deposited from the atmosphere. According to the report's estimates, use-related oil pollution dwarfs that from oil and gas production activities, accounting for about 87% of the oil from human activity in North American waters [16].

An Oceana Report dated 2003 or 2004 estimated that in the Mediterranean, 75% of hydrocarbons discharged every year is a result of tanker operations [17]. By contrast, a UNESCO GOOS Report states that in the Mediterranean Sea, about 50% of oil comes from routine ship operations and the remaining 50% comes from land-based sources via surface runoff [18].

The Global Marine Oil Pollution Information Gateway shows shares of oil pollution from another two reports [19]. The Australian Petroleum Production and Exploration Association (APPEA) claims the following distribution of the inputs from different sources:

– Land-based sources (urban runoff and discharges from industry): 37%
– Natural seeps: 7%
– The oil industry – tanker accidents and offshore oil extraction: 14%
– Operational discharges from ships not within the oil industry: 33%
– Airborne hydrocarbons: 9%

In a report in 1993, the Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) estimated a total input of oils to the world ocean at 2.3 million tonnes per year and ranked the sources as follows:

– Land-based sources (urban runoff, coastal refineries): 50%
– Oil transporting and shipping (operational discharges, tanker accidents): 24%
– Offshore production discharges: 2%
– Atmospheric fallout: 13%
– Natural seeps: 11%

Girin and Daniel [8] and Girin and Carpenter [14] report that the overall oil pollution in the Mediterranean waters is the sum of four different sources (without indication of shares), namely:

1. Accidental spills on the land, 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. Oil spills from pipelines around in the Mediterranean did definitely occur, but the number, volume and location of those spills cannot be assessed due to a lack of accessible documentation.
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 spills over 10 tonnes.
3. Operational spills from 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 most concentrated. They are voluntary and individually small (less than 10 tonnes).

There is no information available on the contribution of the tanker, cargo, container, fishing, leisure, cruise and defence fleets to the total input of oil in the Mediterranean. The same applies to offshore oil exploration and exploitation activities.

4. Natural seeps on the seabed: 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.

Hildebrand et al. [20] summarize that the most commonly identified sources of oil pollution at sea include (a) natural sources; (b) offshore oil production; (c) maritime transportation; (d) the atmosphere; (e) waste, i.e. municipal and industrial; (f) urban and rural runoff; and (g) ocean dumping.

For the Mediterranean Sea, we have identified the following sources of oil pollution that will be described in more details below: shipping, oil and gas platforms, ports and oil terminals, land-based sources, military conflicts, natural oil seeps and the atmosphere, which in general cover all the above-mentioned sources.

3.1 Shipping

Shipping activities pose a threat to the marine environment of the Mediterranean. The diversity of shipping in the region includes fishing fleets, ro-ro ferries, leisure craft, military vessels, large container carriers, bulk carriers and tankers and also fixed "vessels", including offshore oil exploration and exploitation vessels [14]. The numbers presented by REMPEC with regard to merchant vessels showed that there were more than 325,000 voyages in the Mediterranean Sea in 2007 and in 2013 (two-thirds of them were internal – Mediterranean to Mediterranean) (Fig. 2). The Mediterranean Sea accounted for 15% of global shipping activity by number of calls and 10% by vessel deadweight tonnes [20].

Operational oil spills can be voluntary or not, resulting from a human decision, a human error or a technical failure. It seems that they are the most numerous type of spill, with numbers totalling several hundred thousand tonnes yearly. An Oceana Report from the early 2000s (around 2003 or 2004) estimated that the total amount of crude oil passing through EU waters could be over one billion tonnes and that the Mediterranean Sea was most affected by dumping of hydrocarbons in the sea from ships, with nearly 490,000–650,000 tonnes being released annually [17]. A GESAMP 2007 Report indicated that there were more than 200 accidental spills from ships annually in the region and that this reflects the high commercial activity taking place in the region [21].

On the other hand, EMSA Pollution Preparedness and Response Reports for the years 2011–2013 mentioned that between February and December 2011, there were acquired some 2,143 satellite SAR images showing 2,048 possible oil spills detected: 749 of those spills were identified as Class A, most probably oil (mineral or vegetable/fish oil), while 1,299 were identified as Class B – less probably oil

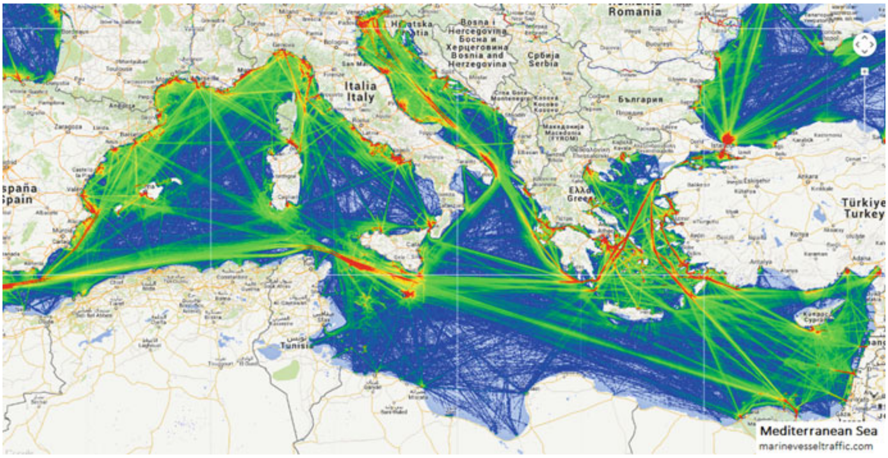

Fig. 2 Density map of ship traffic in the Mediterranean Sea (http://www.marinevesseltraffic.com/MEDITERRANEAN-SEA/ship-traffic-tracker, accessed on 27 August 2018)

[22, 23]. However, these numbers do not represent the real state of oil pollution in the Mediterranean Sea because the number of processed satellite images varied from 3 to 454 per year per country in 2007–2010 [1], thus temporal and spatial coverage of the Mediterranean is incomplete.

In 2017 it was noted that the rate of accidents has gone down in the Mediterranean despite an increase in shipping traffic, and it was concluded that the international regulatory framework, both through the IMO and regional cooperation activities, has had a positive impact on reducing accidents. Despite this, however, it was considered that the risk of spills from oil tankers and also vessels transporting hazardous noxious substances (HNS) cannot be completely eliminated, while illicit spills continue to occur and require ongoing monitoring to identify the source of such spills [10].

Looking at the oil spill maps generated thanks to satellite monitoring of the whole Mediterranean Sea in 1999–2004 performed by the European Commission – Joint Research Centre (Ispra, Italy) (see Fig. 9 in Sect. 4 of this chapter), of French waters in 2000–2009 (see Fig. 1 in [8]) and Eastern Mediterranean in 2007–2011 (see Fig. 8 in [24]), it is clear that operational oil spills continue to be a major problem for the Mediterranean Sea environment and one that needs to be resolved.

3.2 Oil and Gas Platforms

Oil and gas exploration activities pose a threat to the marine environment, the seabed and sea-bottom habitats and species, both during the exploration phase and the production phase [25], since oil contamination can persist in the marine environment for many years, depending on the oil type, the location of a spill and the area in which the contamination occurs [26, 27].

Hydrocarbon exploration activities in Greece date back to the early twentieth century. In the Aegean Sea, a small number of significant oil discoveries were made in the mid-1970s at Prinos (with a smaller gas discovery at South Kavala) with production continuing to the present day. Initial estimated reserves for the Prinos fields were 90 Mbl, which have now been increased to 290 Mbls, with 110 Mbls already having been produced since 1981 [28].

Today, the Eastern Mediterranean Sea, and the east coast of Italy in the Adriatic Sea, is the location of the majority of oil and gas exploration and exploitation activities (Fig. 3). 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), and, in 2005, there were over 350 wells drilled for offshore production in the waters off Italy, Egypt, Greece, Libya, Tunisia and Spain 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) [29, 30].

In 2011, gas was discovered in the Leviathan gasfield (Fig. 4), 135 km off the coast of Israel, with an estimated volume of 16 trillion cubic feet of gas (approximately 453 million m^3) [31]. In August 2017 a contract was signed to drill two wells and complete four production wells in the Leviathan gasfield [32].

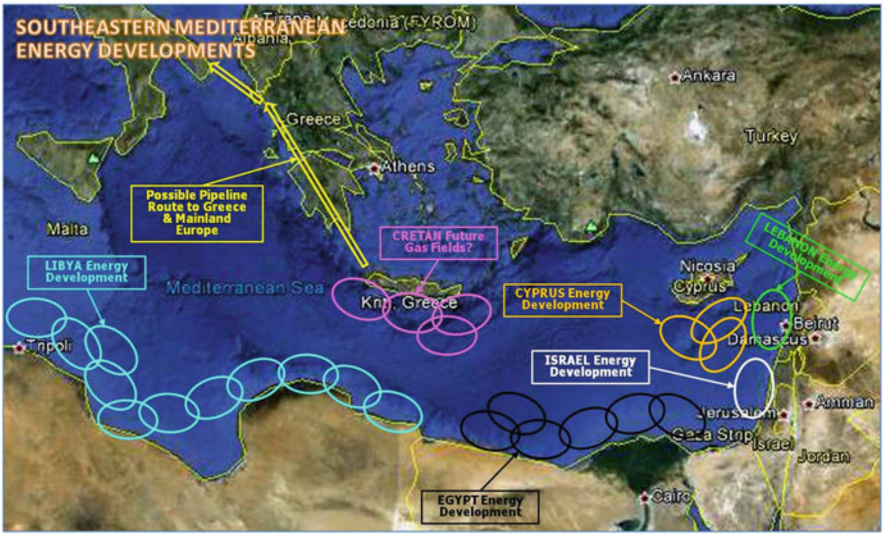

Fig. 3 Oil and gas exploration and exploitation activities in the Eastern Mediterranean (http://www.greekamericannewsagency.com/english-menu/english/politics/30945-egypt-has-joined-greece-and-greek-cyprus-in-calling-for-turkey-to-stop-exploration-work-off-the-cyprus-coast) Copyright © 2012 Pytheas Limited

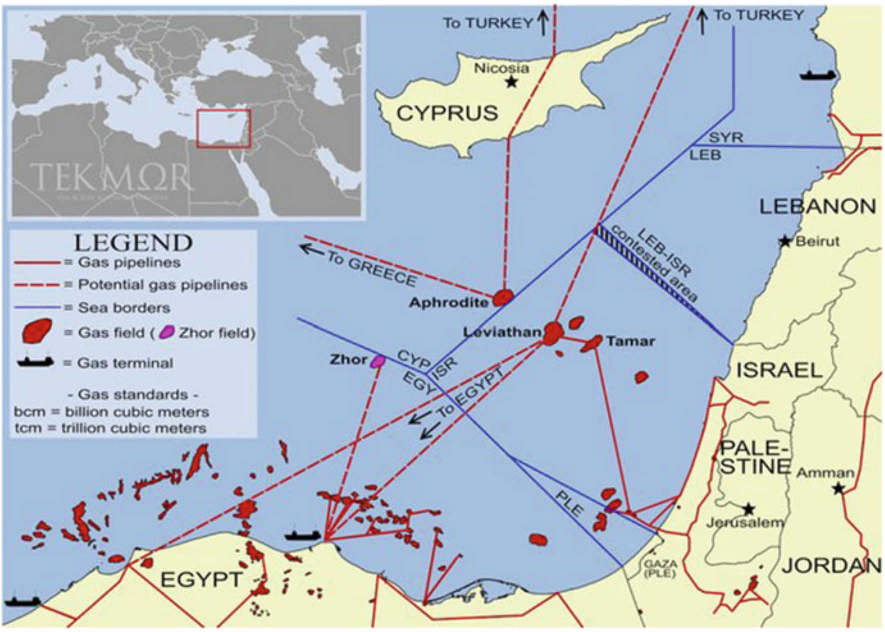

Fig. 4 Gasfields, active and potential gas pipelines and gas terminals in the Southeastern Mediterranean (https://www.vestifinance.ru/articles/97771)

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 [33]. 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 [34].

3.3 Ports and Oil Terminals

The Mediterranean has about 150 coastal cities and ports of different size. The busiest ports by cargo tonnage are Port of Marseille, France (88 mln tons); Port of Algeciras, Spain (77 mln tons); Port of Valencia, Spain (65 mln tons); Port of Genoa, Italy (50 mln tons); Port of Trieste, Italy (48 mln tons); and Port of Barcelona, Spain (43 mln tons).

In 2006 crude oil loaded at Mediterranean ports amounted to 220 million tonnes. The top 20 Mediterranean crude oil loading ports measured by number of calls accounted for 99% of all crude oil loaded in the Mediterranean. The major ten crude oil load ports are Sidi Kerir (74,339,769 tons), Arzew (40,240,000 tons), Ras Lanuf (14,065,500 tons), Es Sider Term (14,640,000 tons), Marsa el Brega (6,136,000 tons), Bejaia (6,750,000 tons), Zueitina Term (7,570,000 tons), Skikda (6,650,000 tons), Zawia Term (6,800,000 tons) and Ceyhan (BTC) (6,480,000 tons) [2].

The total volume of crude oil discharged at Mediterranean ports during 2006 amounted to 255 million tonnes. The top 20 Mediterranean crude oil discharge ports measured by number of calls accounted for 85% of all crude oil discharged in the Mediterranean. The major ten crude oil discharge ports are Trieste (33,838,000 tons) (Fig. 5), Fos (35,195,000 tons), Augusta (20,341,500 tons), Genoa (15,189,500 tons), Sarroch (12,774,000 tons), Algeciras (12,337,500 tons), Savona (7,583,000 tons), Venice (6,151,000 tons), Tutunciftlik (10,541,000 tons) and Port de Bouc (5,889,000 tons) [2].

All ports and oil terminals present a potential danger of oil pollution. For example, along the coasts of the Western Mediterranean, more than 17 major oil ports and 15 refineries are found especially along the Italian and Spanish coasts. For Italian ports facing the Western Mediterranean, the total quantity of crude oil handled during the 2007 was estimated to be around 80 million tonnes [35]. Algeria is one of the top three oil producers in Africa and is a potential source of oil pollution on the southern shore of the Western Basin of the Mediterranean Sea since it has six coastal terminals for the export of petroleum products in Oran, Arzew, Algiers, Bejaia, Skikda and Annaba, together with five oil refineries (three in coastal cities – Skikda, Arzew and Algiers), located along its coastline [36].

Between 1988 and 1997, some 22,563 tonnes of oil entered the Mediterranean Sea each year from coastal refinery effluent sources of which it was estimated that

Fig. 5 Crude oil terminal in Trieste (https://blog.omv.com/en/trieste-crude-oil-terminal-and-transalpine-pipeline/)

around 2,971 tonnes per year came from Algerian coastal refineries (the largest volume for an individual country) [21].

3.4 Land-Based Sources

Land-based sources include (1) discharges of oil with rivers and floods; (2) discharges of untreated or insufficiently treated municipal sewage and storm water (urban runoff); (3) discharges of untreated or insufficiently treated waste water from coastal industries; (4) accidental or operational discharges of oil from coastal refineries, oil storage facilities, oil terminals and reception facilities; and (5) emissions of gaseous hydrocarbons from oil-handling onshore facilities (terminals, refineries, filling stations) and from vehicles exhausts (traffic) [19]. It is very difficult to estimate volumes of oil coming to the sea from the above-mentioned land-based sources; thus this information for the Mediterranean Sea is lacking, except for some estimates of the impact of refineries.

Oil can 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 [21]. 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) [21; Table 27]. The figures for France, Spain and Turkey include all their coastal waters, not just those located in the Mediterranean. As noted at Sect. 3.3 above, Algeria has six coastal oil terminals and five oil refineries (three of which are in coastal cities). These installations have a serious impact on the marine environment [36].

3.5 Military Conflicts

Historically, the Mediterranean Sea was an arena of numerous sea battles, military conflicts and wars which inevitably are accompanied by oil pollution as a result of sinking of war and merchant ships and aircrafts and damages to coastal infrastructure. During World War I (August 1914–November 1918), there were sporadic naval battles in the Mediterranean between the Central Powers' navies of Austria-Hungary, Germany and the Ottoman Empire on one side and the Allied navies of Italy, France, British Empire, Greece, Japan and America on the opposing side. During WWI more than 850 war and merchant ships were damaged and sank in Mediterranean waters. German submarines were very active and sank tenths of the Allied ships every month. On 9 November 1918, *HMS Britannia* (17,500 tons) of the Royal Navy (UK) was on a voyage in the western entrance to the Gibraltar Strait when she was torpedoed off Cape Trafalgar by the German submarine *UB-50* and sank (Fig. 6). *HMS Britannia* was sunk 2 days before the Armistice was signed on 11 November 1918 ending the First World War [37].

During World War II (September 1939–May 1945), "the Battle of the Mediterranean" was the name given to the naval operations in the Mediterranean Sea that occurred between 10 June 1940 and 2 May 1945. The Mediterranean Sea was an arena of naval battles between the British Royal Navy supported by other Allied naval forces from Australia, the Netherlands, Poland, Greece, Canada and the USA (the latter from 1942) and the Italian Royal Navy (*Regia Marina*) and German Navy (*Kriegsmarine*) supported by Vichy French Fleet. German submarines sank 95 Allied merchant ships totalling some 449,206 tons and 24 Royal Navy warships including 2 carriers (Fig. 7), 1 battleship, 4 cruisers and 12 destroyers at the cost of 62 U-boats (submarines) [38]. Up to September 1943, the total losses from the Allied naval forces were 76 warships and 48 submarines, while losses on the Italian/German/France (Vichy) side amounted to 94 warships and 159 submarines. To these numbers can be added more than 1,000 aircraft shot down coming from both sides. In total, 2,304 Italian/German/France (Vichy) ships were sunk by Allied forces, with a combined tonnage of 3,130,969 tonnes [39].

Decades of corrosion of metal will inevitably lead to leakages of fuel and oil from tanks of the sunken warships and aircraft, and such leaks will sporadically appear on the sea surface as oil spills.

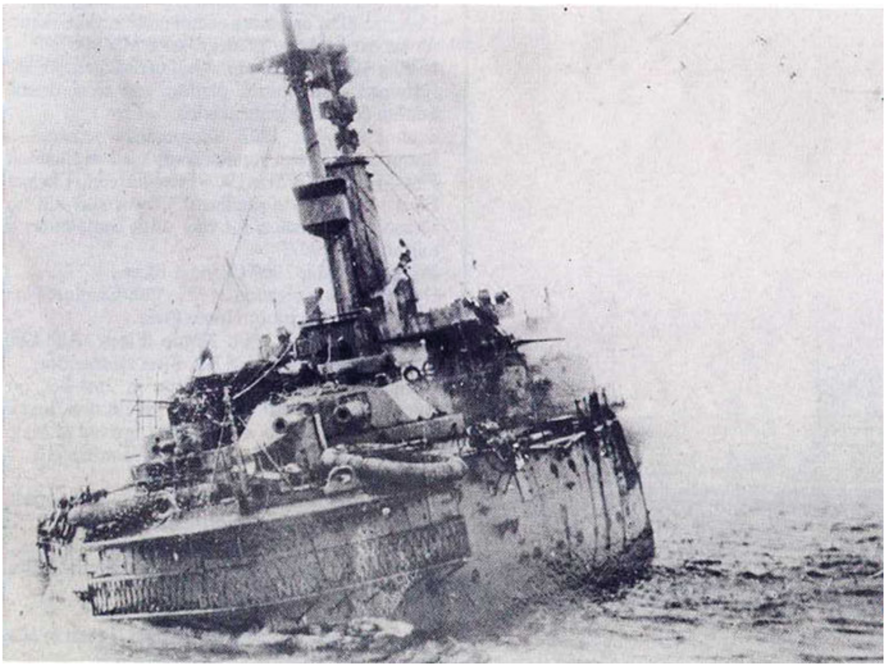

Fig. 6 *HMS Britannia* sinking in the Atlantic Ocean off Cape Trafalgar near Gibraltar Strait on 9 November 1918 [37]

Fig. 7 Aircraft carrier *HMS Ark Royal* of UK Royal Navy sank on 14 November 1941 in 40 km from Gibraltar after being torpedoed by German submarine *U-81* [40]

The most recent serious military incident in the Mediterranean Sea region resulted in a large oil spill and occurred in 2006. In July 2006 on the coast of Lebanon around 15,000–30,000 tonnes of heavy fuel oil was spilled into the sea after the Jiyeh power plant be bombed by the Israeli Air Force on July 14 and 15 during the 2006 Israel-Lebanon conflict. A 10 km wide oil spill covered 170 km of coastline, killed fish and threatened the habitat of endangered green sea turtles (Fig. 8) [9–11].

However, even in times of peace, military fleets produce more sea and air pollution during routine operations, naval patrol or exercises than civil fleets, while navy bases are usually more polluted than civilian ports because warships are primarily designed for military operations and not for protection of the marine environment.

3.6 Natural Oil Seeps

Natural oil seeps from the sea bottom is a very important source of oil pollution in different parts of the world's ocean, namely, in the Gulf of Mexico and the Southern Caspian Sea. Although the public often associate oil in the ocean with tanker accidents, natural oil seeps are the largest single source of oil in the sea, accounting

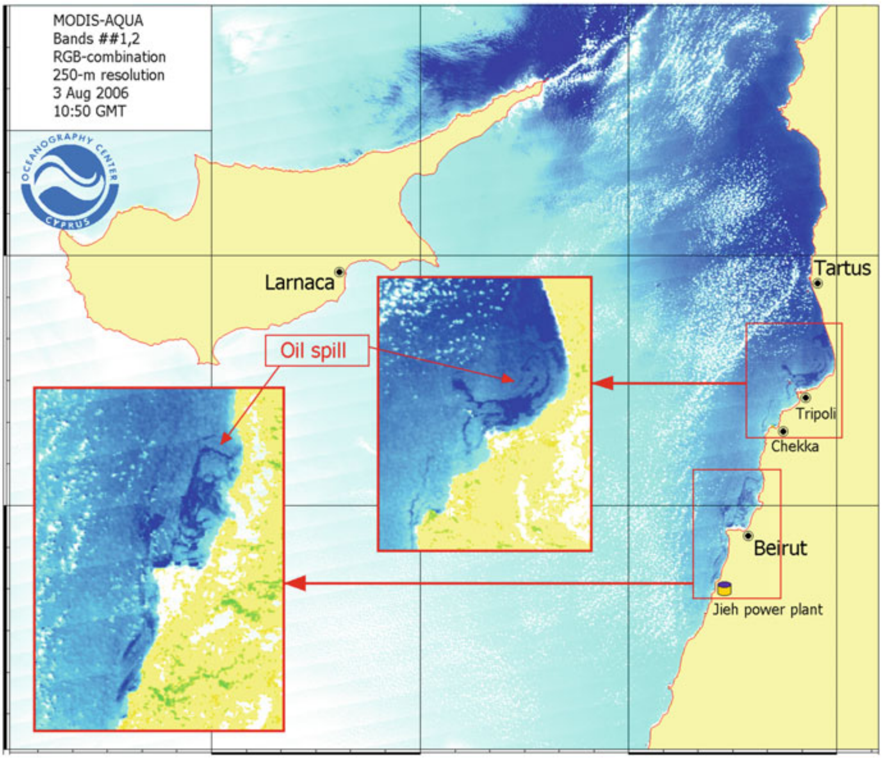

Fig. 8 Oil pollution along the coasts of Lebanon on 3 August 2006. Image courtesy by D.M. Soloviev, Cyprus Oceanography Center

for about 60% of the total in North American waters and 45% worldwide. Oil and gas extraction activities are often concentrated in regions where oil and gas seeps are observed [16].

However it seems that this is not a frequent phenomenon in the Mediterranean Sea as it is not often mentioned in the scientific literature. Only recently, to support oil and gas exploration in the Eastern Mediterranean, Airbus Defence and Space Geo-Intelligence reassessed the area by the analysis of satellite radar data in order to produce a map with the location of potential offshore oil seeps [41]. Slicks on the sea surface are an indicator of the potential location of oil/gas reserves under the seafloor. Based on the interpretation of the satellite radar data, a number of oil slicks have been identified in the Levantine Basin, with particular concentrations adjacent to the Lebanon and Israel coasts, southward of Cyprus and offshore from the Nile Delta [41]. Also, it is well known from other regions, for example, the Southern Caspian Sea, that the frequency of appearance of oil seeps is directly related to seismic activity in the region.

Indeed, a satellite seep study undertaken by “Infoterra” over the East Mediterranean Sea has discovered over 200 seep features. Combining this information with seismic data has provided additional support for the presence of a working petroleum system in the deep Levantine Basin. Often the seeps have a close correlation to direct hydrocarbon indicators, with bright spots, flat spots and gas chimneys seen on the seismic data [42, 43].

The EU-funded GASTIME (Gas seeps and submarine slides in the eastern Mediterranean: Toward comprehensive geohazard prevention) project performed in 2012–2016 set out to study the shaping mechanisms behind gas seepage deep in the Levantine Basin and their connection to slope stability.

The CGG NPA Satellite Mapping seepage database contains extensive satellite coverage across the Northern Aegean Sea made in 2015. Seepage detection by SAR (synthetic aperture radar) is a proven technique for mapping surface oil seeps which could provide the first indication of petroleum systems in these basins. The 2015 NPA's Aegean SAR seepage study has identified many clusters of repeating definite seepage, which confirm the existence of a working petroleum system in this part of the basin, and further enhances the prospectivity of the Eastern Mediterranean region for oil and gas exploration [28].

Unfortunately the above-mentioned research does not provide values of volumes of oil pollution in different parts of the Mediterranean Sea caused by natural oil seeps.

3.7 Atmosphere

Hydrocarbons enter the ocean not only as "wet" oil products but also as gaseous air pollutants. Hydrocarbons from vapours deriving from the loading and unloading of oil at different stages from extraction to consumption, in the form of non-methane volatile organic compounds (nmVOCs), are one of the examples. Polycyclic aromatic hydrocarbons (PAHs) from incomplete combustion (exhaust gases and flue gases) are another category of gaseous hydrocarbons that enter the marine environment as oil pollution [19]. It is difficult to estimate how much oil comes to the Mediterranean Sea from the atmosphere, and we did not find any such data in the publications. It does, however, seems that this specific source of oil could be very important in the industrial areas around the Mediterranean region, and such inputs need to be assessed properly because some reports assign 9–13% of marine oil pollution to this source [16, 19, 44].

4 Volumes of Oil Pollution in the Mediterranean Sea

In this section we have tried to understand what the total volume of oil pollution in the Mediterranean Sea is by collecting appropriate information from different sources. The most obvious incidents usually occur from tankers and oil platforms which result in large oil spills and serious pollution of the marine environment.

The major oil spill from the *MV Haven* in April 1991 off Genoa resulted in a spill of 144,000 tonnes of oil; the second incident was the *Irenes Serenade* spill in Navarino Bay, Greece, in 1980, where 100,000 tonnes of oil was spilled [4]. If we calculate the total amount of oil spilled to the Mediterranean during major incidents (>6,000 tonnes) from ships between 1966 and 2017, this gives us a value of 537,600 tonnes in total during 52 years. Thus, on average, due to major accidents involving ships, we have about 10,000 tonnes of oil pollution yearly. We have to note that over recent decades these events have occurred more and more rarely, and since 1990 there have only been four of them.

WWF [45] based on European Space Agency data estimates that 100,000 tonnes of crude oil are spilled each year in the Mediterranean Sea as a result of illegal washing operations from the 250 to 300 oil tankers crossing the Mediterranean Sea daily.

As noted in Sect. 3, an Oceana Report from the early 2000s estimated that the total amount of crude oil passing through EU waters could be over one billion tons and that the Mediterranean Sea was most affected by dumping of hydrocarbons in the sea from ships, with nearly 490,000–650,000 tonnes being released annually. It is believed that in the Mediterranean, 75% of hydrocarbons discharged every year is a result of tanker operations [17].

UNESCO GOOS Report states that oil pollution in the Mediterranean Sea is estimated at 400,000–1,000,000 tonnes a year. Of this about 50% comes from routine ship operations, and the remaining 50% comes from land-based sources via surface runoff [18].

Ferraro et al. [46] and Kostianoy [9] reported that studies of operational pollution carried out by the European Commission – Joint Research Centre (Ispra, Italy) in the Mediterranean Sea for the years 1999–2004 with the help of satellites in the framework of the OCEANIDES Project give in average 1,700 oil spills yearly. The concentration of oil spills clearly shows the main shipping routes in the Mediterranean Sea, which can be considered as proof that shipping activities are a major cause of oil pollution (Fig. 9). This number of oil spills, which should be regarded as a lower limit because of irregularity in time and space coverage of the Mediterranean by satellite data, may be equal to 1,700–10,000 tonnes of oil yearly.

The Barcelona Convention – Mediterranean 2017 Quality Status Report, Results and Status, including trends (CI19), 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 [10, 11]. This value seems to contradict to the previous report stating that between 2000 and 2009, it was estimated that 4,200 tonnes of oil was spilled in Western Mediterranean waters, 100 tonnes in the Adriatic Sea, 5,500 tonnes in the Central Mediterranean and 19,200 tonnes in the Eastern Mediterranean [14, 47]. Thus 29,000 tonnes in total during 10 years (2000–2009) in comparison with 32,000 tonnes during 20 years (1994–2013) which comprise the 2000–2009 period. These values give us 1,600–2,900 tonnes per year.

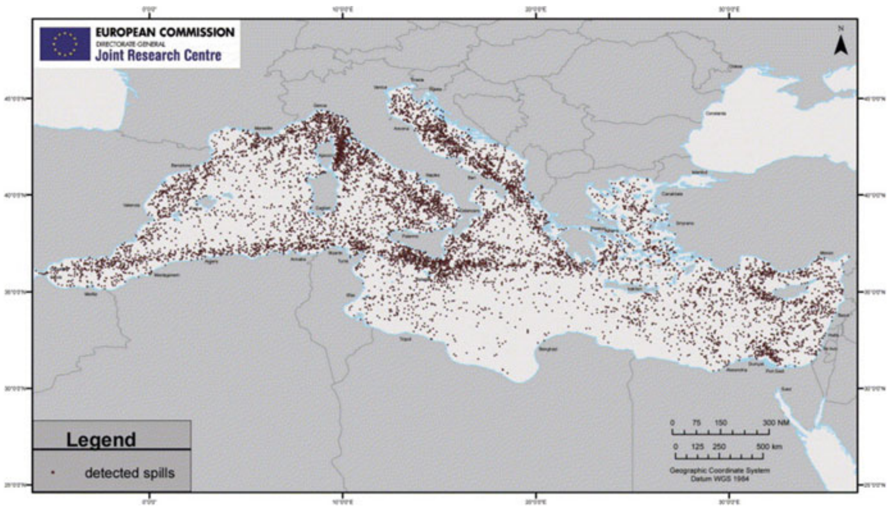

Fig. 9 Potential oil spills detected by satellite monitoring in 1999–2004 by the European Commission – Joint Research Centre (Ispra, Italy) (https://www.sciencedirect.com/science/article/pii/S0025326X06005005?via%3Dihub)

To marine sources we can add land-based sources. For example, we know that between 1988 and 1997, some 22,563 tonnes of oil entered the Mediterranean Sea each year from coastal refinery effluent sources [21].

Cucco and Daniel [15] showed that in the Western Mediterranean, the Central Mediterranean (the Sicily Channel) and the Eastern Mediterranean roughly the same quantities (between 4,000 and 6,000 tonnes) of oil are spilled every year. Thus, it gives us about 15,000 tonnes yearly in total for the whole Mediterranean Sea.

Girin and Daniel [8], based on air surveillance of oil pollution in French waters, made an estimate of 10,560 oil spills or 63,360 tonnes of oil for the whole Mediterranean Sea every year.

Hildebrand et al. [20] states that the United Nations Environment Programme/Mediterranean Action Plan (UNEP/MAP) has estimated that the Mediterranean Sea receives about 129,000 tonnes of mineral oil per year, and due to its geographical position and warm waters, it takes more than 80–90 years to clean up.

In the end, if we exclude major oil spill accidents from ships, which are very rare events in the Mediterranean now, we get total volumes of oil pollution ranging from 1,600 to 1,000,000 tonnes per year. The 625 times difference in values means that we still do not know the real volume of oil pollution entering the Mediterranean Sea and the share from different sources, and this is a big problem. We think that 1,600 tonnes is far too small an amount, while 1,000,000 tonnes is far too large an amount for yearly oil pollution inputs to the Mediterranean Sea, and the truth is as usually somewhere in the middle – of the order of 50,000–100,000 tonnes, as mentioned by ESA, UNEP and other reports. If we divide 1 mln tonnes by 365 days, we will get 2,740 tonnes per day, and bearing in mind 2,000 ships sailing the Mediterranean Sea daily, we have 1.4 tonnes of oil or oil products released by every ship daily. This value seems to be unrealistic, but we pay attention to the fact that this amount (1 mln tons) in the above-mentioned calculation does not include land sources, oil platforms, natural seepages and the atmosphere, amounts of which are unknown.

The uncertainty in oil pollution volume estimates is a typical problem for other seas also. For example, for the Baltic Sea which is also one of the world's busiest waterways (about 40 ports and oil terminals, 9% of the world's trade and 11% of the world's oil transportation, compared to 15% and 18%, respectively, for the Mediterranean Sea), the estimates range from 20 to 60,000 tonnes yearly [48].

Despite this, the good news is that experts in the Mediterranean countries and international organizations are not raising the alarm about increasing levels and trends in oil pollution and degradation of marine environment, which means that the Mediterranean Sea waters appear to have the ability to self-purify which allows, in general, for Mediterranean waters to be quite clean and attractive for tourism and generally safe for the marine environment and ecosystems.

5 Conclusions

Fortunately, since accident with the *MV Haven* in 1991, the Mediterranean Sea is rarely mentioned in the chronicles of major oil spills. This was not the case in the 1970s when large accidents occurred almost yearly. We can speculate that in the pre-industrial times, we could expect oil pollution only from natural oil seepages from the bottom which is related with geological processes. It seems that serious anthropogenic pollution of the Mediterranean Sea started with WWI and continued during WWII when several thousands of ships, submarines and aircrafts were sunk. It is evident that there are no records on the amount of oil pollution during wartime.

Today, oil pollution of the Mediterranean Sea may result from releases of crude oil and oil products from tankers, offshore platforms, drilling rigs, wells and pipelines as well as from releases of bunker fuel, waste oil and bilge water from cargo, ferry, tourist, military, fishery, leisure and other ships. Oil pollution may occur as a result of accidents or during routine operations in the sea or in the ports and oil terminals. Releases of oil products into the sea may be legal, illegal or accidental. Oil enters the Mediterranean Sea also from the land-based sources, via river runoffs, from the atmosphere and from the ocean bottom due to natural seepages. Oil pollution is often divided into the chronic (permanent pollution by small volumes of oil due to anthropogenic or natural causes) or accidental (rare, but high levels of pollution due to a catastrophe involving a ship, offshore platform or pipeline).

In this chapter we have discussed the following sources of oil pollution: shipping activities, oil and gas platforms, ports and oil terminals, land-based sources, military conflicts, natural oil seeps and even atmosphere. Unfortunately we could not identify real amounts of oil pollution from individual sources; as in the above-mentioned reports, they are sparse, diverse and sometimes contradictory. Accordingly, we could not estimate correctly the shares of these sources as a proportion of the total amount of oil pollution in the Mediterranean Sea which ranges from 1,600 to 1,000,000 tonnes a year.

We also have to note that the share in percentages of sources/reasons of oil pollution varies significantly (10–100 times) between scientific publications, regions of the world ocean and different time periods, but one of the largest belongs to different kinds of shipping activities, 20–50%, while, for example, natural oil seepages give from 0.45 up to 46% [48].

Almost 1,000 times difference in the estimates of total oil pollution of the Mediterranean Sea is not something striking because similar range of values was found for the Baltic Sea also [48]. This means that that we still do not know the real values of oil pollution in both seas, and this is a big problem that should be addressed.

Fortunately, the Mediterranean Sea has its own reserves to fight against oil pollution. Microbes play a significant role in the degradation of crude oil, often being the dominant factor controlling the fate of toxic hydrocarbons in aquatic environments. All together they can degrade as much as 40–80% of a crude oil spill in addition to evaporation and other factors. Several factors influence biodegradation rates: oil composition, water temperature, nutrient availability, oxygen levels and salinity. Kostianoy and Lavrova [49] suggested that the total amount of hydrocarbons, which the bacterioneuston can oxidize during the vegetation period in the Baltic Sea, is estimated as of 1,200–5,000 tonnes. This estimate shows a capability of the Baltic Sea to a complete self-cleaning from anthropogenic oil pollution by natural processes. This fact may also explain, at least partially, why we do not observe, in general, accumulation of oil pollution in the Mediterranean Sea, which is almost seven times larger than the Baltic Sea, but it will be interesting to know how much biodegradation can help really.

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Shipping and Oil Transportation in the Mediterranean Sea

Michel Girin and Angela Carpenter

Abstract This chapter starts by putting oil shipping in a Mediterranean context, with a review of the different ways to transport crude and refined oils in large quantities and over long distances. It then considers the hazards presented by pipelines and tankers, both in terms of the oil market today and how it will probably be in a decade. The chapter then presents the current state of knowledge concerning (1) the ship accidents in the Mediterranean, and (2) operational spills in the region and more broadly. The discussion on operational spills is complemented by an analysis of the possible contribution of satellite imagery to the establishment of both proof of pollution and identification of the polluter. Finally, it appears that the necessary tools to combat operational spills and to deal with large accidental spills exceed the individual capacities of the different countries in the region, rendering international cooperation essential.

Keywords Accidental oil spill, Mediterranean Sea, Oil pollution, Operational spill, Polluter identification, Prosecution of offenders

Contents

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1 Introduction: A fast Changing Activity

When examining the overall circulation of oil in a region of our globe, one must be conscious that things change quickly in the world of the black gold. There is no long term market guaranteed (see Box 1): oil is an international commodity, the instant price of which is fixed by supply and demand. Furthermore, a major producer may be suddenly forced out of the business by a foreign army (see Kuwait or Iraq), by social unrest (see Yemen [1]) or by a revolution (see Iran or Libya). An importer country may become exporter by tapping unexploited, conflicting resources (see Canada or the USA). When an important exporter is impeached, the big ones increase slightly their exports to compensate the loss. When the impeached country returns to the exports table, the same big ones make room for its products if it is a political friend, or embark it in a volumes and price war, if it is an old competitor. Disputes are moderated by a worldwide professional association, OPEC (Organization of the Petroleum Exporting Countries).

When an exporter country is impeached, new routes are opened in a matter of weeks by tankers sailing to where oil can be loaded and distributing their cargo where there are buyers. Inasmuch as a pipeline cannot change route along its operational life, tankers can change route any time, on a phone call of the owner of their cargo. There are no borders in high seas, and international agreements under the International Maritime Organization grant them a right of "innocent passage" of capes and international straits. From an exporter coastal country to another coastal country, there is a route with only two custom offices: the "out" one at departure, and the "in" one, on arrival.

That situation makes it so that any map of the main routes of oil is already in part obsolete when published, unless it is very general. This is the case for Fig. 1.

Box 1: A Case Study: The Routes of the French Oil Supplies

In the decade of the 1950s, France was buying the oil it needed almost exclusively from the Gulf countries. It was transported in tankers small enough to sail through the Suez Canal, making it of paramount importance for France that the canal would remain operational. During the 1970s, tankers had grown bigger and the main route from the Arabian Gulf to France became via the Cape of Good Hope. At the same time, oil from the Gulf of Guinea started taking a noticeable part in the French imports and a French warship started permanently patrolling in the Gulf of Guinea. In the 1990 decade, the trans-Mediterranean route from the Gulf ceased to be the major oil supply route of France.

Not all routes will remain port to port ones: deep sea wells can be far away at sea and the temptation of loading their production on site from a buoy or a storage vessel is strong. In the 2010 decade, a French oil company, exploiting deep sea resources in the Gulf of Guinea, hundreds of miles from the coast, started operating 100% offshore, i.e. oil is now loaded on site aboard a storage tanker at anchor transferred from there to transport tankers and exported without ever entering into the supplier country.

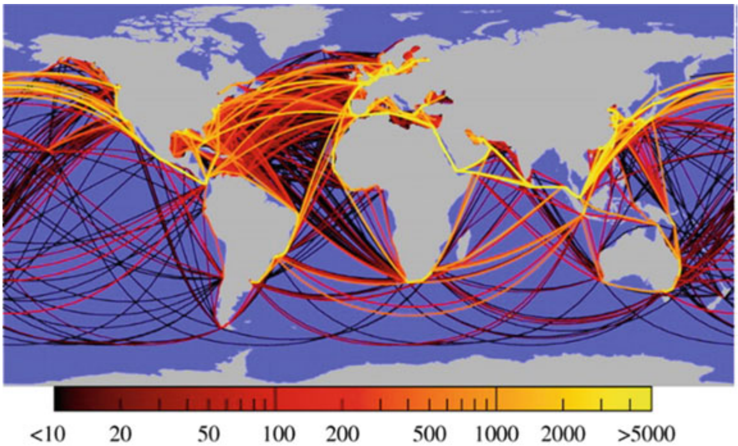

Fig. 1 Global routes and flows of world shipping, estimated by GPS (courtesy: Journal of the Royal Society) [2]

2 Sources of Oil Spills in the Mediterranean

2.1 Marine Sources

The Mediterranean Sea is host to a large diversity of shipping fleets, namely:

- an important fishing fleet, implementing coastal and high seas fishing, the routes of which are seasonal and market dependent;
- a no less important cruise ships fleet, to which only the Caribbean cruise ships fleet can be compared, with set routes within the Mediterranean;
- a modern fleet of ro-ro ferries, wit set routes between islands or between the mainland and an island;
- a fast growing leisure fleet, composed mainly of small craft sailing a few days per year, in majority within view of the coastline;
- as many defence fleets as there are countries bordering the Mediterranean, plus a US Navy Mediterranean fleet presence, with routes governed by political unrest;
- a fleet of passenger, cargo plus passenger and pure cargo ships serving internal Mediterranean routes, both permanent and seasonal;
- a modern fleet of large container carriers and tankers, passing through the Mediterranean as a shortcut between the waters East and West of Africa and calling at terminals in the Black Sea, Europe, Asia and the Americas, as illustrated in Fig. 2;
- and finally, activities based on fixed "vessels", for example, oil exploration and exploitation offshore (for this latter aspect see [3]).

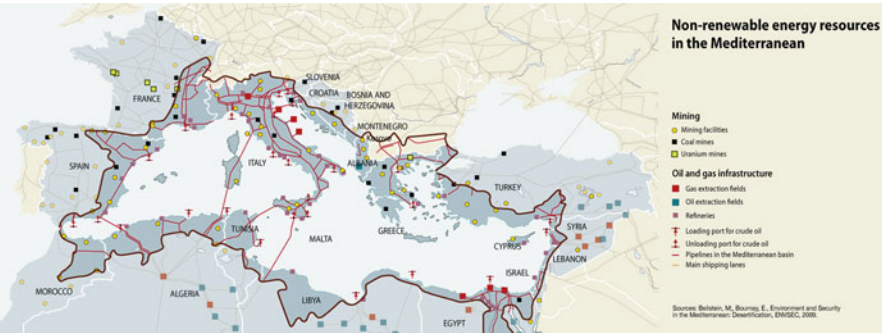

Fig. 2 Mediterranean network of oil/gas pipelines and land based related services. Reproduced from GRID Arendal – http://www.grida.no/graphicslib/detail/non-renewable-energy-resources-in-the-mediterranean_9c34

All these fleets contribute to the presence of oil in the sea: the operation of a motorboat unavoidably generates oily waste in the form of oily bilge waters and used lubrication oil. Those wastes are stored in special tanks, from which they are either pumped to a storage tank in a harbour, or released at sea. The lack of adequate reception facilities in many ports and the price charged by ports offering used oil reception facilities have made it so that many ship-owners expect their captains to release oily wastes in the open sea, at times through the same piping used for water carrying organic waste.

Because the quantity of oil in a particular release is small (from a few litres for a small leisure craft to a few cubic metres for the larger ships), sailors do not see themselves as polluting the oceans through this practice. Such releases are called "operational spills". They can be voluntary or accidental, resulting from a human decision, a human error or a technical failure. They are legal if made in high seas, out of areas recognized as "special zones"[1] by the International Maritime Organization (IMO) and within an accepted limit of 15 parts of oil per million. Operational discharges are illegal anywhere over the 15 ppm limit, and below that limit in the special zones.

In addition to these operational spills, any ship can run aground or suffer from a collision with another ship, as a result of a human error or a technical failure. Additionally, of course, any ship can sink in a storm. When a small leisure or fishing craft is concerned, the quantities of oil involved are small and their impact is too small to be quantified. When a large, long distance, container carrier is involved, the spill can be quantified in thousands of tons; in the case of a super tanker, it can be a matter of several hundred thousand tons. In such situations, shipmasters pray to be close to the shore of a country with high level long distance visibility (use of planes and satellites) and an efficient response organization [4].

There is no information available on the contribution of the fishing, leisure, cruise and defence fleets to the total input of oil in the Mediterranean. The same applies to offshore oil exploration and exploitation activities.

2.2 Inland Sources

Technically, crude and refined oils can be transported on land by truck, train, barges (on rivers) or by pipeline. Transport by truck is the basis of the delivery of heating fuel to individual houses or multi-storey buildings, an immense number of consumers each taking a small quantity per delivery. Transport by train or barge is

[1] http://www.imo.org/en/OurWork/Environment/SpecialAreasUnderMARPOL/Pages/Default.aspx.

particularly relevant to industrial facilities, power plants and sets of storage tanks, when connected to the national railway network. All of these can be sources of oil spills with the potential to be carried by rivers to the sea.

River barges and pipelines are two complementary options, capable of transporting considerable quantities of oil, in a continuous flow for pipelines and in batches for barges. Pipelines are fixed installations, crossing borders on the basis of bilateral agreements and staying where they are whatever happens. Pipelines offer a service with a very low risk of accidental spill, but without flexibility in a situation of socio-political unrest. Should socio-political conditions change, should a border be moved, they have to make with such change. Their fate is governed more by political decisions than by costs versus benefits considerations. River barges are generally the property of private companies, often multi-nationals, that continuously compete between themselves to offer the best price with sufficient guarantees on their capacity to deliver.

There exist extensive networks of oil and gas pipelines in the USA and across Europe. However, the very few maps regarding that matter are essentially qualitative, giving no assessment of the quantities transported and it was not possible to find a map of a network around the Mediterranean Sea. A glance at Fig. 2 shows that the Black and Caspian seas are better served in pipelines than the Mediterranean (and see also [5]).

Oil spills from pipelines around in the Mediterranean did definitely occur, but the number, volume and location of those soils cannot be assessed by lack of accessible documentation. As a consequence, while they will not be further considered in this document, they will be the sum of:

1. Accidental spills over 20 tons of oil (smaller ones are rarely if ever documented in national statistics) resulting from shipping and coastal storage accidents or acts of war. They release, without warning, a large quantity of oil in a particular place. They are quite rare (less than one per decade on average), but they make the headlines of the media, with the same question being asked each time: “will the Mediterranean survive to this new crisis?”
2. Operational spills visible from a low flying aircraft [6], each releasing a small amount of oil, weekly or more frequently on some heavy traffic routes, where they are concentrated. Most of these spills contain much less than 20 tons of oil, but their frequency in some areas makes them a concern for the Authorities.

Accidental spills are considered to be acts of God, but analysis of their causes shows that many could have been avoided by improved management. The main oil consumption areas (i.e. North America, Europe, Asia) are far on the globe from the main production areas (i.e. Arabian Gulf, Latin America, Western Africa, the Caspian Sea, Western Siberia, etc.). Oil must therefore be transported from the latter to the former, at times over considerable distances.

There is a general belief in the public, that the risks of pollution would be lower, should crude oil be cracked in the production areas and transported in refined form. In fact, such a move would neither reduce the overall quantities to be transported nor the transport distances to be covered. The only efficient way to reduce the quantity versus distance transported would be for the large buyers to purchase "local", i.e. to prefer oil from their nearest suppliers. However, one should not expect a buyer initiative in that direction. The transport costs are much too low and the competition between suppliers much too fierce for the buyers to find an economic advantage in buying local. The only possible approach would be to impose a worldwide ecological tax on oil transport distances, on the ground that the longer the voyage, the more operational pollution there is and the higher the risk of accidental pollution there is as a result.

It has also been suggested that there could be natural spills in some places within the Mediterranean, indicative of the presence of fossilized oil and gas reserves. Oil companies drilling for new offshore wells in the waters under jurisdiction of Cyprus, Greece and Tunisia have been suspected to know about these natural spills and to use them as indicators.

2.3 Shipping Routes

Where all other parameters be equal, the risk of a spill would be a direct proportion of the density of traffic along a pipeline or a ship route. But those parameters are most generally far from equal. As an example, there are more risks of a collision when a tanker has to make its way among a number of ships at anchor by a foggy night, out of a port, waiting for their turn to unload, than on a bright, sunny day, with nearly no ship waiting. There are also more risks of damage to a pipeline passing through a hostile, very poor population, than for a pipeline in a quiet, classy borough of a modern city. The response plans must take those factors into account.

But there is an essential difference between accidental and operational spills: Accident statistics fall prey to the erratic law of small numbers whereas operational spills are frequent enough to be statistically exploitable.

Vessels other than oil tankers, i.e. fishing, leisure, military ships, chemical tankers, general cargo, roll-on-roll-off (Ro-Ro) ships and container ships, were relatively small half a century ago. The release of bunkers in an accident or bilge water in operation caused no major problems. Since China became the "factory of the world", however, in competition with Thailand and Vietnam for cheap human labour, the situation has dramatically changed with growing numbers of extra-large container carriers, the bunkers of which, if spilled at sea, could cause significant damage to local tourism, fisheries and aquaculture activities.

The map in Fig. 3 shows places of incidents involving spills of oil or chemicals, major and minor containers routes and traffics, expressed in containers voyages per year. But no information is provided on the relative importance of regional routes (starting and ending in the Mediterranean) and worldwide ones (starting or/and ending out of the Mediterranean).

Large container ships are now assigned to set routes, making it possible to know in advance the passage of a mega ship in a dangerous area or its calling at a port. Container ships companies call it "liner shipping". In that frame, the ten larger

Fig. 3 Container transport routes in the Mediterranean Sea with main ports of call. Reproduced from UNEP GRID Arendal – http://www.grida.no/graphicslib/detail/maritime-transportation-routes-in-the-mediterranean_e5bd

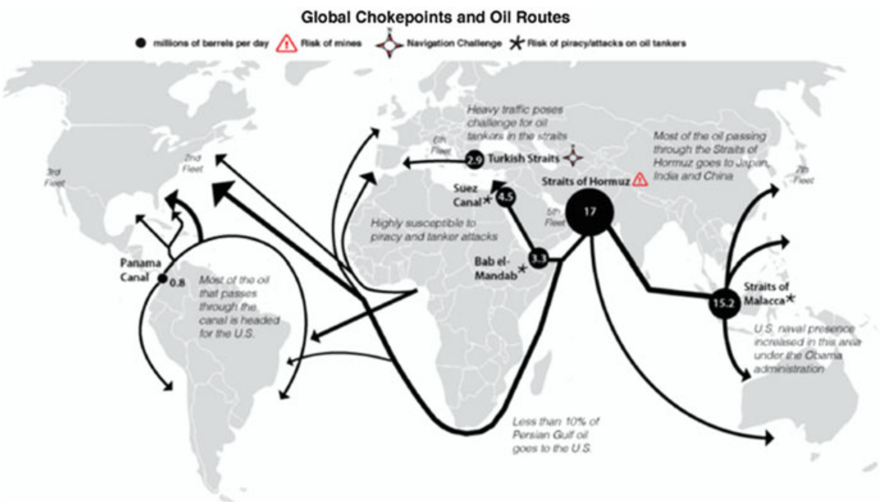

Fig. 4 Main routes of the intercontinental maritime transport of oil. Reproduced from U.S. Energy Information Administration – http://www.eia.gov/todayinenergy/detail.php?id=330#

container ships companies in the world have built between themselves a "world shipping council" overlooking at the interest and advantages of liner shipping, i.e. assigning vessels to set routes, calling on fixed dates at ports on the way.

As regards oil, there exists a main feeder route, gathering ships loaded with oil from Saudi Arabia, the United Emirates, Kuwait and Iran, sailing out of the Arabian Gulf through the Straits of Hormuz, illustrated in Fig. 4 [7].

Out of the Hormuz Strait, the feeder divides in two routes:

- the Eastern route, serving Asia through the Indian Ocean, with a Southern branch to South East Asia and a Northern branch to China, Japan and Korea; and

- the Western route, with a Southern branch to Europe and the Americas, through the Cape of Good Hope, and a Northern branch, through the Red Sea and the Suez Canal, to the Mediterranean countries and Western Europe.

Figure 4 shows those branches as they were about a decade ago, with the trans-Mediterranean route already overtaken by the Cape of Good Hope branch and the Asian route.

The Northern branch of the Western route enters the Mediterranean through the Suez Canal, extending all along its main axis and leaving it by the Gibraltar Strait, to supply Western Europe. A minor part of the oil transported along that trans-Mediterranean route is diverted to Mediterranean ports, mainly Greek, Italian and French. Those losses are compensated for by an accessory feeder, coming from the Black Sea through the Turkish straits.

2.4 The Mediterranean Perspective

There exist today uses of crude oil that are much more valuable than simply burning it for energy and many, from the political ruler to the modern farmer, accept now that we should all reduce our consumption of that unique gift from ancient times. Furthermore, the first importer in the world, the USA, has embarked on a vast programme of exploitation of its resources of natural gas extracted from shale formations. Although highly controversial from the environmental point of view, this programme (known as "fracking") has turned the country into a net exporter of hydrocarbons. As a consequence, the Suez–Gibraltar trans-Mediterranean oil route will most probably see no change or only very little change in the amount of oil transported, over the next 10 years.

Manufactured goods present a highly different pattern: their transport needs are entirely linked to the capacity of the Chinese plants to deliver what the rest of the world uses. Although the dynamics of the Chinese new deal have lost considerable strength over the last 2 years, faced with dramatic air and water pollution, there is a consensus among observers that Chinese manufacturing capacity will continue to grow, albeit at a slower pace.

In this context the doubling of the capacity of the Suez Canal (from 50 to 100 ships per day), operational since August 2015, will most presumably generate close to a doubling of the shipping of containers through the Mediterranean. A clear sign of that evolution is shown by the dimensions of the latest mega container carriers (see Box 2) and the development of Suez Max container ships. The essence of containerized cargo shipping is the capacity of the vessels to call at their port of destination on the day and hour indicated in their schedule, fully available to customers on the Internet.

Box 2: On the Way to a Suez Max Container Ship

Since August 2015, the Suez Canal has been able to accept vessels with a width of 50 m and a draught of 20 m. The *CMA/CGM Benjamin Franklin* has a draught of 16 m. It burns 330 tons of fuel per day and it has an autonomy of 30 days, i.e. a bunkers capacity of 9,900 tons. The *MSC Oscar* and its four sister ships under construction, *Zoe*, *Oliver*, *Maya* and *Sveva* all have a draught of 16 m.

Source: www.cma-cgm.fr/detail-news/1069/le-cma-cgm-benjamin-franklin/.

3 Inventory of Past Oil Spills in the Mediterranean

Each accidental spill is unique and a shock for the local population. When it exceeds about a thousand tons, it becomes a national concern. Operational spills are frequent and most generally remain unnoticed. But one can draw important lessons from a documented inventory of both types of spills.

However, proper comparison requires authors to make clear what oil is considered, in terms of source and period. As an example Fig. 5 attributes to the 2000–2009 decade a total spill of 28,900 tons over the whole Mediterranean. In comparison, our Table 1 below reports 12,030 tons accidentally spilled by ships during the same decade. But if we add to the accidental spills by ships the estimated 15,000 tons released after the bombing of the Jiyeh Lebanese power station (12,030 + 15,000 = 27,030), we end up with two very close estimates (27,030 against 28,900). Could the difference (1,890 tons) represent the operational spills? Figure 5 may give an answer.

3.1 Accidental Spills

Table 1 shows that, from 1970 to early 2016, the 14 accidental oil spills over 10 tons we could identify in the databases and one act of war occurred across the whole Mediterranean, totalling close to 180,000 tons of oil released.

Within the total from Table 1 are included:

- a single incident, that of the *Haven*, which accounted for 80% of the total spilled;
- the waters under the jurisdiction of Italy were affected by 50% of the accidental spills in number, representing 82% of the total quantity spilled and
- the waters under the jurisdiction of Greece came second, far behind Italy, with three spills representing less than 13% of the total spilled.

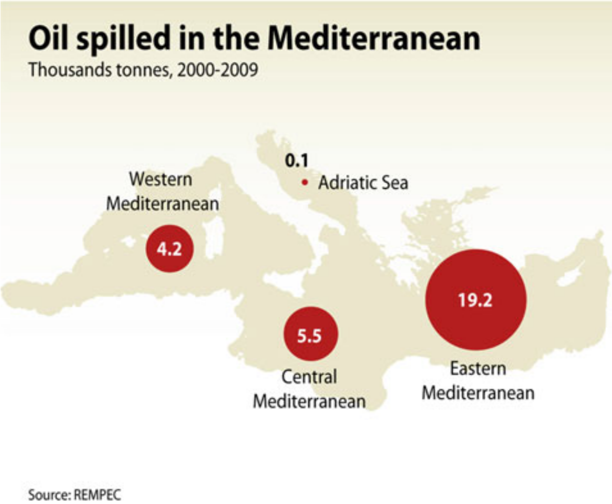

Fig. 5 Possible amounts of oil spilled in the Mediterranean Sea from 2000 to 2009. Source: Originally from UNEP GRID-Arendal – http://www.grida.no/graphicslib/detail/oil-spilled-in-the-mediterranean_9883

An act of war, the bombing of the Lebanese Jiyeh Power Plant by the Israeli Air Force in 2006 added a further 15,000 tons of intermediate fuel oil in the Eastern Mediterranean, in conditions comparable to a shipping spill (unpredictable and massive).

3.2 Operational Spills

The only way to monitor operational spills and to gather sufficient evidence to prosecute offenders was, until quite recently, to fly light fixed wings aircraft equipped with infra-red, ultra-violet and possibly micro-wave sensors, with a sworn officer on board, to record facts. Until the *Prestige* incident in Galician waters, two countries only flew such aircraft: France, operating two specialized marine pollution surveillance planes; and Italy, implementing joint customs and pollution surveillance flights.

Shipmasters knew that they had very little risk of being spotted polluting waters under the jurisdiction of any area of the Mediterranean Sea, except the waters in front of the French coastline. They also knew that, if spotted, they had practically no risk of being prosecuted. After the *Erika* and *Prestige* incidents in Galician waters.

The French authorities designated two courts at national level, with competence in oil and chemicals spills at sea and started processing spills in the water under their jurisdiction, sentencing jointly the master and owner to penalties from €50,000 to €500,000, i.e. not yet the levels of the US sentences, but levels sufficient for the owners to warn their captains not to release oily waters in marine areas under French jurisdiction. In the same time:

Table 1 Oil spills over 10 tons by ship accidents in the Mediterranean Sea, 1970–2015 (author's elaboration from Cedre data)

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
1980	*Irenes Serenade*	Navarin Bay, Greece	Tanker. Explosion at anchor, sinking	Heavy fuel + crude oil	20,000
1985	*Patmos*	Messina Strait, Italy	Tanker. Collision with other ship	Crude oil	700
1991	*Agip Abruzzo*	Off Livorno port, Italy	Tanker. Collision with ferry boat	Crude oil	2,000
1991	*Haven*	Off Port of Genoa, Italy	Tanker. Fire at anchor, explosion, sank in three parts	Crude oil	144,000
1991	*Svangen*	En route by Almeria, Spain	Tanker. Sinks in a storm	Fuel	180
1993	*Iliad*	Port of Pylos, Greece	Tanker. Stranded on rocky shore by storm	Crude oil	200
1996	*Kriti Sea*	Port of Agioi 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
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
Total					181,876

- the Spanish authorities purchased three oil spill surveillance planes; and
- the EU commissioned through the European Maritime Safety Agency (EMSA), a study on the proofs of pollution and prosecution of offenders [8].

As a result, research on improved surveillance has been very active since the wreckage of the Erika, in 1999, particularly on matters such as oil volume in a slick, unmanned aircraft for extensive surveillance and surveillance planes, and research on oil weathering at sea and slicks drift prediction (see, for example, [9–12]).

However, prosecution of Mediterranean offences is still in infancy out of France. There is a long way to go for the bordering countries to match the US heavy hand in that field (see Box 3).

Box 3: Prosecution of Offenders, US and Mediterranean Style

Two examples, among many others, of the differential treatment of a spill in different countries. Source: World Maritime News magazine.

In March 2016, the Norwegian Shipping Company DSD Shipping was sentenced to pay a corporate penalty of USD 2.5 million for "discharge of oil-contaminated waste water into the Ocean". The Company was also convicted for obstructing justice, tampering with witnesses and conspiring to commit these offenses. USD 500,000 of the penalty was to be paid to the Dolphin Island Sea Lab Foundation to fund marine research and enhance coastal habitats in the Gulf of Mexico and Mobile Bay.

The *Billesborg*, a 2011-built Panamanian-flagged general ship anchored at the Israeli Port of Haifa, was fined NIS 6,000 (approximately USD 1,580) after its wastewater sanitation system discharged effluents into the sea. The inspectors of the Israeli Marine Environment Protection Division questioned the ship's captain and inspected the vessel. They discovered that the sanitation system, which includes measures for biological treatment had no storage tank. Thus, the system automatically pumped sewage into the sea as soon as the small tank, which held less than a cubic meter of wastewater, filled up.

Source: World Maritime news.

3.3 The Possible Contribution of Satellite Imagery

There is at the current time no evident will of the countries not flying oil spill monitoring aircraft to embark in the purchase of such equipment and to finance their operation. On the contrary, there has been keen interest from the southern countries to develop techniques of exploitation of satellite imagery to monitor operational oil spills in the waters under their jurisdiction and to use that information to prosecute offenders. Great progress has been made over the last decade on close to real time acquisition and exploitation of radar satellite imagery, the close to real time condition being a must if the information is to be used for prosecuting offenders. The delay between the pass of a satellite and the exploitation of its images has gone down in the last decade from a full week to a few hours. Satellite imagery has been accepted in courts as additional proof, but a court decision stating that satellite imagery was determinant proof to a judge, is still to be obtained.

There has been along the past decade considerable development of techniques to estimate the thickness of a spill recorded on satellite imagery, in order to monitor oil spills for statistical purposes. Those techniques are now close to being fully effective. The only remaining weaknesses are the calibration of a spill image, in terms of quantity of oil present in an oily sheen of bilge water, and the proper representation of the results so that figures would not be misleading.

Figure 6 is a good illustration of the problem. Ferraro et al. [13] produced in 2009 a map titled “Mediterranean oil spills”, made up of black dots with a legend explaining that each dot represented a possible spill detected and a caption confirming to the reader that the black dots are not actual spills but artefacts that could be caused by spills. Furthermore, it was stated that the map is the super-imposition of 6 years of satellite imagery exploitation represented as though a slick of oily bilge water would remain drifting unaltered at the sea surface for 5 years, when in reality it will normally be dispersed by waves and wind within 2–3 days [13]. The figure was reproduced by the EU DG Environment news alert service in a brief dated April 2012 with the original legend and caption “Possible oil spills detected in the Mediterranean environment by satellite imaging…” but without reproduction of the warning text, leaving it open for the reader to interpret the black dots as they wished.

Each black dot signals a place where a possible oil spill was once detected on a satellite image once in the overall period and remained unaltered all along. Furthermore, the surfaces of the dots (around 600 km^2 each) are unrelated to the sizes of the slicks.

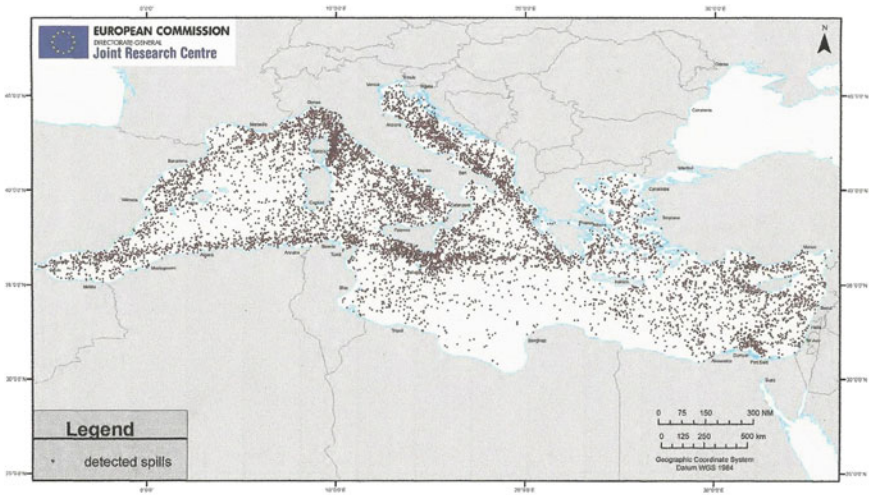

Fig. 6 Possible oil spills in the Mediterranean Sea, as shown by the exploitation of satellite imagery from 1999 to 2004 [13]

4 Regional Cooperation

The past accidental oil pollutions in the Mediterranean, particularly those of the *Haven* tanker and Jiyeh Power Plant, clearly demonstrate that none of the countries bordering the Mediterranean has the capacity to respond efficiently alone to a large oil spill (say beyond 10,000 tons). The aerial surveillance implemented by the three countries on the northern bank of the western Mediterranean shows that an extended technical and legal cooperation is essential to fight the plague of the operational spills. Mediterranean countries are conscious of that and they have already implemented a series of cooperative actions in that direction.

4.1 The Mediterranean Blue Plan

This plan has been implemented since the late 1970s, within the frame of the Mediterranean Action Plan[2] of the United Nations Programme for the Environment and the Convention for the protection of the Marine Environment and Coastal Region of the Mediterranean (Barcelona Convention). Its purpose is to enlighten the environment and development issues in the Mediterranean, studying the solutions allowing for more sustainable development.[3] Activities of the Blue Plan, as expressed on its website, include:

- development of database and meta-database on environment, economy and society;
- analysis and prospective regarding sustainable development's major issues through the Mediterranean Basin and its ecologic and geographic components by using systemic methods;
- publication and dissemination of its studies and synthesis results;
- development and facilitation of experts networks in the Mediterranean countries and capacity-building support and
- support to the Review of the Mediterranean Strategy for Sustainable Development.

Among other activities, the Blue Plan operates the "Mediterranean Information System on Environment and Development" (SIMEDD),[4] which aims to:

- Gather the data used in the Blue Plan studies and reports;
- Give access to the data and their sources to the Blue Plan experts and to the general public.

[2]See: http://web.unep.org/unepmap/index.php?action=&catid=&module=&mode=&s_keywords=&s_title=&s_year=&s_category=&id=&page=&s_descriptors=&s_type=&s_author=&s_final=&s_mnumber=&s_sort=&lang=en.

[3]Contact: http://planbleu.org/sites/default/files/publications/red_resume_uk.pdf.

[4]Contact: http://planbleu.org.fr/ressources-donnnees/simedd.

As a whole, the Mediterranean Blue Plan is not directly involved in activities on marine pollution prevention and response implemented in the region, but it provides them a United Nation umbrella.

4.2 The Regional Marine Pollution Emergency Response Centre

The Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea (REMPEC) was established in 1989, as a continuation of the "Regional Oil Combating Centre" (ROCC) originally established in 1976 by decision of the Contracting Parties (24 countries) with the mandate, as stated on its website, to "strengthen the capacities of coastal States in the Mediterranean region and to facilitate cooperation among them in order to combat massive marine pollution by oil, particularly by developing national capacities to combat oil pollution and by establishing a regional information system with a view to dealing with marine pollution emergencies". The Centre's mandate was subsequently extended over the years in conformity with the decisions of the Contracting Parties with a view to addressing relevant emerging issues and the respective global developments and with a particular focus on preventive measures against pollution from ships for the Mediterranean Sea. REMPEC is administered by the International Maritime Organization (IMO) in cooperation with the Mediterranean Action plan under the UNEP Mediterranean Action Plan (MAP).

In 2001, with a view to the adoption of a new Protocol concerning Cooperation in Preventing Pollution from Ships and, in Cases of Emergency, combating Pollution of the Mediterranean Sea [14], the Contracting Parties reaffirmed the involvement of the Centre in activities related to prevention of, preparedness for and response to marine pollution.

The objective of REMPEC[5] is "to contribute to preventing and reducing pollution from ships and combating pollution in case of emergency". In this respect, the mission of REMPEC is to assist the Contracting Parties in meeting their obligations under Articles the Barcelona Convention and related protocols and implementing the Regional Strategy for Prevention of and Response to Marine Pollution from Ships, adopted by the Contracting Parties in 2005 the key objectives and targets of which are reflected in the Mediterranean Strategy for Sustainable Development (MSSD). The Centre assists the Contracting Parties when requested in mobilizing regional and international assistance in case of an emergency under the "Offshore Protocol". Whether accidental or operational, oil spills from shipping are an indisputable element in REMPEC's mandate. For further information on REMPEC, see also [15].

[5]Contact: http://www.rempec.org/.

4.3 The EuroMed Partnership[6]

EuroMed, the Union for the Mediterranean, is an initiative of the member countries (the 28 EU Member States together with 15 non-European countries that have a Mediterranean coastline), aims to promote the economic integration of all its participants and democratic reforms in the southern countries. It was developed by merging an existing cooperation programme, called the “Barcelona agreements” with new regional and sub-regional agreements, and has a true interest for the populations around the Mediterranean in the fields of economy, environment, energy, health, migration and culture. The secretariat of EuroMed is based on Barcelona. Its priorities are:

- the depollution of the Mediterranean Sea;
- the creation of maritime and coastal fast tracks;
- a common civil protection programme for prevention, preparedness and response to catastrophes;
- a solar plan, exploring the possibilities to develop alternative sources of energy alternatives in the region;
- a Euro-Mediterranean university, inaugurated in Slovenia in 2008 and
- a support programme, the Mediterranean initiative for enterprise development, sustaining small enterprises intending to deploy their activities in the region.

5 Conclusions

Like many other countries in the globe, the Mediterranean countries are faced with a common permanent risk (an accidental oil spill) and a common plague (operational spills). A major part of those risks and plague are due to transiting tanker ships *en route* between the Suez Canal and the Gibraltar Strait. However, Mediterranean countries benefit to some extent from that nuisance; as the spillers bring them supplies of oil. One of them, namely Egypt, also makes in addition a direct profit from it, through the Suez Canal passage fees.

Accidental spills are rare, but they can be extremely massive (see the 144,000 tons from the *Haven* in Table 1, for example), and can have severe economic and environmental impacts. Operational spills are more frequent, and the scientific community has not succeeded up to now in producing proper evaluations of their impacts whether individually (the actual impact of an operational spill may be too small to be quantified) or globally. Without a good knowledge of the baseline level of oil in water caused by natural seeps, no proper quantification of the global impact of the man-related yearly spills can be made.

[6]See http://euromedp.eupa.org.mt/the-euro-mediterranean-partnership/.

In the northern part of the western basin the three richer countries of the region, members of the European Union, namely France, Spain and Italy, have invested in aerial surveillance. That surveillance is still far from being 24 h a day, 7 days a week. But shipmasters and ship-owners know that they can be seen polluting and that it may cost them dearly in the areas under French jurisdiction. They also know that, although satellites or drones can spot them in action, they still cannot deliver proofs of offences that can be used in court against them, for spills occurring in the eastern Mediterranean basin.

Finally, recognizing that the levels of pollution preparedness and response are far different between northern and southern countries and that no country can satisfactorily fight alone against such pollution, three complementary regional cooperation programmes are doing their best to transfer experience and training from the more advanced countries to the less advanced.

However, due to issues such as the global economic crisis, money is getting short for everyone and there is a strong risk that the cooperation programmes would not survive necessary public budget cuts. There might be merits, therefore, to look for the possibility of a "green ticket" attached to the existing Egyptian Suez canal fee, for example, to support a pan-Mediterranean anti-pollution force and stockpile of equipment, as Japan already does for ships entering its "interior sea".

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Oil and Gas Exploration and Production in the Mediterranean Sea

Andrey G. Kostianoy and Angela Carpenter

Abstract This chapter presents a review of knowledge on oil and gas exploration and production in the Mediterranean Sea. Oil and gas production and exploration is not so important in the Mediterranean Sea, unlike in the Gulf of Mexico, the North Sea, or the Caspian Sea, but its history goes back to the early twentieth century when hydrocarbon exploration activities started in Greece. In the Aegean Sea, a small number of significant oil discoveries were made in the mid-1970s at Prinos with production continuing to the present day. Today, the Eastern Mediterranean Sea, and the east coast of Italy in the Adriatic Sea, 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) and, in 2005, there were over 350 wells drilled for offshore production in the waters off Italy, Egypt, Greece, Libya, Tunisia, and Spain of which the majority were located along the Northern and Central Adriatic coasts of Italy. In the last decade, there has been serious development of offshore gas fields along the Mediterranean coasts of Israel, Palestine, Cyprus, and Egypt which in the near future will completely change the gas market in this region.

Keywords Mediterranean Sea, Offshore oil and gas platforms, Oil and gas production, Oil pollution

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Contents

1 Introduction

Oil and gas production and exploration is not so important in the Mediterranean Sea, unlike in the Gulf of Mexico, the North Sea, or the Caspian Sea [1, 2], but its history goes back to the early twentieth century when hydrocarbon exploration activities started in Greece. In the Aegean Sea, a small number of significant oil discoveries were made in the mid-1970s at Prinos (with a smaller gas discovery at South Kavala) with production continuing to the present day. Initial estimated reserves for the Prinos fields were 90 million barrels (MMbbl), which have now been increased to 290 MMbbls, with 110 MMbbls already having been produced since 1981 [3].

Today, the Eastern Mediterranean Sea, and the east coast of Italy in the Adriatic Sea, is the location of the majority of oil and gas exploration and exploitation activities (Fig. 1). 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) and, in 2005, there were over 350 wells drilled for offshore production in the waters off Italy, Egypt, Greece, Libya, Tunisia, and Spain 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) [4–6].

In 2011, gas was discovered in the Leviathan Gas Field (Fig. 2), 135 km off the coast of Israel, with an estimated volume of 16 trillion cubic feet (tcf) of gas (approximately 453 million m^3) [7]. In August 2017 a contract was signed to drill two wells and complete four production wells in the Leviathan Gas Field [8].

In the last decade, there have also 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 [9]. 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 [10].

Finally, in the last decade, there is a serious development of offshore gas and oil fields along the Mediterranean coasts of Egypt, where the most active companies are *BP, BG, IEOC, EGAS, Total, RWE Dea*, and *Dana Gas*. *BG* is active in five

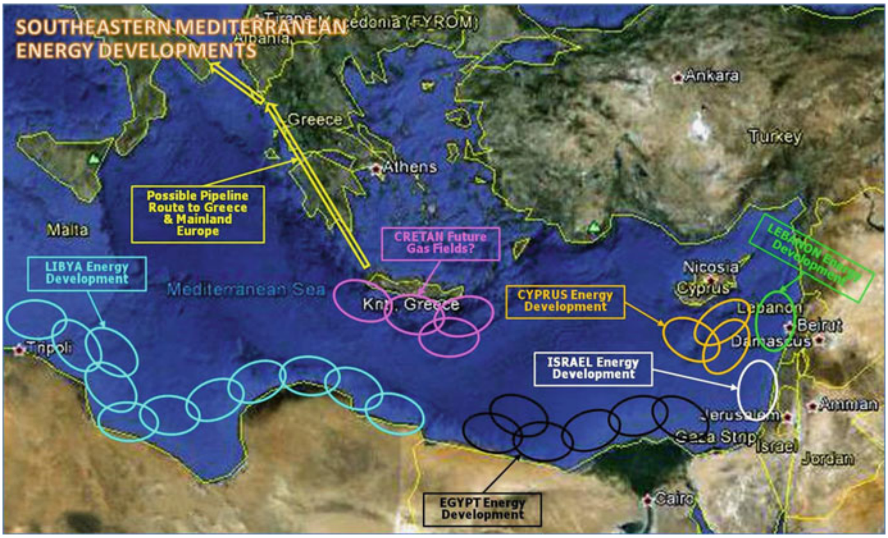

Fig. 1 Oil and gas exploration and exploitation activities in the Eastern Mediterranean (http://www.greekamericannewsagency.com/english-menu/english/politics/30945-egypt-has-joined-greece-and-greek-cyprus-in-calling-for-turkey-to-stop-exploration-work-off-the-cyprus-coast). Copyright © 2012 Pytheas Limited

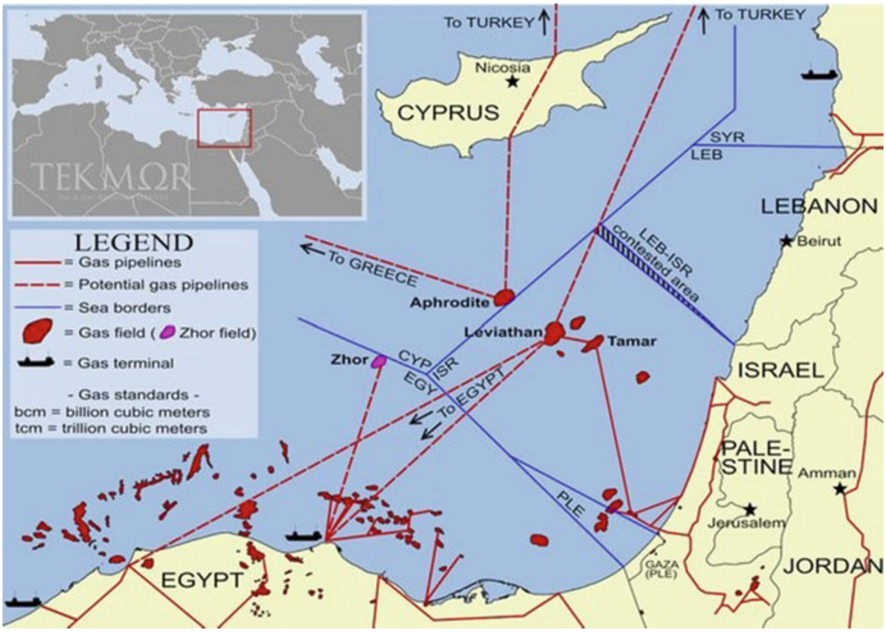

Fig. 2 Gas fields, active and potential gas pipelines, and gas terminals in the Southeastern Mediterranean (https://www.vestifinance.ru/articles/97771)

concessions. *Dana Gas*, a regional company, has about 10 producing fields. In August 2015, *Eni* announced the discovery of the Zohr gas field 150 km from Egypt's north coast. The reserve is estimated as 30 trillion standard cubic feet (trn scf) of natural gas, making it the largest in the Mediterranean. This discovery seems to increase Egypt's total gas reserves by about 40% [11].

Oil and gas exploration or production also takes place off the coasts of Algeria, Spain, Libya, Tunisia, Malta, and Turkey.

Oil and gas exploration and production activities pose a serious threat to the marine and coastal zone environment, the seabed, and sea-bottom habitats and species, since oil contamination can persist in the marine environment for many years, depending on the oil type, the location of a spill, and the area in which the contamination occurs [12–16]. Today, accidental spills from offshore platforms represent only about 1% of petroleum discharged in North American waters, for example, and about 3% worldwide [6, 17]. In the Mediterranean Sea this share should be even less than 1% of total oil pollution as the number of offshore oil and gas platforms is small in comparison with other regions of the World Ocean (Fig. 3).

In the North Sea and the Gulf of Mexico (United States), 184 and 175 offshore rigs are located, respectively, as of January 2018, while in the Mediterranean Sea, there are only 26 rigs. Globally, the number of oil platforms had been expected to rise from 389 units in 2010 to 500 in 2017 [18]. Offshore oil rigs enable producers to extract and process oil and natural gas through drilled wells. Rigs can also store the extracted products before being transported to land for refining and marketing. There are several different types of offshore rigs for use in the oceans and seas such as fixed platforms that are anchored directly onto the seabed by concrete or steel legs and tension leg platforms that float but remain in place by being tethered to the seabed (Fig. 4) [19]. There are some risks involved with the operation of offshore drilling, including explosions and fires, resulting in a serious and large-scale oil pollution of the sea, as it was the case with *Deepwater Horizon* in April 2010 in Gulf of Mexico.

In this chapter we review information on offshore oil and gas exploration and production in different countries of the Mediterranean Sea.

2 Oil and Gas Production in the Mediterranean Sea

2.1 Greece

The history of oil production in Greece goes back to the early twentieth century when hydrocarbon exploration activities started here. In the northern part of the Aegean Sea, a small number of significant oil discoveries were made in the 1970s at Prinos (Fig. 5) with a smaller gas discovery at South Kavala and with production continuing to the present day. Initial estimated reserves for the Prinos oil fields were 90 MMbbl, which has now been increased to 290 MMbbl, with 110 MMbbl already having been produced since 1981 [3].

In 2011 Greece approved the start of oil exploration and drilling in three locations with an estimated output of 250 to 300 million barrels over the next 15 to 20 years. In

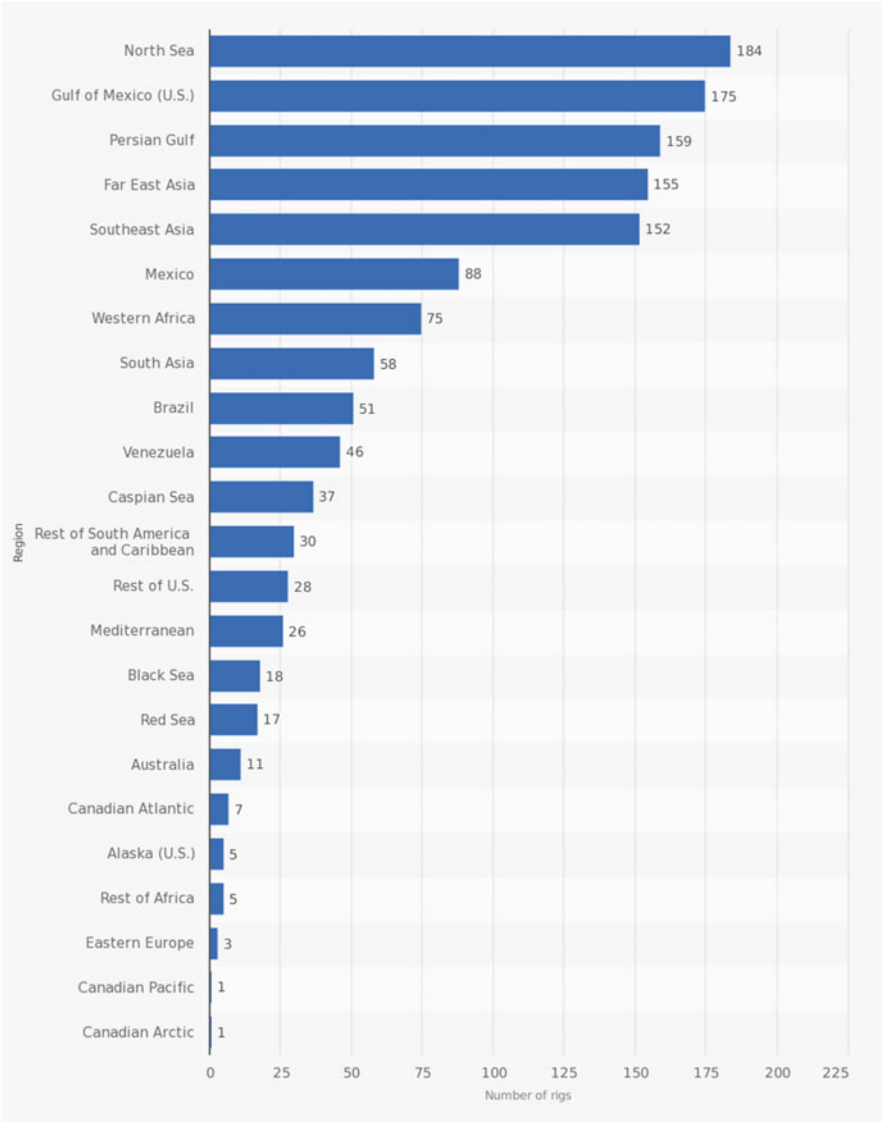

Fig. 3 Number of offshore rigs worldwide by region in January 2018 [18]. Source: Rigzone.com © Statista 2018. Additional Information: Worldwide; As of January 2018

2012 Greece started oil and gas exploration in the Ionian Sea as well as the Libyan Sea, within the Greek Exclusive Economic Zone, south of Crete. The Ministry of the Environment, Energy, and Climate Change announced that there was interest from various countries (including Norway and the United States) in oil and gas

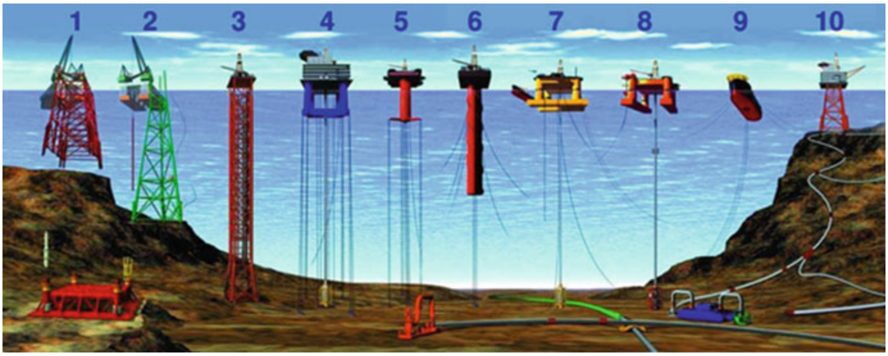

Fig. 4 Different types of offshore oil platforms: (1) and (2) conventional fixed platforms; (3) compliant tower; (4) and (5) vertically moored tension leg and mini tension leg platform; (6) spar; (7) and (8) semi-submersibles; (9) floating production, storage, and offloading facility; (10) subsea completion and tieback to host facility [19]

Fig. 5 The *Prinos D* oil production platform in the northern part of the Aegean Sea (1982) (https://en.wikipedia.org/wiki/Prinos_oil_field)

exploration in these regions. 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 [10].

The Prinos North Oil Field is one of the satellite fields within the Prinos-Kavala Basin. It is located approximately 3 km north of the Prinos Oil Field and about 18 km southwest of the mainland of Eastern Macedonia, Northern Greece, where the depth is 38 m (Fig. 6). Since 2008, *Energean Oil and Gas* Company has invested more

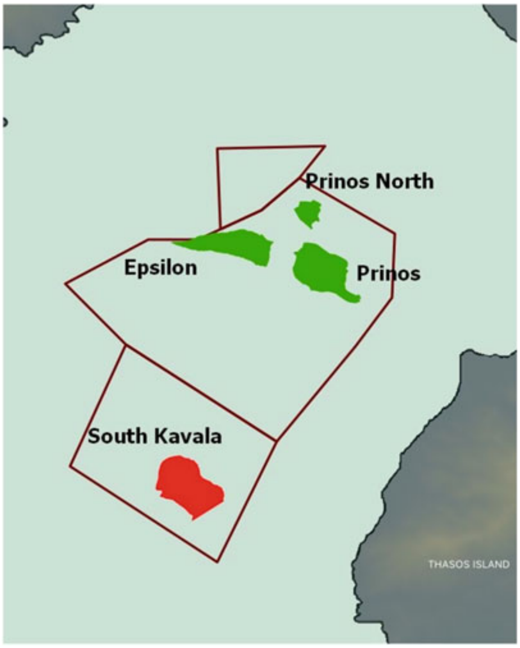

Fig. 6 Oil and gas fields operated by *Energean* in the northern part of the Aegean Sea [20]

than US$30 million in redeveloping the field to revive oil production which was interrupted in 2004. Prinos North 2017 exit production was 263 barrels per day, and the cumulative oil production is 4.2 MMbbls. Currently only one well is producing oil [20].

The Prinos Oil Field is the main structure in the Prinos-Kavala Basin (Fig. 6), located offshore in the Gulf of Kavala. It covers an area of 6 km^2 and is about 8 km northwest of the island of Thassos and 18 km south of the mainland of Northern Greece (depth 31 m). Prinos 2P reserves have been independently audited at 17.8 MMbbls of oil and 2.9 billion cubic feet (Bcf) of gas, while 2C contingent resources are 15.6 MMbbls of oil and 4.9 Bcf of gas. Currently, 14 wells are producing and 4 are injecting sea water. Prinos 2017 exit production reached 3,823 bbls and cumulative production stands at 111 MMbbls [20].

The Epsilon Oil Field (Fig. 6) has 19 million barrels of oil equivalent (MMboe) 2P reserves which have been audited by *Netherland Sewell & Associates Inc. (NSAI)*. *Energean* is developing the field through a new project which consists of (1) drilling of up to nine wells until 2020; drilling of an Extended Reach Drilling (ERD) well and a vertical one are in progress; and (2) the design, fabrication, installation, commissioning, and subsequent operation of a new well-head jacket platform (called Lamda) approximately 3.5 km northwest of the existing Prinos platforms [20].

In November 2015, *Energean* was awarded a 3-year extension to the duration of the South Kavala (Fig. 6) license, from where gas is produced since 1981. A development plan is under evaluation and includes the installation of downhole pumps in two of the existing wells to remove liquids from the well bores and enable the field to be placed back into continuous production, increase condensate yields, and bring recovery up to 98.5%. The remaining gas reserves are approximately 2.6 Bcf. The depleted field is suitable to be converted into an underground gas storage (UGS) linked to the TAP pipeline that will transport gas 2 km from Energean's onshore processing plant [20].

A dispute between Greece and Turkey over territorial waters in the Aegean Sea poses substantial obstacles to oil exploration in the Aegean Sea.

In the Ionian Sea *Energean Oil and Gas* Company is the operator of the proven *Katakolo (West Katakolo-1, West Katakolo-2, and South Katakolo-1)* offshore oil and gas fields, for which the company was granted a 25-year exploitation license in November 2016. The *Katakolo* license covers an onshore, shallow water, and deep water area of 545 km^2 on the west coast of the Peloponnese. The water depth is 200–300 m, while the depth of the reservoir is 2,300–2,600 m. Drilling is planned for 2019 and production is planned to start in 2020 [20].

Recently, the European Bank for Reconstruction and Development (EBRD) has identified energy as one of its core activities in Greece. In addition to supporting green energy with a €300 million renewables framework, the EBRD has also provided a US$ 90 million loan to *Energean Oil and Gas* Company for the development of the company's assets. This loan has now been complemented with a technical assistance program for the implementation of new regulations to strengthen the safety of oil protection and increase the protection of humans and the environment [21].

2.2 Montenegro

Oil and gas exploration activity in Montenegro took place in 1949–1966, when the state company *Nafta Crne Gore* drilled 16 onshore exploration wells which showed no discoveries despite the presence of oil and gas in several drilled wells. In 1973, responsibility for exploration for hydrocarbons in Montenegro was taken over by the government-owned *Jugopetrol Kotor* which, in cooperation with foreign oil companies, conducted over 10,000 km seismic research in the offshore region. One nearshore and 3 offshore wells were drilled between 1975 and 1991. The *JJ-1* well (TD at 4,700 m) found significant quantities of natural gas within the clastic deposits of the Oligocene. The *JJ-3* well recovered 183bbls of oil from Cretaceous age shelfal carbonates. Additional offshore wells had significant gas shows in Lower Tertiary sands but were not tested [20].

The eastern Adriatic Sea over decades remained substantially underexplored, despite having all the necessary hydrocarbon-generating components in place as well as the western offshore. The Adriatic Sea has been a prolific hydrocarbon-producing province for over 50 years for oil in Italy and gas in Italy and Croatia. The widespread distribution of oil and gas seepages offshore of Montenegro indicates the presence of an active petroleum system. These are connected with recent oil

Fig. 7 Blocks 26 and 30 explored by *Energean* offshore of Montenegro in the Adriatic Sea (https://www.energean.com/operations/montenegro/montenegro/)

discoveries in northern Albania, such as the onshore *Shpirag-2* reserve with over 5 billion barrels of oil. In addition, the Tertiary age sandstones in offshore Montenegro are considered highly prospective for biogenic gas. The biogenic gas play is prolific in the Po Basin of offshore northern Italy/Croatia, where over 30 TCFGIP have been discovered to date. The play has been proven in the Duresi basin offshore Albania and Italy, but to date only limited exploration drilling has been carried out in offshore Montenegro [20].

In May 2014, *Energean* submitted a bid in Montenegro's First Round for Production Concession Contracts for offshore hydrocarbons exploration and exploitation. The company reached an agreement with the Ministry of Economy of Montenegro in June 2016, and 6 months later the agreement was ratified by the Montenegrin Parliament. In March 2017, *Energean* signed a Concession Agreement with the State of Montenegro for hydrocarbon exploration and exploitation in offshore blocks 4219-26 and 4218-30 (Fig. 7). The two blocks are located offshore at a water depth of 50–100 m, close to the Montenegrin coast near the town of Bar. Total investment will be US$19 million over an exploration phase of 7 years, including new 3D seismic survey, geophysical and geological studies, and the drilling of one well. According to the NSAI CPR, *Energean*'s combined prospective resources at Blocks 26 and 30 are estimated of 143.9 MMbbls of hydrocarbons liquids and 1,766.1 Bcf of gas [20].

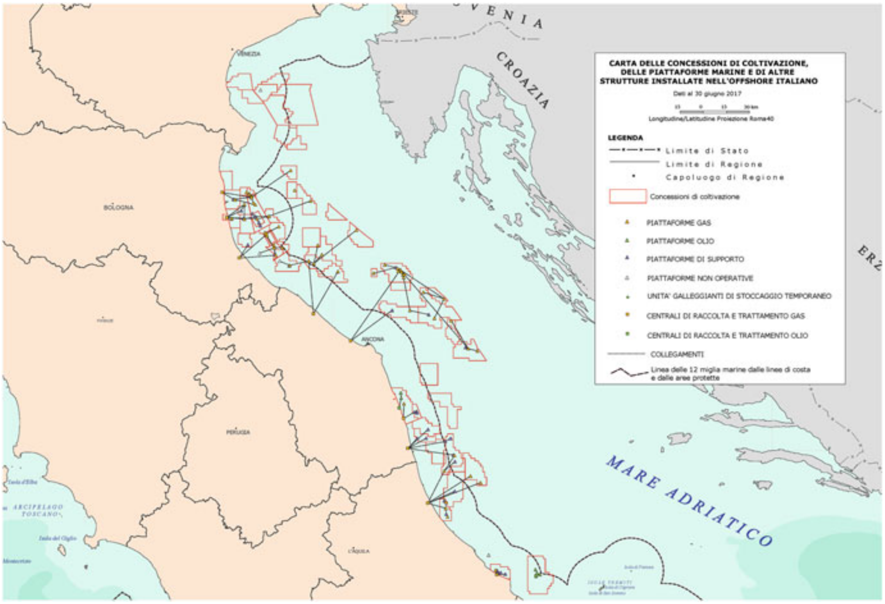

Fig. 8 Italian offshore oil and gas concessions and installations in the North and Central Adriatic Sea (http://unmig.sviluppoeconomico.gov.it/unmig/strutturemarine/carta%20impianti%20offshore%201di2.pdf)

2.3 Italy

Offshore oil and gas production constitutes an important energy source of hydrocarbons in Italy. In 2012, offshore oil production in the EU totaled approximately 60 million tons produced in the continental shelves of different EU member states. For example, UK produces 75.38%, Denmark 17.17%, and Italy 0.83%. Additional considerable quantities of oil were extracted from the continental shelf of Norway. In 2012 offshore oil production in Norway was almost 78 million tons, more than 130% of the total European offshore oil production. In 2012 offshore natural gas production in EU-28 was approximately 63 million tons of oil equivalent with the UK and the Netherlands having a predominant role with 54.60% and 25.23%, respectively, and Italy 8.06% [22]. In Italy natural gas in 2017 was produced in the offshore zones A, B, C, D, and F totaling 3,754 million Sm^3 while crude oil production in the offshore zones B, C, and F totaling 0.65 million tons [23].

The east coast of Italy in the Adriatic Sea is the location of the majority of oil and gas exploration and exploitation activities (Figs. 8 and 9). The majority of offshore rigs is located along the Northern and Central Adriatic coasts of Italy (in February 2018): 138 platforms and subsea wellheads, from them production platforms, 120; production support platforms, 10; and non-production platforms, 8. In addition Italy has three FPSO (Floating Production Storage and Offloading): *Alba Marina*, *Firenze*

Fig. 9 Gas platform *Annamaria B* in the Adriatic Sea off the coast of Ravenna (Emilia-Romagna) (https://commons.wikimedia.org/wiki/File:Platform_Annamaria_B.jpg)

FPSO, and *Leonis* [23]. Several offshore platforms are located in the South Adriatic Sea, Ionian Sea, and Sicily Channel (Figs. 10 and 11).

The history of offshore oil and gas exploration in Italy goes back to the mid-1950s when the first offshore seismic survey was conducted in the northern part of the Adriatic Sea. In 1959, the drilling of the well *Gela-21*, the first offshore well drilled in Europe, was highlighting further exploration possibilities. The largest gas discovery was *Agostino-Porto Garibaldi* which occurred in 1968 in the Northern Adriatic Sea. It is a biogenic gas giant field of about 600 MMboe of recoverable reserves [24]. Starting from 2007, the level of exploration drilling dropped to under ten wells per year with investments also reaching an historical minimum. That year was also the starting point of the decline of the Italian E&P industry. This negative trend was confirmed in 2014, when no onshore exploratory wells were drilled. The situation is even worst for the offshore drilling, where the last well was realized in 2008. One of the causes of this decline is certainly the exploration maturity of the biogenic gas play together with the heavy bureaucratic process to obtain exploration authorizations which has discouraged further investments. In addition, during 2010, potential investors faced a new federal law permanently banning the E&P activities within 12 miles from the Italian coast. Additionally, there is increasing general opposition of a large part of the Italian population to any kind of petroleum related domestic activities both onshore and offshore [24].

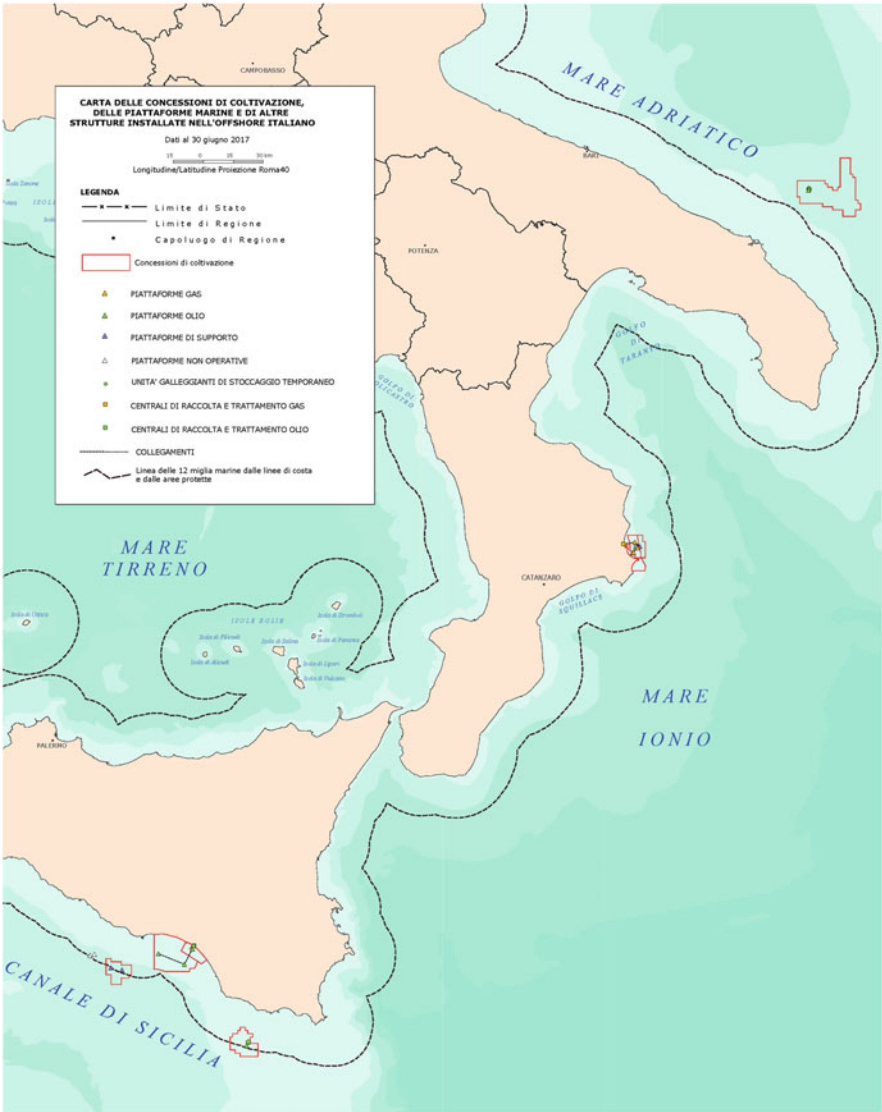

Fig. 10 Italian offshore oil and gas concessions and installations in the South Adriatic Sea, Ionian Sea, and Sicily Channel (http://unmig.sviluppoeconomico.gov.it/unmig/strutturemarine/carta%20impianti%20offshore%202di2.pdf)

Since 2013, new drilling is prohibited in the Tyrrhenian Sea, in the marine protected areas, and in the waters within 12 nautical miles from the coast, but the concessions approved before 2013 may continue until all of the resources are extracted. A referendum on oil and natural gas drilling was held in Italy on 17 April 2016, which concerned the proposed repealing of a law that allows gas

Fig. 11 Oil platform *Vega* in the Mediterranean Sea off the coast of Pozzallo, Ragusa (Sicily) (https://commons.wikimedia.org/wiki/File:EDISON21.jpg)

and oil drilling concessions extracting hydrocarbon within 12 nautical miles of the Italian coast to be prolonged until the exhaustion of the useful life of the fields. Although 86% voted in favor of repealing the law, the turnout of 31% was below the minimum threshold required to validate the result [25].

2.4 Croatia

The first gas field was discovered in Croatia in 1917 and first oil field in 1941. Intense onshore exploration and exploitation of oil and gas in Croatia has occurred over the last 60 years and has had an important value for economy growth of the country. During the last 40 years, Croatia has explored and exploited hydrocarbon deposits in the North Adriatic Sea. Since 1999 Croatia has produced gas in the north part of the Adriatic Sea. Today it holds 60 exploration fields of hydrocarbons; 3 of them are offshore (Fig. 12) [26].

Exploration offshore of Croatia started in the North Adriatic in 1968 with the acquisition of 2D seismic data. In 1973 the *Ivana* gas field was discovered spurring further exploration in the region. Six more major discoveries (*Ika, Ida, Annamaria, Ksenija, Koraljka, and Irma*) resulted from surveys made in 1978–1993. The largest offshore oil discovery *Elsa 1* was made in 1992. The most recent discovery was made in 2008 with the *Monte Della Crescia* gas discovery in the Italian Sector.

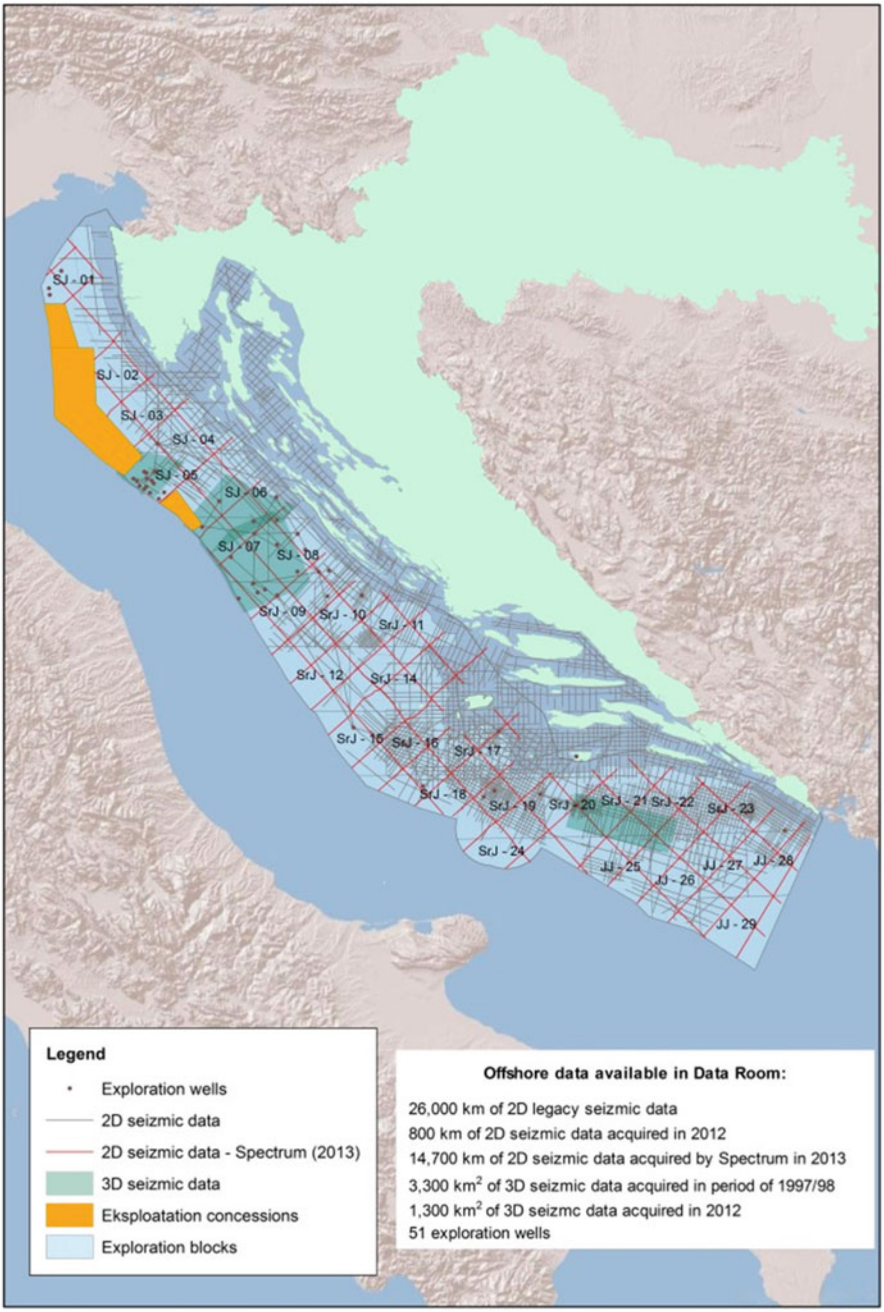

Fig. 12 Exploration blocks and exploitation concessions offshore Croatia in the North Adriatic Sea (https://www.azu.hr/media/1461/karta-more-data-room-eng-novo.jpg). Copyright © 2014 Esn

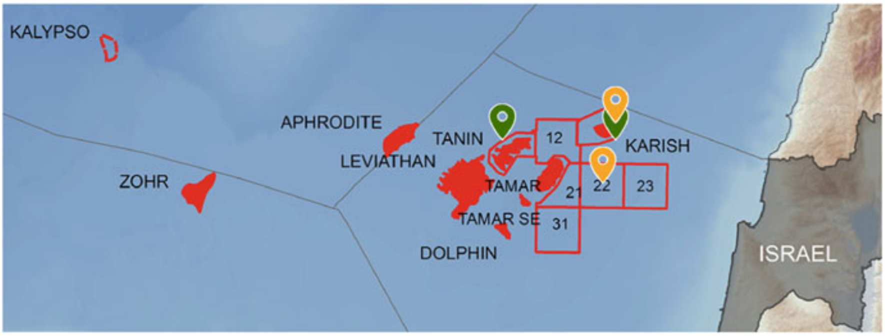

Fig. 13 Tanin and Karish gas fields and blocks 12, 21, 22, 23, and 31 explored by *Energean Israel* as well as other gas fields offshore Israel (https://www.energean.com/operations/israel/israel/)

The region has over 90 producing fields. Exploration in the Southern Durres Basin area has been much reduced due to a lack of data. There are currently 11 onshore and 5 offshore discoveries in the area. Many structures are still unexplored in the central and western part of the basin, where gas-generating conditions are more favorable, increasing the possibilities for new discoveries [26].

Until recently 15 offshore gas platforms were active in the North Adriatic Sea, 14 of them produced gas with natural drive, and on one compression facilities are being installed. The gas field *Marica* is being produced from two platforms. The maximum annual production of gas was achieved between 2007 and 2010, and it reached a total production of about 1.8 billion m^3 of gas. Another significant production peak, significantly lower than maximum, was achieved in 2012, and it reached approximately 1.1 billion m^3 of gas. Since then, it continuously decreases, and gas field production will probably end by 2040 [27].

2.5 Israel

The *Tamar* gas field (Fig. 13) was discovered by *Noble Energy* in January 2009 in Levantine Basin and is the company's largest find to date. *Noble Energy* owns 36% in *Tamar* and is the operator of the field. The Levantine Basin covers about 83,000 km^2 of the eastern Mediterranean region offshore Israel, Lebanon, and Syria. The US Geological Survey (USGS) estimates that the entire Levantine Basin holds a mean approximation of 1.7 billion barrels of recoverable oil and about 122 tcf of recoverable gas. According to estimates, the *Tamar* gas field has reserves of 10 tcf of gas. First production from *Tamar* was achieved in April 2013, and full production capacity was reached by the end of July 2013. Gas is produced through five subsea wells tied back to the *Tamar* platform. The wells are linked to the platform through 150 km long flowlines. The platform is installed at a depth of 800 ft. and has a processing capacity of 1.2 bcf per day of natural gas [28].

In December 2010, gas was discovered in the *Leviathan Gas Field* (Fig. 13), 135 km off the coast of Israel, with an estimated volume of 16 tcf of gas (approximately 453 million m3) [7]. *Noble Energy* obtained approval for the plan of development (POD) from the Ministry of National Infrastructure, Energy and Water Resources of Israel in June 2017. The company signed a gas sales and purchase agreement (GSPA) to provide natural gas from the *Leviathan* field to National Electric Power Company (NEPCO) for a period of 15 years. In August 2017 a contract was signed to drill two wells and complete four production wells in the *Leviathan* Gas Field [8]. The *Leviathan* gas field is scheduled to come online in late 2019. The Leviathan gas field's natural gas reserves are estimated to be 18 tcf. Besides natural gas, the field is said to contain 600 million barrels of oil beneath the gas layer [29].

Energean Israel is the operating the *Karish* and *Tanin* leases offshore Israel (Fig. 13). Both fields were discovered by *Noble Energy* in the Levantine Basin in 2011 and 2013. The *Karish* and *Tanin* fields are world-class assets with 2,2 TCF of natural gas and 31.8 million barrels of light hydrocarbon liquid 2P reserves. The *Karish* Main Development envisages drilling three wells, using a new Floating Production Storage and Offloading (FPSO) unit that will be installed approximately 90 km offshore, with 800 mmscf/day capacity. First gas is expected in 2021. The *Tanin* Development will follow the development of *Karish* and envisages drilling six wells, connected to the same FPSO that will serve *Karish* Development. In December 2017 *Energean* was successfully awarded five offshore exploration licenses within the Israeli Exclusive Economic Zone (EEZ). The licenses awarded comprise blocks 12, 21, 22, 23, and 31 and are located near the currently producing *Tamar* gas field and the *Karish* and *Tanin* gas fields (Fig. 13) which are currently under development by *Energean* [20].

2.6 Palestine

The *Gaza Marine natural gas field* (Fig. 14) was discovered in 2000 by *British Gas* 36 km offshore the Gaza coast (depth 610 m) in waters under the control of the Palestinian National Authority. *British Gas* holds a 90% interest in the field [30]. *Energean* is ready to purchase a 45% stake in the offshore *Gaza Marine gas field*, pending approval by Palestinian and Israeli authorities. The Palestine Investment Fund (PIF) is currently the field's sole owner looking for an operator and buyer for the 45% stake. Under current plans, the gas would go to Israel's Ashkelon natural gas terminal and from there to a Palestinian power plant in Jenin in the West Bank. Palestinian political disputes and conflict with Israel, as well as economic factors, have delayed plans to develop the gas field, which possesses estimated reserves of over 1 tcf of natural gas, the equivalent of Spain's consumption in 2016 [30, 31].

Development of the Gaza field is expected to benefit both Israel and the Palestinian National Authority. The *Gaza gas field* is expected to supply for 10% of the energy requirement of Israel. The country currently relies on Egypt for its gas

Fig. 14 Oil and gas fields in the southeastern Mediterranean (http://www.connection-mag.com/?p=5333)

supplies. Steadily growing economy calls for access to newer sources of energy for Israel. The country is planning to purchase the gas produced by the Gaza field to reduce its dependence on Egyptian gas [30, 31].

2.7 *Cyprus*

In the last decade, there have also been significant exploration activities off the coast of Cyprus (Figs. 1 and 2), following the development of new technologies to assess and reach previously inaccessible reserves, worth an estimated $131 billion [9].

The *Aphrodite* gas field was discovered in December 2011. It lies approximately 160 km south of Limassol offshore of the Republic of Cyprus in the Eastern Mediterranean Sea (Figs. 13 and 14). The gas field is located 30 km northwest of the *Leviathan* gas field in Block 12 of the Cypriot Exclusive Economic Zone (EEZ). The field covers an area of 120 km^2, and it was the first gas discovery to be made in the Cypriot EEZ. The owners of Block 12 are *Noble Energy International* (35%), *BG Cyprus* (35%), *Delek Drilling Limited Partnership* (15%), and *Avner Oil Exploration Limited Partnership* (15%). The *Aphrodite* gas field is jointly owned by *Delek Drilling* (30%), *Noble Energy* (35%), and *Shell* (35%) [32].

The *Cyprus A-1* discovery well discovered gas reserve with estimation of a gross resource range from 5 to 8 tcf. *Aphrodite's Cyprus A-2* appraisal well was drilled in 2013 (6.4 km to the northeast of the Cyprus A-1) and resulted in an estimate of the gross resources of the field between 3.6 and 6 tcf of gas [32].

First gas from the field is expected after 2023 following the identification of a suitable export option. The Cypriot Government has signed an energy cooperation agreement with the Egyptian Government to examine the option of exporting gas from *Aphrodite* field to Egypt. A technical study was conducted by the Egyptian Natural Gas Holding Company and the Cyprus Hydrocarbons Company in 2015 to design a possible gas connecting route from the *Aphrodite* gas field to Egypt. It is planned that the processed gas from the FPSO will be transported through pipelines to a proposed onshore natural gas liquefaction plant. The proposed onshore plant will include three LNG production units with a capacity of five million tonnes per annum (Mtpa) each. It will also include a power plant, supporting and auxiliary services, an operation and control center, as well as two LNG storage containers with a capacity of 180,000 m^3 each [32].

The development of the *Aphrodite* gas field is expected to enable Cyprus achieve energy independence and help the country minimize air pollution while strengthening businesses, employment opportunities, and the overall economy of the country. According to *Noble Energy*, a total gross unrisked deep oil potential is 3.7 billion barrels, and the field has a gross mean average of 7 tcf of natural gas [32].

2.8 Egypt

In the last decade, there has been serious development of offshore gas and oil fields along the Mediterranean coasts of Egypt (Figs. 1, 2, and 14), where the most active companies are *BP*, *BG*, *IEOC*, *EGAS*, *Total*, *RWE Dea*, and *Dana Gas*. *BG* is active in five concessions. *Dana Gas*, a regional company, has about ten producing fields. In September 2013, *BP* announced a significant gas discovery in the East Nile Delta named *Salamat*. The *Salamat* discovery is located around 75 km north of Damietta city and only 35 km to the North West of the *Temsah* offshore facilities. The *Atoll* gas field was discovered by *BP* in March 2015 by drilling the *Atoll-1* deepwater exploration discovery well 15 km north of *Salamat* discovery. In August 2015, *Eni* announced the discovery of the *Zohr* gas field 150 km from Egypt's north coast. The reserve is estimated as 30 trn scfd of natural gas, making it the largest in the Mediterranean. This discovery seems to increase the Egypt's total gas reserves by about 40% [11].

The *Atoll* gas field is a significant discovery lying in the *North Damietta Concession* offshore Egypt in the East Nile Delta (Fig. 14). *BP* announced the *Atoll* discovery in March 2015. The field was developed by *BP*, which has a 100% equity in the discovery, and on 12 February 2018, *BP* announced start of gas production [33]. The field development was approved by *BP* in collaboration with *Egyptian Natural Gas Holding Company* (EGAS) on 20 June 2016. It was decided that *Atoll* would be developed as a fast-track project after the heads of agreement was signed in November 2015 between *BP* and the Egyptian Minister of Petroleum and Mineral

Resources. *BP* has also signed a number of agreements for transportation and processing arrangements related to the field development. *Pharaonic Petroleum Co.* (PhPC), *BP*'s joint venture with *EGAS* and *Eni*, will execute and operate the project [33].

The *Atoll* field was discovered by *BP* in March 2015 by drilling the *Atoll-1* deepwater exploration discovery well to a depth of 923 m and is expected to be Egypt's deepest well ever drilled. The drilling site is located 15 km north of *Salamat* discovery, 80 km north of the city of Damietta, and 45 km to the northwest of *Temsah* offshore facilities. The exploration well was drilled to a depth of 6,400 m and encountered approximately 50 m of gas pay in high-quality sandstones. The field is estimated to contain approximately 1.5 tcf of natural gas and 31 million metric barrel (mmbl) of condensates. The gas and the liquids produced from the field are processed onshore at the existing West Harbour gas processing facility, which currently processes 280 mmscfd from Ha'py and 265 mmscfd from Taurt fields [33].

The *Zohr* gas field (Figs. 1, 2, and 14) is located within the 3,752 km^2 *Shorouk Block*, within the Egyptian Exclusive Economic Zone (EEZ), in the southeastern part of the Mediterranean Sea. The field is situated more than 150 km from the coast of Egypt. *Eni* owns a 100% stake of the *Shorouk* license through IEOC Production, and the property is operated by *Belayim Petroleum Company* (*Petrobel*), a joint venture between IEOC and *Egyptian General Petroleum Corporation (EGPC)* [34]. Eni was granted approval for the *Zohr* Development Lease by the *Egyptian Natural Gas Holding Company* (EGAS) in February 2016. Production at the deepwater gas field has started by the end of 2017 and will reach full production capacity in 2019 [34].

The gas field was discovered in August 2015 by drilling the *Zohr 1X NFW* well at a water depth of approximately 1,450 m. The exploration well was drilled to a total depth of 4,131 m and encountered 630 m layer of hydrocarbon column. The field was successfully appraised in February 2016 by drilling the *Zohr 2X* appraisal well, approximately 1.5 km southeast of the exploration well. It was drilled to a total depth of 4,171 m, encountering 455 m layer of continuous hydrocarbon column. Phase I of the project envisages the development of six production wells to produce an initial 1bcf/d of gas in 2018 and is expected to reach its peak production capacity of 2.7 bcf/d by 2019. The project will involve the construction and installation of an offshore control and production platform, which will further be connected to an onshore processing plant by means of subsea pipelines. The full field development plan entails the drilling of 254 wells over the field's production life. The gas produced from the field is expected to be distributed within Egypt, while the excess will be exported to overseas markets [34].

2.9 Libya

In 1974, the Italian oil company *Eni S.p.A* signed a Production sharing agreement (PSA) awarded by the state-owned *National Oil Corporation (NOC)* of Libya for onshore and offshore exploration in areas near Tripoli. Two years later, the *Eni's*

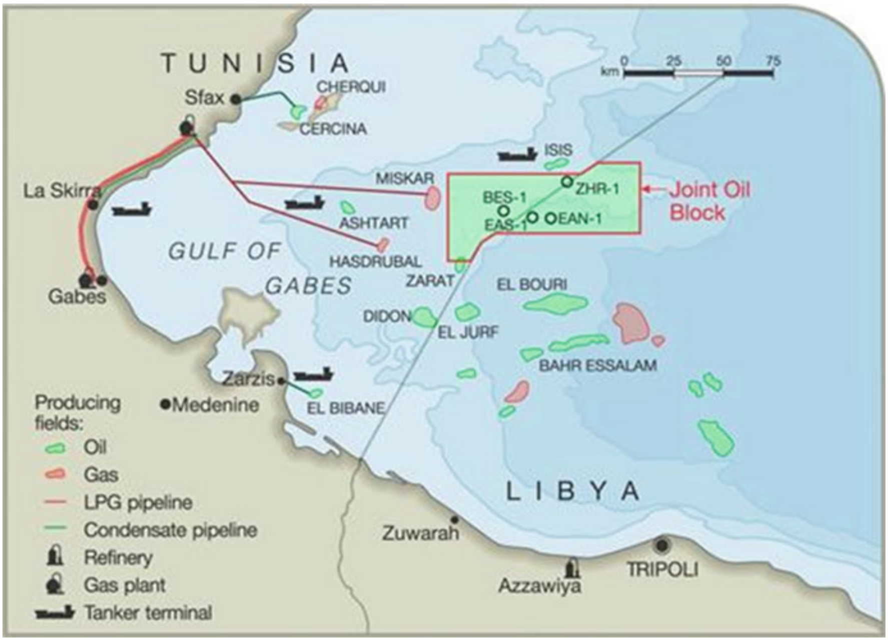

Fig. 15 Offshore oil and gas fields in Libya and Tunisia (https://www.energy-pedia.com/news/tunisia/sonde-resources-updates-152743)

subsidiary company *Agip Oil* announced discovery of the offshore *Bouri* field at a depth of 2,700 m in the Gulf of Gabes (Fig. 15). The *Bouri* field is jointly operated by *Eni* (30%) in partnership with state-owned *NOC* (70%), with the two partners jointly setting up *Mellitah Oil and Gas Company* to manage the field. The *Bouri* Offshore Field is part of Block NC-41, which is located 120 km north of the Libyan coast in the Mediterranean Sea. Its reserves are estimated to contain 4.5 billion barrels in proven recoverable crude oil and 3.5 tcf of associated natural gas with an annual production potential of 6 billion m^3. The *Bouri* field is considered the largest producing oilfield in the Mediterranean Sea [35].

Production from the field started in 1988 through two production platforms and *Sloug* floating storage and offloading (FSO) vessel. In 2006, *Eni* reported that the *Bouri* field was producing about 60,000 barrels of oil per day. In 2012, it was announced that the existing FSO will be replaced by a new FSO named *Gaza*. Built at a cost of $424.78 m, the new vessel reached the Libyan field in May 2016 [35].

The Western Libyan Gas Project is a 50/50 joint venture between *Eni* and *NOC* which came online in October 2004. This project transports natural gas from *Bouri* and other *Eni* fields through the 520 km long *Greenstream* underwater pipeline. Currently, 280 Bcf of natural gas per year is exported from a processing facility at

Melitah, on the Libyan coast, via *Greenstream* to southeastern Sicily in Italy. From Sicily, the natural gas goes to the Italian mainland and then onward to Europe [35].

The *Bouri* field is situated in the Djeffara-Pelagian Basin Province (also known as the "Pelagian Basin"). The Province is primarily an offshore region of the Mediterranean, located off eastern Tunisia and northern Libya (northwest of the Sirte Basin) and extending slightly into Italian and Maltese territorial waters (Fig. 15). The Pelagian Basin contains over 2.3 billion barrels of total recoverable petroleum liquids, consisting of about 1 billion barrels of recoverable oil reserves and approximately 17 tcf of natural gas [35].

3 Conclusions

Until recently, the Mediterranean Sea was not known as an important region for offshore oil and gas exploration and production, unlike the Gulf of Mexico, the North Sea, and the Caspian Sea. This was with the exception of offshore activities in the Adriatic Sea by Italy since the 1950s, in the Aegean Sea by Greece since the 1970s, and in the Gulf of Gabes by Italy and Libya in the 1970s–1980s. However 10 years ago the situation significantly changed with the discovery of a series important gas fields in waters of Israel, Palestine, Cyprus, and Egypt, which in the near future will change completely the gas market in this region of the Mediterranean.

In 2015, Israel produced over 8.5 billion cubic meters (bcm) of natural gas a year, while its proven reserves are estimated as 199 bcm. Future production at the *Tamar* and *Leviathan* gas fields is seen as an opportunity for Israel to become a major energy player in the Middle East. As of 2017, even by conservative estimates, *Leviathan* field holds enough gas to meet Israel's domestic needs for 40 years ahead. The offshore gas fields of *Zohr*, *Salamat*, *Atoll*, *North Alexandria*, *and Nooros* are among the most important offshore projects that will increase natural gas production in Egypt and will contribute to natural gas self-sufficiency by the end of 2018. Today oil and gas exploration or production also takes place off the coasts of Algeria, Spain, Libya, Tunisia, Malta, and Turkey.

Different types of offshore platforms are used for oil and gas exploration and production in the sea [36]. These activities pose a serious threat to the marine and coastal zone environment, the seabed, and sea-bottom habitats and species (Fig. 16), since oil contamination can persist in the marine environment for many years, depending on the oil type, the location of a spill, and the area in which the contamination occurs [36, 37]. Today, accidental spills from offshore platforms in different parts of the World Ocean represent only about 1–3% of total amount of petroleum discharged in the sea. In the Mediterranean Sea, this share should be even less than 1% of total oil pollution as the number of offshore oil and gas platforms and production is small in comparison with other regions of the World Ocean.

In the Mediterranean Sea, there is contradictory information about the total number of oil and gas platforms operating in the sea. According to Statista [18] as

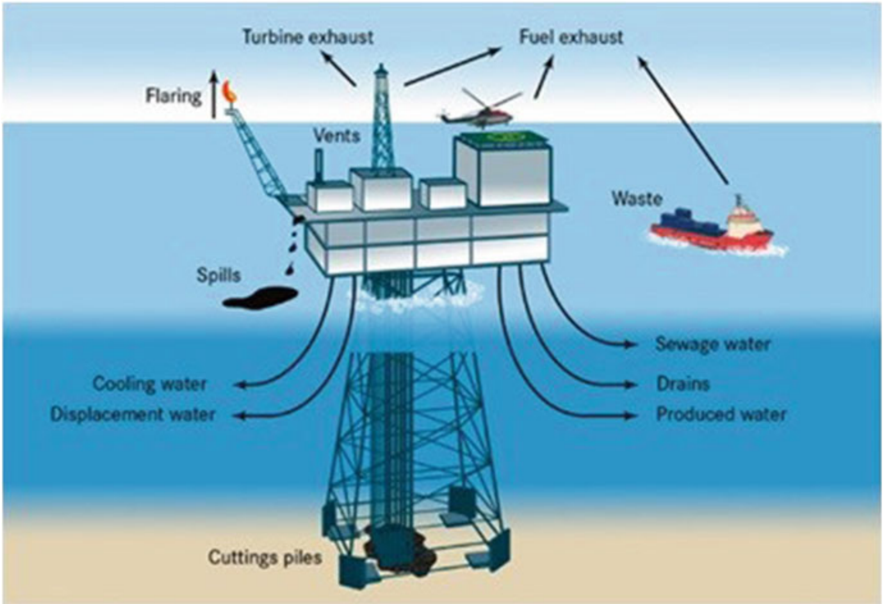

Fig. 16 Sources of oil inputs from offshore oil and gas installations. Source: OSPAR Quality Status Report 2010, Fig. 7.1, page 65 [38]

of January 2018, there were only 26 rigs operating in the sea, while according to Ministry of Economic Development of Italy in February 2018, Italy alone had 138 offshore platforms. On the other hand, again according to Statista [18] in the North Sea and the Gulf of Mexico (United States), 184 and 175 offshore rigs were located, respectively, as of January 2018, and globally, the number of oil platforms was expected to rise from 389 units in 2010 to 500 in 2017. This number corresponds to the weekly updated information given by Petrodata Weekly Rig Count [39] which for October 2018 shows 77 offshore rigs in the Gulf of Mexico, 38 in South America, 91 in Northwest Europe, 60 in West Africa, 175 in Middle East, 86 in Southeast Asia, and in total 766 worldwide. Unfortunately this database does not provide information about offshore rigs located in the Mediterranean Sea. The discrepancy may be explained by unclear terminology when, for offshore rigs, only oil platforms are counted.

Following the *Deepwater Horizon* accident in the Gulf of Mexico in April 2010, the European Commission launched an assessment of safety of offshore oil and gas exploration activities as well as production activities in European waters [40]. The investigation concluded that while a number of best practices already existed in the European Union (EU) member states in relation to safety, preparedness, and response, the divergent and fragmented regulatory framework, along with current industry safety practices, did not provide adequate protection from risks of offshore accidents. These conclusions are all the more relevant in light of the transformation of the European oil and gas industry in response to the progressive depletion of "easy" reservoirs. Exploration is moving toward more complex environmental conditions characterized by high-pressure/high-temperature reservoirs, deeper waters and/or extreme climate conditions, and weather events that may complicate the control of subsea installations and incident response [21].

At the same time, production facilities in maturing fields are ageing and often taken over by specialist operators with smaller capital bases. The study concluded that while risks could not be totally eliminated in the offshore hydrocarbon industry, the safety and integrity of operations and assurances of maximum protection of people and the environment needed to be guaranteed [40]. Following this examination, the European Parliament issued the European Offshore Safety Directive (Directive 2013/30/EU) in 2013 [41]. It aims to reduce, as far as possible, major accidents relating to offshore oil and gas operations and to limit their consequences, increase the protection of the marine environment and coastal economies against pollution, establish minimum conditions for safe offshore exploration and exploitation of oil and gas, and improve the response mechanisms in case of an accident. Each EU member state had to transpose the directive into national legislation [21].

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Oil Spill Intervention in the Mediterranean Sea

Neil Bellefontaine, Patrick Donner, Lawrence Hildebrand, and Tafsir Johansson

Abstract It is axiomatic that maritime transportation is essential for international trade. As the global economy and commerce continue to grow, significant pressure falls on maritime transportation. The types of goods conveyed by maritime transportation are innumerable. Oil is one of the transported commodities that rank high among import–export items. Without oil, the world's energy supply is predicted to slowly run dry and in that instance, the ever-expanding global economy might lose its raison d'être. Marked by its versatile utility, oil supply has been in high demand in the international market for a considerable period of time. Occasionally, oil transportation via tankers does not always go as expected. Even though accidental discharges from incidents such as the *Torrey Canyon, Amoco Cadiz*, and the *Exxon Valdez* are considered to be less when compared to other types of vessel-source pollution, those incidents have nevertheless, demonstrated the need for a comprehensive national contingency plan to combat the deleterious effects of oil pollution at sea. Hence, they have been the reason behind the outcry of affected coastal communities and increased public attention to the threat of oil spills.

Although studies show that oil tanker incidents have been declining significantly, accidental spills as a part of the broader "oil spill" regime have been a contentious issue for decades and therefore, the "cause and effect" cannot be overlooked by Coastal States. While operational spills can be regulated through stringent laws and regulations, an accidental spill due to its unpredictable nature cannot be fully regulated by stringent policies. Again, compared to operational spills, the quantity of oil spilled from a single accident can be more than a number of operational spills combined and far more devastating. Researchers are, therefore, leaving no stones unturned to help the shipping industry lower the number and volume of accidental oil spills. While maritime engineers, scientists, and

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researchers are focusing on technical defects and human errors, governments of Coastal States are trying to develop ways to protect the marine environment through immediate response. More recently, countries within North America are studying an emerging concept related to oil spill immediate response. This modern concept entitled “oil spill intervention” is a combination of first response prior to a spill and rapid response in the immediate aftermath of a spill. In other words, governments are looking at advanced ways of dealing with oil spills, which go beyond the concept of ordinary “oil spill response.” Since the semi-enclosed Mediterranean Sea, bordered by 23 states, consists entirely or primarily of Territorial Seas and Exclusive Economic Zones, an accidental oil pollution incident in any part of the Mediterranean Sea is likely to effect a significant number of States whether they are adjacent, opposite, or located at a far distance. The marine ecology of the semi-enclosed Mediterranean Sea is known to science as unique and there is a limit to how much oil contaminants these sensitive sea areas can absorb. Therefore, the Mediterranean Sea areas are in need of better governmental control and advanced rapid response plans. This is where the national laws of the Mediterranean States and regional cooperation need further scrutiny to confirm whether they contain the required elements of “oil spill intervention.” Furthermore, Mediterranean national measures aimed at preventing, limiting, or responding to oil pollution needs to be cross-examined against the backdrop of status quo international law, which governs immediate response and intervention.

Although there has not been any major maritime oil spill incident within the Mediterranean region, accidents are considered as inevitable occurrences and the risk of one happening in the near future cannot be ruled out. Past incidents have taught us that an oil tanker accident is a force to be reckoned with. So, time not only runs against first responders who jump into immediate action in the aftermath of a maritime incident, but it also runs against the concerned governments of the Mediterranean Sea region. They need to review their current action plans and look into a functional and effective intervention plan before any future occurrence impacts the quality of the marine environment. This review is needed mainly because maritime traffic in the Mediterranean is increasing and the shipping industry will continue to take advantage of the Mediterranean transportation corridor.

Keywords Accidental pollution, Boundary delimitation agreement, Immediate response, International law, Mediterranean action plan, Mediterranean coastal states, National contingency plan, Oil spill intervention

Contents

1 Introduction

The name "Mediterranean" originates from the two Latin terms "medius" and "terrae" [1]. When combined, the term "medius terrae" is translated as "inland" or "in the middle of the earth" whereby the sea itself is formed by several other seas or basins, i.e., the Adriatic Sea, the Tyrrhenian Sea, the Alboran Sea, the Balearic Sea, the Ligurian Sea, and the Aegean Sea [1]. Encyclopaedia Londinensis has defined the Mediterranean Sea as "a large gulf or lake of the Atlantic Ocean, bounded on the north by Europe and Asia, on the east by Asia, and on the south by Africa; towards the west it joins the Atlantic by a narrow passage, called the Straits of Gibraltar" [2]. From a geographical perspective, the Sea stretches 3,800 kilometers (km) from East to West and its surface area is 2,511,000 square km [1]. The usage of the Mediterranean Sea dates back to ancient times when merchants and travellers began to use the Sea as a route for trade and cultural exchange between "emergent peoples" belonging to that region, i.e., the Mesopotamian, Egyptian, Phoenician, Carthaginian, Iberian, Greek, Macedonian, Illyrian, Thracian, Levantine, Gallic, Roman, Albanian, Armenian, Arabic, Berber, Jewish, Slavic, and Turkish cultures [1]. Today, the Mediterranean Sea is considered as the main transportation corridor between Far-East Asia and Europe [3].

Given the fact that international business is conducted in a "just-in-time" fashion, over the years it has become necessary to transport goods from the manufacturer to the buyer in a faster, safer, and more efficient manner. Therefore, it was important to modernize the central element of maritime commerce, i.e., the merchant fleet, which consists of a variety of ship types that range from oil tankers, bulk carriers and container ships to general cargo ships, and many specialized ship types. As science and technology began to progress at a rapid pace, maritime transportation has undergone significant transformations so that there is continuity in the so-called just-in-time fashion. Parallel to the advancement in technology and modernization of maritime transportation, the number of merchant vessels has simultaneously increased by the shipping industry in order to satisfy the growing economic demands of both developed and developing countries. In short, development of "national economy and international exchange" is seen as a logical rationale behind the increase in maritime traffic in sea areas such as the Mediterranean.

Although the Mediterranean coastal and marine ecology differs from one place to another, the sea areas, which are considered to be the transportation corridor between Europe and Asia, are highly valued and are subject to equal pressure from heavy usage by the shipping industry [4]. Today thousands of oil tankers carrying large quantities of crude oil cross the main routes of the Mediterranean Sea [5]. It is also observed that the extensive maritime traffic coupled with the carriage of large quantities of crude oil: (a) from the Middle East to ports in Europe and North America via the Suez Canal; (b) between the Mediterranean and the Red Sea; (c) through the Straits of Gibraltar; and (d) through the Turkish Straits, has not only given rise to maritime congestion in the Mediterranean semi-enclosed sea, but it has also increased the chance of major oil pollution in the sensitive Mediterranean Sea areas [5]. In 2006, it was estimated that the "Mediterranean alone sees 360 million tonnes of oil and refined products per year" being carried, which accounts for 22% of the global total [5, 6]. In the same year, it was estimated that a staggering 220 million tonnes of crude oil were loaded at Mediterranean ports [7]. Therefore, the risk of oil pollution and possibilities of acute contamination have placed the Mediterranean region in a vulnerable state.

Although the oil pollution "risk factor" increases with increased shipping of oil, states are required to control and regulate all sources of marine pollution in accordance with customary international law. As such, Coastal States are required to exercise "due diligence" to ensure that chronic pollution originating from maritime transportation will be controlled and prevented. While operational discharges can be limited and narrowed down to a certain permissible amount, accidental discharges or spills from accidents[1] involving oil tankers have resulted in massive oil spills. Fifty years have passed since the *Torrey Canyon* (1967) spill and since then, there have been other major oil spills, e.g., *Amoco Cadiz* (1978), the *Exxon Valdez* (1989), the *Erica* (1999), the *Prestige* (2002), the *Tasman Spirit* (2003), and the *Hebei Spirit* (2007) that have stood out as landmarks in the history of accidental oil pollution [8]. These accidental spills are often termed as the most apparent, visible, and dramatic examples of oil pollution in the marine environment [9]. From a general perspective, accidental spillage of oil in the wake of a maritime incident is dependent on the occurrence of an unforeseeable event and calls for rapid response and preparedness actions. Whether it is a vessel collision, a vessel in distress or a blowout of an offshore oil well, the first responders of a Coastal State usually engage in rapid "response" in order to control the extent and degree of oil pollution.

While oil pollution response actions have dominated the aftermath scenario, major maritime nations including the United Kingdom of Great Britain and Northern Ireland (UK), the United States of America (US), and Canada have made an effort to develop a form of "advanced response action plan" to: (a) deal with the "likelihood of a spill," i.e., control a situation that poses an "imminent threat" of a

[1]A series of occurrences in any maritime zone of a state having the same origin, which results or may result in the discharge of oil and may pose a threat to the marine environment, or to the coastline of related interests of one or more states, which may require an emergency action or other immediate response.

spill; and (b) minimize the amount of pollution if the "imminent threat" transposes to an "actual spill" situation. This advanced response action, known as "intervention," is the current term associated with maritime accidents. It is considered to be a phase that is comprised of: (a) actions prior to actual response; and (b) the "actual response"[2] actions initiated by responsible authorities whereby the central objective is to control the source of the pollution that could lead to a major oil spill or control the amount that has already spilled into the water. "Oil spill intervention," therefore, refers to the planned actions and measures taken during a casualty to limit damage or avoid a spill or contain the amount spilled altogether. In other words, this chapter is guided by the term "intervention" insofar as the strategy itself concerns first responders and instantaneous decisions during an incident to correct "imminent" situations, "cap" a developing leak, minimize potential damage leading to the final response in case of unwanted spill. The time duration is critical during an intervention phase and may be narrowed down as:

> The first responders of a coastal state generally undertake "intervention" actions and the phase commences the very minute a national authority is advised of an incident in progress that has the potential for a spill and concludes the very minute the spill has been successfully contained.

In addition to the preparedness and response actions mapped out in respective national contingency plans, oil spill intervention could include directing a vessel to a place of refuge and directing said place of refuge to accept the vessel or providing/directing a resource onto a vessel to aid in stopping a leak. With the projected increase in maritime traffic in the Mediterranean region and the lessons learned from major oil spills that received global attention, it is deemed important to analyze the status quo of the Mediterranean "oil spill response" regime and examine whether features of "intervention" can be found in the national laws. To that extent, both primary and secondary sources with regard to national law and international law governing regional cooperation have been taken into account. It should be noted that in the study and examination of "oil spill intervention" approaches, significant consideration is given to the oil spill preparedness, prevention, and response regime because of the limited usage of the term "intervention" and due to the existing differences in the way "intervention" is perceived by authorities of different jurisdictions. Therefore, the term intervention has been extended to include first response in the immediate aftermath of an oil spill and is not only limited to potential spills or near spills or the likelihood of a spill. Although some countries have given authorities intervention powers, which are limited to a potential spill or threat of significant pollution from maritime incidents, to date, there are no concrete examples where such "intervention" to contain a "potential spill" has been successful. Again, there is a thin line between potential spill "intervention" and oil spill response because a number of incidents, e.g., the *Rocknes* (2004), the *TK Bremen* (2011), the *Golden Trader* (2011), the *Gdansk*

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[2] Delivering effective and fit-for-purpose oil spill response preparedness and capability to contain oil already discharged.

(2011), the *ECE* (2006), the *Bunga Kelana* (2010), the *Braer* (1993), the *Baltic Carrier* (2001), the *Atlantic Empress* (1979), the *Aragon* (1989), the *Tanio* (1980), the *Aegean Sea* (1992), and the *Agios Dimitrios* (2009), demonstrate the fact that potential spill "intervention" might be completely impossible and at any given moment the potential spill "intervention" phase may shift to a response, containment, or clean-up stage, leaving the potential spill "intervention" phase distorted and completely indiscernible. Therefore, the term "intervention" in this chapter follows the theme of the International Convention Relating to Intervention on the High Seas in Cases of Oil Pollution Casualties of 1969 (Intervention Convention) and has not been restricted to the examination of actions taken to prevent potential spills or near spills or the likelihood of a spill.

2 Oil Spill Intervention in an International Context

Principles, standards, and actions corresponding to the prevention and control of vessel-source marine pollution are currently one of the most regulated areas of international law. Vessel-source pollution, or in more restricted terms "oil pollution" from ships, is not a new phenomenon [8]. Lessons learned from maritime incidents that have left their marks in history make it clear that the seas cannot continue to absorb oil contaminants and still remain healthy. The source of the pollution, i.e., the vessel in distress, requires immediate intervention by authorities concerned states and this action by authorities relates to the "precautionary principle" under international law [10]. The "precautionary principle" indicates that in certain situations it may not be necessary to wait for scientific certainty or conclusive scientific proof of actual or imminent harm before taking actions to control harmful activities that may cause irreversible damage to the marine environment [10]. It is generally understood that the global regulations related to oil pollution control stem from either the United Nations Convention on the Law of the Sea 1982 (UNCLOS) or from the "generally accepted international regulations and standards" as adopted by the International Maritime Organization (IMO) [8].

2.1 The OPRC Convention

As a response to the *Exxon Valdez* incident, the IMO adopted the International Convention on Oil Pollution Preparedness Response and Co-operation (OPRC) in November 1990. The initial connection between OPRC and "oil spill intervention" may be established through Article 2 insofar as "oil pollution incident" has been defined as:

> ... an occurrence or series of occurrences having the same origin, which results or may result in a discharge of oil and which poses or may pose a threat to the marine environment,

> or to the coastline or related interests of one or more States, and which requires emergency action or other immediate response [11]

Since the main essence of "intervention" revolves around the efforts to: (a) limit damage; (b) avoid a spill; or (c) contain the amount spilled from the source, the keywords observed in the aforementioned definition, i.e., "which results," "or may result," "discharge of oil," "which poses," and "or may pose a threat," elucidates the implied yet inherent connection between the OPRC and the notion of "oil spill intervention." In terms of immediate response or intervention actions, Article 3 of the OPRC makes it obligatory for each state party to require that ships entitled to fly its flag have on board a shipboard oil pollution emergency plan [11]. To confirm and ensure this "required" readiness of the Flag State, the Port State also has an obligation to inspect the ship and confirm that the operator has the oil pollution emergency plan in place in accordance with "international agreements" or its "national legislation" [11]. From a purely "intervention" perspective, the Flag State is considered to be the first responder if there is a need to intervene in an oil pollution incident. In all other cases, the OPRC stresses "international co-operation in pollution response" as encapsulated in Article 7 of the Convention. As the title suggests, parties are asked to cooperate in every aspect "when the severity of such incident so justifies" and "upon the request of any party affected or likely to be affected" [11]. From an analysis of the wordings of Article 7(1), it is presumed that "likely to be affected" can be considered as being synonymous with "near spill," which has an "imminent factor" involved. This hypothesis emanates from the fact that "intervention" is a word that is not readily used in the OPRC itself and the flexibility of the phrase "likely to be affected" needs to be taken into consideration. Furthermore, based on the arrangements of wordings in Article 5, the OPRC is observed to promote intervention cooperation at the international level:

> (1) Whenever a Party receives a report referred to in article 4 or pollution information provided by other sources, it shall: (a) assess the event to determine whether it is an oil pollution incident; (b) assess the nature, extent and possible consequences of the oil pollution incident; and (c) then, without delay, inform all States whose interests are affected or likely to be affected by such oil pollution incident, together with (i) details of its assessments and any action it has taken, or intends to take, to deal with the incident, and (ii) further information as appropriate, until the action taken to respond to the incident has been taken . . . [11]

It should be noted that 19 out of 23 Mediterranean countries bordering the Mediterranean Sea are parties to the OPRC. These Mediterranean Sea countries include Gibraltar, Spain, France, Monaco, Italy, Malta, Slovenia, Egypt, Croatia, Albania, Greece, Turkey, Syria, Lebanon, Israel, Libya, Tunisia, Algeria, and Morocco.

2.2 The Intervention Convention

The only Convention that has explicitly used the term "intervention" is the 1969 Intervention Convention and the scope of the Convention is limited to oil pollution on the high seas [12]. The Intervention Convention was ratified by the governments of 29 states by 1977 and came into force in 1975. Although the term "intervention" has not been distinctively defined in the "definition" section (Article II), the Intervention Convention has nevertheless, provided a definition of "maritime casualty." It is also observed that the words that are used in Article 1 refer to the conditions that may give rise to an "intervention" operation and includes both "pollution" and "threat of pollution":

> Parties to the present Convention may take such measures on the high seas as may be necessary to prevent, mitigate or eliminate grave and imminent danger to their coastline or related interests from pollution or threat of pollution of the sea by oil, following upon a maritime casualty or acts related to such a casualty, which may reasonably be expected to result in major harmful consequences [12]

Under Article III of the Intervention Convention, the Coastal State is under an obligation to consult with "independent experts" before proceeding to undertake any measures. However, it should also be noted that consultations can be overridden in cases of extreme urgency, and whereto there is a need to take immediate measures [12]. More often, it seems that a threat from an "oil spill" can at any stage transpose to an actual "oil spill incident" and "consultation" with other parties may take up the time that could be used to control the pollution at source. To remedy the situation, the Coastal State has a prerogative to take measures rendered necessary by the urgency of the situation. This oil spill intervention action can be undertaken by the Coastal State "without prior notification or consultation or without continuing consultations already begun" in accordance with Article III of the Convention [12].

Similar to the OPRC Convention, the Intervention Convention incorporates the word "consultation" instead of "cooperation." In this context, it can be deduced that consultation and cooperation are participatory processes, which involve the participation of various stakeholders, i.e., Flag State and Coastal State in the decision-making and the successful completion of an "oil spill intervention operation." The term "consultation," as implemented in the Intervention Convention, is a medium to increase transparency and trust by establishing a dialogue over objectives, projects, needs, and problems. It is noteworthy that 9 out of 23 Mediterranean Coastal States had become parties to the Intervention Convention by late 1977 and as of April 2016, the number has increased to 13, i.e., Spain, France, Monaco, Italy, Slovenia, Egypt, Croatia, Montenegro, Syria, Lebanon, Tunisia, Algeria, and Morocco.

The Intervention Convention has emerged with a certain limitation and stirred international debate due its departure from the traditional principle of "freedom of the high seas." This was the first time that states, other than the Flag States, were granted permission to take preventative, mitigating, and intervention actions against foreign vessels on the high seas in cases where oil pollution posed a threat.

However, from a positive perspective, the Intervention Convention is unique in the sense that it has done its best to address immediate response issues that emanate from "grave and imminent danger" and has paved a roadmap for Coastal States to follow and undertake "oil spill intervention" actions in sensitive areas through mutual cooperation.

2.3 The Barcelona Convention and Regional Cooperation

The Convention for the Protection of the Mediterranean Sea Against Pollution, also known as the "Barcelona Convention," entered into force on 12 February 1978 [13]. It was modified by amendments in 1995 by the "Conference of Plenipotentiaries on the Convention for the Protection of the Mediterranean Sea against Pollution and its Protocols" [13]. The amended Convention was renamed to the "Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean." The "precautionary principle" and the "polluter pays principle" are the two doctrines that are suggested to be applied by the Contracting States whereby the former relates to cost-effective measures, which need to be applied without delay, and the latter identifies with costs, which are related to pollution prevention, control, and reduction. It is important to mention that the Barcelona Convention currently has 22[3] Contracting parties. The main objectives of the Barcelona Convention include:

(a) to assess and control marine pollution;
(b) to ensure sustainable management of natural marine and coastal resources;
(c) to integrate the environment in social and economic development;
(d) to protect the marine environment and coastal zones through prevention and reduction of pollution, and as far as possible, elimination of pollution, whether land- or sea-based;
(e) to protect the natural and cultural heritage;
(f) to strengthen solidarity among Mediterranean Coastal States; and
(g) to contribute to improvement of the quality of life [14].

The Barcelona Convention is based on a Mediterranean Action Plan (MAP) that was signed in 1975 and adopted by 16 Mediterranean countries and the European Community. It is relevant to mention that the Mediterranean became the first region to adopt an Action Plan in 1975, just after the creation of the Regional Seas Programme in 1974. The Barcelona Convention has seven Protocols that address different aspects of environmental conservation:

[3]Albania, Algeria, Bosnia and Herzegovina, Cyprus, the European Community, Croatia, Egypt, Spain, France, Greece, Israel, Italy, Lebanon, Libya, Malta, Morocco, Monaco, Montenegro, Slovenia, Syria, Tunisia, and Turkey.

(1) Dumping Protocol (from ships and aircraft) of 1995;
(2) Prevention and Emergency Protocol (pollution from ships and emergency situations) of 2002;
(3) Land-based Sources and Activities Protocol of 1980;
(4) Specially Protected Areas and Biological Diversity Protocol of 1995;
(5) Offshore Protocol (pollution from exploration and exploitation) of 1994;
(6) Hazardous Wastes Protocol of 1996;
(7) Protocol on Integrated Coastal Zone Management (ICZM) of 2008.

When it comes to matters concerning first response, imminent danger, containment of near spills or actual spills, it seems that state responsibility is not the sole basis of giving effect to international law. Civil liability, in this context, can serve as an option. Several treaties dealing with civil liability have merged to form a comprehensive civil liability regime and in reality, due to the shortage in the number of ratifications, these treaties dealing with civil liability, such as the Protocol on Civil Liability for Damage Caused by Transboundary Effects of Industrial Accidents on Transboundary Waters of 2003, have not yet entered into force. On the other hand, some of the treaties, which are currently in force, do not adequately embody the core concept of "intervention" and even if there is adequate relevance, it is not tailor made to fit all Sea regions. Therefore, consideration has to be given to regional initiatives based on cooperation, which are decided, agreed upon, and entered into by concerned states of a particular region. The reason behind regional cooperation is quite clear. Through regional cooperation, states come together to achieve a few common goals, e.g., to "restrict" the spread of pollution or "control" pollution at source. The Protocol of the Barcelona Convention that reflects regional cooperation and one that is relevant to "oil spill response" or "intervention" is the Protocol Concerning Cooperation in Preventing Pollution from Ships and, in Cases of Emergency, Combating Pollution of the Mediterranean Sea adopted in 2002 (1978 Protocol) [15]. Article 1 of the 1978 Protocol contains the basic definitional element of "intervention" and this is evident from the usage of specific words (for example, "grave and imminent danger"):

> The Contracting Parties to this Protocol (hereinafter referred to as "the Parties") shall cooperate in taking the necessary measures in cases of grave and imminent danger to the marine environment, the coast or related interests of one or more of the Parties due to the presence of massive quantities of oil or other harmful substances resulting from accidental causes or an accumulation of small discharges which are polluting or threatening to pollute the sea within the area defined in article 1 of the Convention for the Protection of the Mediterranean Sea against Pollution [15]

The 1978 Protocol has the same features as observed in regional agreements for the Baltic Sea and the North Sea insofar as it highlights the responsibility of "competent national organization or authorities" (Article 6) [15]. Moreover, similar to the OPRC, a nexus can be established between the 1978 Protocol and "intervention" through the definition of "pollution incident" as incorporated in Article 1 [15]. One of the important Articles of the 1978 Protocol is Article 10 entitled "operational measures" that suggests Contracting States to take pragmatic measures to "prevent, reduce and, to the fullest possible extent, eliminate the effects of the pollution incident" whether it is oil or other noxious substances [15]. Again, the 1978 Protocol is commendable, as it makes an effort to cover significant points of what is known as "oil spill intervention." The three keywords, i.e., prevent, reduce, and eliminate, can be hypothesized as being synonymous to avoid, limit, and contain the three inherent features related to the term "intervention." It is observed that the 1978 Protocol is primarily founded on "cooperation" and endeavors to promote "cooperation" in every aspect and is consistently spread across the 13 Articles of the Protocol. The 1978 Protocol also encourages Coastal States to "promote" respective contingency plans (Article 3) and to "develop" monitoring activities (Article 4) [15]. Finally, the "assistance" aspect pursuant to the 1978 Protocol can be seen as an essential pre-requisite for the success of an "immediate response" or "intervention" operation and is also observed to be in sharp contrast with the Intervention Convention, which emphasizes only "consultation."

2.4 MARPOL 73/78

The IMO instrument that has always been the center of discussion when it comes to operational spills and accidental spills is the International Convention for the Prevention of Pollution from Ships, 1973 as Modified by the Protocol of 1978 (MARPOL 73/78). All countries bordering the Mediterranean Sea region (except Bosnia and Herzegovina) are parties to both Annex I and Annex II of MARPOL 73/78. Pursuant to Annex I Regulation 47 of MARPOL 73/78, oil tankers of 150 gross tonnage (GT) and above, as well as all ships of 400 (GT) and above, must carry an approved Shipboard Oil Pollution Emergency Plan (SOPEP) [16]. This is observed to be similar to the requirement of a shipboard emergency plan as incorporated in Article 3 of the OPRC. From a generic context, Annex II Regulation 17 of MARPOL 73/78 requires all ships of 150 gross tonnage and above that carry "noxious liquid substances" in bulk to have an SOPEP approved by the national administration [17]. Moreover, for practical reasons, these plans could be combined into one single plan and if combined, the "joint" plan should be called Shipboard Marine Pollution Emergency Plan (SMPEP). In order to meet the requirements of these emergency plans, IMO has issued Guidelines for the Development of Shipboard Marine Pollution Emergency Plans in 2010 [18]:

> To help Administrations and shipowners meet these requirements, IMO has produced the Guidelines for the Development of Shipboard Marine Pollution Emergency Plans, 2010 Edition which includes Guidelines for the development of Shipboard Oil Pollution Emergency Plans (SOPEP) (resolution MEPC.54(32), as amended by resolution MEPC.86 (44) and Guidelines for the development of Shipboard Marine Pollution Emergency Plans of Oil and/or Noxious Liquid Substances (Resolution MEPC.85(44), as amended by resolution MEPC.137(53)). [18].

These guidelines indicate that the plan must provide specific guidance for dealing with a range of issues, for example, pipe leakage, tank overflow, hull leakage, groundings, fire, and collision [19]. These comprise the intervention aspects and procedures and can be termed as fairly detailed. Examples can be cited from the New Shipboard Oil Pollution Emergency Plan (SOPEP) Manual whereby the US Coast Guard (USCG) provides clear intervention instructions in terms of first response measures, which are closely tied to operator responsibility:

> Possible sources for hull leakage are welded seams and cracks in hull plating due to fatigue or stress. Oil leakage can occur above or below the water line. The appropriate agencies should be notified and the following considered:
>
> When oil sheen is observed around the vessel, any bunkering operations should be stopped immediately. Shore-side personnel should be notified immediately ... Depending on the location of the leak, it may be necessary to bring the oil level below the water line ... If the source of oil leak from the hull is below the water line, identification of the compartment may prove difficult due to tidal and current conditions. When the source is identified, any deck openings, e.g., ventilation pipes, filling lines or sounding tubes on the damaged tank should be closed to hermetically seal the tank and avoid further release of oil overboard.
>
> If divers are unable to identify the source of the underwater leak, then to the extent possible, the oil level should be reduced in tanks nearest to the source. That may be possible through internal transfer to other tanks, or, if along side a terminal, pumped ashore ...[20]

3 Mediterranean Zones and National Legislation on Oil Spills

"Near spills" and "oil spills" are common phenomena and originate from maritime casualties. Since many of them are accidental, it is hard to presume as to when, where, or how they will occur. However, to remedy the situation, oil spill preparedness, prevention, and response are the best strategies for avoiding potential or significant damage to human health and the environment. Hence, prevention of a near spill or response to an actual spill is primarily an issue that is linked to an "intervention" or "first response" process. Once a spill occurs, the best approach for containing and controlling the spill is to respond quickly in a well-organized manner. It is generally understood that a "first response" will be quick and organized if intervention measures have been planned ahead of time. Moreover, this success also depends on weather conditions, the area of the maritime zone in question and the time it may take for the first responder to reach the incident site. The national contingency plans are more or less developed taking into consideration the total area of the coastline, the offshore areas, and the areas within national jurisdiction.

3.1 Maritime Zones of the Mediterranean Sea

International environmental law has developed and reached a level of high standard during the past few decades, and as a result, the world has seen the emergence of several core principles that provide for a framework of customary international law [21]. These core principles have been consolidated and codified in different international environmental legal instruments [21]. The umbrella Convention, i.e., UNCLOS, is one such instrument that is a unified effort by the international actors to provide a "Charter of the Ocean" that could act as a basic framework to deal with issues concerning maritime boundary delimitation and usage of the ocean space [21, 22]. Under UNCLOS, Flag States and Coastal States enjoy prescriptive and enforcement jurisdiction so that all maritime activities can be governed in a rational manner.

In the context of boundary delimitation, a range of maritime zones, i.e., Internal Waters, Territorial Sea, Contiguous Zones, and Exclusive Economic Zones (EEZ), have been established in the Mediterranean pursuant to the provisions of UNCLOS. The status quo maritime zones of different states within the Mediterranean is quite complex and in some cases undetermined and unresolved [23]. The coastline of the Gaza Strip, which has a 40 km coastline, is one case the legal status of which is complex and controversial [23]. While many of the Mediterranean Coastal States have claimed a 12 nautical mile (nm) Territorial Sea, some countries, i.e., Greece and Turkey, have claimed 6 nm [23]. Gibraltar, in this respect, has claimed a Territorial Sea with a breadth of 3 nm [23]. A majority of these countries have already adopted applicable national legislation to seal their claims (see Table 1).

To date, only 11 Mediterranean countries, i.e., Algeria, Cyprus, Egypt, France, Italy, Malta, Monaco, Morocco, Spain, Syria, and Tunisia, have claimed a Contiguous Zone that extends to 24 nm [23]. Although a few states, i.e., Algeria, Bosnia and Herzegovina, are not geographically positioned to claim an EEZ, a number of Mediterranean countries have proceeded to establish "derivative zones" based on applicable national legislation [23]. These zones are considered to be broad enough to establish (full) EEZs [23]. It is also observed that some countries, such as Albania, have national legislation in place, but have not taken any steps to establish an EEZ. On the other hand, countries like Lebanon have lodged the coordinates of its EEZ based on a national instrument (Law no. 163 of 2011) with the UN and to that extent has deposited a decree setting out its EEZ boundaries [23]. Again, in an effort to understand the maritime zones of different Mediterranean Coastal States, it can be said that many of the boundary delimitations are governed by agreements between two or more States (see Table 2). Some of the important agreements/treaties include:

Table 1 Mediterranean coastal states with a Territorial Sea claim and relevant national instrument

Mediterranean country	Applicable domestic instrument
Albania	Law on the State Border 2008
Algeria	Decree No. 63-403 of 12 October 1963 establishing the Breadth of the Territorial Waters
Croatia	Maritime Code of 1994
Cyprus	Treaty concerning the Establishment of the Republic of Cyprus (Annex A) 19 August 1960
Egypt	Decree concerning the Territorial Waters of the Arab Republic of Egypt of 15 January 1951, as amended by presidential Decree of 17 February 1958
France	Law No. 71-1060 of 24 December 1971 regarding the delimitation of French territorial waters
Greece	Law No. 230 of 17 September 1936
Israel	Territorial Waters Law, 5717/1956, as amended by the Territorial Waters (Amendment) Law, 5750-1990, of 5 February 1990
Italy	Navigation Code of 30 March 1942, as amended by Law No. 359 of 14 August 1974, Law No. 1658 of 8 December 1961 authorizing accession to the Convention on the Territorial Sea and the Contiguous Zone, adopted at Geneva on 29 April 1958, and giving effect to that Convention
Lebanon	Legislative Decree No. 138 concerning territorial waters and sea areas, of 7 September 1983
Libya	Gulf of Sirte Claim United Nations, Legislative Series, ST/LEG/SER.B/18, p. 26
Malta	Territorial Waters And Contiguous Zone Act, 10th December, 1971 as amended
Monaco	Act No. 1,198 of 27 March 1998 containing the Code of the Sea
Montenegro	Maritime and Inland Navigation Law, 12/98
Morocco	Dahir concerning Act No. 1-73-211 of 26 Muharran 1393 (2 March 1973) establishing the limits of the territorial waters and the Exclusive Fishing Zone
Palestine	The 1995 Israeli–Palestinian Interim Agreement regarding the West Bank and the Gaza Strip states that the territorial jurisdiction
Slovenia	Maritime Code 2001, as amended
Spain	Act No. 10/1977 of 4 January 1977
Syria	Law No. 28 of 19 November 2003
Tunisia	Act No. 73-49 delimiting the territorial waters, of 2 August 1973
Turkey	Act No. 2674 of 20 May 1982, on the Territorial Sea of the Republic of Turkey
UK – Gibraltar	Interpretation and General Clauses Act 1962 and other references in legislation

Source: MRAG Ltd. In partnership with IDDRA and LAMANS Management Services S A (2013) Client: European Commission, DG MARE. Costs and benefits arising from the establishment of maritime zones in the Mediterranean Sea, Final report (Original Source: Maritime Space: Maritime zones and Maritime Delimitation http://www.un.org/Depts/los/LEGISLATIONANDTREATIES/europe.htm)

Table 2 Important boundary delimitation agreements of the Mediterranean

Name of the agreement/treaty	Year
Agreement on Provisional Arrangements for the Delimitation of the Maritime Boundaries between the **Republic of Tunisia** and the **People's Democratic Republic of Algeria** (with annex of 7 August 2002)	6 December 1978
Treaty on the State Border between the **Republic of Croatia** and **Bosnia and Herzegovina**	30 July 1999 (yet to be ratified by either party)
Agreement between the **Republic of Cyprus** and the **Arab Republic of Egypt** on the Delimitation of the Exclusive Economic Zone	17 February 2003
Agreement between the Government of the **State of** Israel and the Government of the **Republic of Cyprus** on the Delimitation of the Exclusive Economic Zone	17 December 2010 (Signed); Entry into force 25 February 2011
Agreement between the **Republic of Cyprus** and **Lebanon** on the Delimitation of the Exclusive Economic Zone	January 2007
Agreement between the Government of the **French Republic** and the Government of the **Italian Republic** on the Delimitation of the Maritime Boundaries in the Area of the Strait of Bonifacio	28 November 1986
Agreement between the Government of the **Republic of Tunisia** and the Government of the **Italian Republic** concerning the Delimitation of the Continental Shelf between the two countries	Entry into force 6 December 1978
Agreement between the **Great Socialist People's Libyan Arab Jamahiriya** and the **Republic of Malta** implementing Article III of the Special Agreement and the Judgment of the International Court of Justice	29 January 1987 (ratified)

Source: MRAG Ltd. In partnership with IDDRA and LAMANS Management Services S A (2013) Client: European Commission, DG MARE. Costs and benefits arising from the establishment of maritime zones in the Mediterranean Sea, Final report (Original Source: Maritime Space: Maritime zones and Maritime Delimitation http://www.un.org/Depts/los/LEGISLATIONANDTREATIES/europe.htm)

3.2 Intervention and National Contingency Plans

In a number of cases, the process of determining the different layers of maritime zones is incomplete due to the lack of political will or simply because the adjacent or opposite states have failed to come to an agreement. In hindsight, given the fact that IMO has designated the Mediterranean Sea as a "special area"[4] – the concerned

[4]Through Annex I of MARPOL 73/78, the Mediterranean Sea proper including the gulfs and seas therein with the boundary between the Mediterranean and the Black Seas constituted by the 41°N parallel and bounded to the west by the Straits of Gibraltar at the meridian of 5°36′W" as a "special area" in which, "for technical reasons relating to their oceanographic and ecological condition and to their sea traffic, the adoption of special mandatory methods for the prevention of sea pollution is required."

Coastal States should have acted differently. In the midst of this complex and uncertain situation, two positive points can be gathered from certain actions by the Coastal States: (a) the states are making an effort through agreements/treaties (see Table 2) to reach an understanding; and (b) Coastal States have established a large number of Marine Protected Areas (MPA) in areas within national jurisdiction [23]. These actions, to a certain extent, solidify the Coastal State's commitment to protect and preserve the marine environment. But the inevitable question is – what effect do unresolved maritime boundary issues have on oil spill interventions?

An immediate response or intervention plan should be mapped out on the basis of a state's maritime-geography and the roles and responsibilities of maritime authorities, governmental departments, and first responders are allocated and divided on the basis of the total area that comprises the maritime-geography of a particular Coastal State. Furthermore, based on the total area of different maritime zones, the government may allocate resources; e.g., aerial surveillance, satellite surveillance, helicopters, and vessels of opportunity. In some cases, the regional chapters of a country's contingency plan detail and outline the action procedures, resources, and strategies used to prepare for and conduct a response to a marine pollution incident within a region's geographic area [24].

All in all, the concerned authorities must be aware and well-informed about the geographical points of coastal waters and the geographical coordinates of the areas beyond national jurisdiction. There needs to be a clear understanding of where national jurisdiction begins and where it ends. If the maritime boundary is properly delimited, the government can then station authorities in different parts with specific management responsibilities. Although "intervention" can be seen as that readiness to respond in the likelihood of a spill or that immediate response to contain a certain amount of oil that is spreading fast, underneath it all, there are numerous complex layers. An undetermined boundary adds to the complexity and has a chance of frustrating the emergency response operation developed under the national contingency plan. It should be borne in mind that "intervention" is not merely a phase, it is also a continuum with sensitive features. During an intervention operation, authorities should ensure that all resources are at hand and there are no internal slips or discontinuity through any kind of disturbance. If the Mediterranean Coastal States have entered into maritime boundary delimitation agreements, it may be argued that the Coastal State authorities will not face any form of disturbance in an oil spill intervention operation. However, maritime boundary delimitation can be seen only as a part of the problem. The smoothness of the operation will largely depend on the way the national response plans or national contingency plans have been structured. The following table provides an overview of the competent national authorities involved and oil spill response plans developed by respective governments of the Mediterranean Sea region.

It is observed that (see Table 3) with the exception of Lebanon and Libya, the other countries have a form of contingency plan in place to deal with emergency spills. Although it is not possible to provide a detailed evaluation of each and every plan, a cursory observation from the titles of individual national plans makes it clear that the plans solely focus on response. Although more than half of the

Table 3 Concerned authority and response arrangements of individual Mediterranean coastal state

Country	Concerned authority	Response arrangements
Albania	National Environmental Agency	A national contingency plan and national system for accidental marine pollution, preparedness, and response was adopted in July 1993
Algeria	Comite National (TELBAHR) (for Oil and HNS) Ministère de l'Aménagement du Territoire et de l'Environnement	A National Contingency Plan was adopted in 1994
Croatia	Ministry of Interior	A national contingency plan for accidental marine pollution, extending to the 12-mile territorial limit, was adopted by the government of the Republic of Croatia in January 1997
Cyprus	(1) Department of Fisheries and Marine Research (for Oil and HNS) (2) Ministry of Agriculture, Natural Resources and Environment	A National Contingency Plan was developed in 1983. It was updated in 1997 and underwent review in 2011
Egypt	Egyptian Environmental Affairs Agency	A National Oil Spill Contingency Plan was implemented in 1986
France	(1) Préfecture maritime de la Manch et de la Mer du Nord; (2) Préfecture maritime de la Méditerranée; (3) Préfecture maritime de l'Atlantique	Response arrangements are governed by the "At sea pollution response" section of ORSEC MARITIME (Organization de la Réponse de Sécurité Civile), i.e., France's civil defence plan
Gibraltar	Gibraltar Maritime Authority	Gibraltar Oil Spill Contingency Plan (updated in 2015)
Greece	Marine Environment Protection Division	Greek National Contingency Plan
Israel	(1) Marine and Coastal Environment Division (2) Ministry of the Environment	National Contingency Plan for Preparedness and Response to Combating Marine Oil Pollution (approved by government in 2007)
Italy	Ministero dell'Ambiente (Ministry of Environment) (HNS and Oil)	Two national plans exist for the Ministry of Environment and for the Department of Civil Protection
Lebanon	Service of Regional Departments and Environmental Police (for Oil and HNS)	**No national contingency plans**
Libya	Environment General Authority	**No national contingency plans**
Malta	(1) Pollution and Incident Response (for Oil and HNS) (2) Malta Planning and Environment Authority (3) Transport Malta	The National Marine Pollution Contingency Plan of 2010
Monaco	Direction des Ports et du Service de la Marine	In the event of an incident the Monaco authorities would collaborate closely with France under the French National

(continued)

Table 3 (continued)

Country	Concerned authority	Response arrangements
		Contingency POLMAR plans and the RAMOGEPOL plan (which details response arrangements between France, Monaco and Italy)
Montenegro	Ministry of Maritime Affairs, Transportation, and Telecommunications	The Montenegro National Contingency Plan for Response to Marine Pollution from Shipping and Offshore Installations
Morocco	Ministère de l'Environnement (for oil and HNS)	National Contingency Plan of 1996
Slovenia	(1) Administration for Civil Protection and Disaster Relief (2) Ministry of Transport	National Contingency Plan
Spain	Dirección General de la Marina Mercante (DGMM)	Royal Decree 253/2004 on prevention and counter pollution measures in maritime and port activities. In 2006 the Spanish government approved a new national plan which contains practical measures to augment its response capability
Syria	Directorate General for Ports (for Oil and HNS)	A draft national contingency plan for oil and other hazardous substances was prepared in 2003 but it was never tested or exercised. Syria is updating the plan with assistance from the Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea (REMPEC) (information current May 2011)
Tunisia	(1) Agence Nationale de Protection de l'Environnment (ANPE) (2) Ministère du Transport	A national contingency plan was prepared in March 1996, covering two levels of emergency – national and regional
Turkey	(1) Ministry of Environment and Forestry (MOEF) (2) Ministry of Transport, Maritime Affairs and Communications	The Undersecretariat for Maritime Affairs has ultimate responsibility for dealing with oil pollution at sea and the Ministry of Environment and Forestry (MOEF) undertakes or causes to be undertaken the necessary response measures, as formalized under the framework of Law 5312 adopted in 2005

Source: Official homepage of the International Tanker Owners Pollution Federation (ITOPF) http://www.itopf.com/knowledge-resources/countries-regions/mediterranean/. Retrieved 8 May 2016 (*N.B*. No information is provided on Bosnia and Herzegovina, State of Palestine oil spill national plans and it is unclear whether there are any ongoing plans to implement such plans at the national level)

Mediterranean Coastal States are parties to the Intervention Convention, it is unlikely that the aforementioned plans give due consideration to the term "intervention." Again, intervention is marked by a form of advanced response system that contains alternative methods, for example: (a) electronic tools for faster and more reliable data collection; (b) advanced electronic tools for quick and efficient mapping and surveys; (c) Unmanned Aerial Vehicle (UAV) technology to provide rapid and accurate geo-referenced imagery for both planning and evaluating the effectiveness of clean-up efforts; and (d) special "caps" to seal a developing leak. In the review process, the governments need to update their contingency plans and provide specific reference to these alternative methods and consider other aspects that might be useful to the first responders. It is also observed that in most cases the governments do not allow the use of dispersants and its usage has not been covered by specific national regulations. Moreover, when it comes to dispersants, a number of issues need to be considered and regulated; i.e., selection of dispersant products that can be used, the specific zones where they may be allowed or prohibited and their place in the response strategy. If these factors are not considered, they may not produce the desired results and on the contrary, pose additional risks to the environment.

In a maritime casualty, whether it means a collision of ships/oil tankers, stranding or other incident related to navigational safety, or any occurrence on board a ship – time is an essential factor. Whether it is a mechanical failure that can be fixed, a response to operational or mystery spills from vessels, or directing the distressed vessel to a place of refuge, the term "intervention" needs to be clearly defined and marked by a possible timeframe in the national plans. Since imminent danger may differ from one incident to another and the time for intervention may vary according to the vessel size and the type of risk, one possible way to calculate the timeframe is to commence from the very minute an early alert or distress signal has been sent to the response authority to the very last minute it took the response authority to complete the intervention action. This can be developed via joint exercises by concerned adjacent or opposite Coastal states. Although there has not been any major tanker incident in the Mediterranean, some of the States that are a part of the European Seas have already experienced problems with accidental spills in the past. These States include France (grounding of the *Amoco Cadiz*, off Brittany: 223,000 tonnes), Italy (explosion of the *Haven*, Genoa: 144,000 tonnes), Spain (hull failure of the *Prestige*, off Cap Finistere: 62,657 tonnes), and Turkey (collision of *Nassia*, Black Sea: 33,000 tonnes).

4 Examples of a (Potential Spill) Intervention Plan for the Mediterranean

Coastal States are becoming increasingly concerned about ecological and natural resource damage from tanker accidents. The concern is constant for the governments of the Mediterranean Sea region. The orthodox oil spill response system is being modified and taken to the next level by a few maritime nations. The paradigm shift of using “intervention” to deal with oil pollution has already begun and maritime nations, i.e., the UK and Australia, have already vested authorities with “intervention” powers to deal with near spills or potential spills. For the UK, there is the Secretary of State’s Representatives for Maritime Salvage and Intervention (SOSREP) and an important function of SOSREP is “acting at the earliest point during a shipping or offshore incident to assess the risk to safety, to prompt the end of any such incident and to ensure that increasing risk is evaluated and appropriate measures taken to prevent or respond to any escalation of risk” [24, 25]. The powers of the SOSREP are clearly indicated in the UK National Contingency Plan and the legal foundation of the Plan is Section 293 of the Merchant Shipping Act of 1995 (MSA), as amended by the Merchant Shipping and Maritime Security Act of 1997, the Pollution Prevention Control Act of 1999, and the Marine Safety Act of 2003 [24, 25]:

> The SOSREP has the ultimate and decisive voice for maritime salvage, offshore containment and intervention. The SOSREP role does not include any responsibility for either at sea or shoreline clean-up activities. In the unlikely event of conflicting priorities between the “at-sea” and “land based” response cells, the SOSREP may, where appropriate, consider exercising the intervention powers where actions being taken, or being proposed, are not deemed to be in the overriding UK public interest [25].

The role of the SOSREP is to represent the Secretaries of State for the Department of Transport and for the Department of Energy and Climate Change. The former representation is in relation to ships while the latter is in relation to offshore installations. It is noteworthy that the government of UK has extended the power of SOSREP to territorial waters, i.e., 12 nautical miles from the coast (baseline) and to the UK Pollution Control Zone, i.e., 200 nautical miles or the median line with neighboring states. The SOSREP works closely with the Marine and Coastguard Agency (MCA), its parent organizations, i.e., the Department for Transport (DFT) and the Department of Energy and Climate Change (DECC) [26].

The key responsibilities of SOREP are

(a) acting at the earliest point during a shipping or offshore incident to assess the risk to safety, to prompt the end of any such incident, and to ensure that increasing risk is evaluated and appropriate measures taken to prevent or respond to escalation;
(b) monitoring all response measures to significant incidents involving shipping and the offshore industry;
(c) if necessary, exercising control by implementing the powers of intervention, acting in the overriding interests of the UK and its environment;
(d) participating in major national and international exercises;
(e) reviewing all activities after significant incidents and exercises; and
(f) intervening if there has been any occurrence causing material damage or a threat of material damage to an offshore installation [26, 27]

Similar to SOSREP, the Australian Maritime Emergency Response Commander (MERCOM) has the responsibility to ensure an appropriate level of response to shipping incidents in the Commonwealth waters and the "intervention" led by MERCOM is for incidents where there is "an actual or threat of significant pollution posed by ships" [28]. The MERCOM is appointed by the Australian Maritime Safety Authority (AMSA) pursuant to the Protection of the Sea (Powers of Intervention) Act of 1981 (Act of 1981) [29, 30]. MERCOM is empowered to issue direction to the owner or the master of ship if it is: (a) in Internal Waters; or (b) in the Australian coastal sea; or (c) in the EEZ of Australia; or (d) an Australian ship [29]. If the maritime casualty is on the High Seas, then the authority may take a number of actions:

> (a) the taking of action, whether or not directions have been issued under paragraph (b) in relation to the ship:

(i) to move the ship or part of the ship to another place;
(ii) to remove cargo from the ship;
(iii) to salvage the ship, part of the ship or any of the ship's cargo;
(iv) to sink or destroy the ship or part of the ship;
(v) to sink, destroy or discharge into the sea any of the ship's cargo; or
(vi) to take over control of the ship or part of the ship . . . [29]

5 Conclusion

In 2008, the Contracting parties to the Barcelona Convention adopted the ecosystem approach roadmap in view of an ecological vision for the Mediterranean as "a healthy Mediterranean with marine and coastal ecosystems that are productive and biologically diverse for the benefit of present and future generations" [31]. Three years into the adoption of the ecosystem approach, the UNEP/Barcelona Convention Initial Integrated Assessment was completed [32]. The 2011 Assessment provides a sharp conclusion that "despite compelling evidence of the importance of services delivered by Mediterranean coastal and marine systems . . . ecosystem degradation continues" [32]. In the list of many pressures and impacts, the 2011 Assessment includes disturbance and pollution from maritime industries. Although the IMO has given the Mediterranean Sea the title of "special area" and Coastal States have established MPAs, the question is whether the ecosystem degradation caused by increased maritime traffic can be properly addressed?

Due to its geographical and historical characteristics, authors have dubbed the Mediterranean as an original and unique eco-region that is comprised of 23 countries and territories [33]. Due to these unique and special characteristics, the region brings Coastal States of the Mediterranean region together in a common platform guided by a common interest, i.e., the protection of the Mediterranean Sea from pollution [33]. To this end, the Regional Oil Combating Centre (ROCC) was established in 1976 with the mandate to strengthen the capacities of the Mediterranean Coastal States to deal with marine pollution by "oil" [34]. The ROCC was renamed in 1989 to REMPEC, currently administered by the IMO in cooperation with UNEP/MAP [34]. Although renamed to REMPEC, the objective of ROCC remains constant [34]. One of the many scopes of action of REMPEC includes assisting Coastal States of the Mediterranean region in the development of national capabilities in terms of oil spill response.

Although many of the Coastal States have already developed national contingency plans to combat and prevent oil pollution, the efforts of REMPEC to assist the Coastal States still continue. While some States continue to develop their own contingency plans with the help of REMPEC, it seems that even after development or amendment of national oil spill contingency plans, the response situation has a high chance of being frustrated due to the number of unresolved maritime boundary issues, which still persists among Coastal States. However, there is an indication that boundary problems are being resolved through agreements/treaties between two or more states. While this reveals a positive picture of the problem, there is an emerging issue that reveals a not-so-positive picture. The statistical analysis database from the 2011 Assessment, referred to earlier, of "alerts and accidents" shows that for "collision, grounding, sinking and "other" accidents, about 50–65% of the cases cause an oil release" [35]. The "statistical analysis" study also concludes that there is a decrease in the number of oil tanker accidents from 70% (between years 1977 and 1984) to 23% (between years 2004 and 2010) [35].

Although there is a decline in the percentage of oil tanker accidents, considering the "original and unique eco-region" characteristics of the Mediterranean, 23% needs to be further reduced. Whether it is due to inconsistencies in recording the number of incidents or boundary issues, the 23% tanker incidents will continue to cause irreparable damage to the marine environment and as such, national measures aimed at limiting, preventing, or eliminating oil pollution caused by maritime industries should be encouraged. Although the Intervention Convention was adopted more than 3 decades ago, the concept of "intervention" has surpassed the original concept and many states have enforced a national "intervention" policy through which authorities "intervene" only in the likelihood of a spill. "Intervention" has been separated from "oil spill response" and pursuant to the UK and Australian legislation; they can be performed in both areas within and beyond national jurisdiction. As for Mediterranean Coastal States, the possibilities for development of an "intervention" plan are yet to be ventured into.

The *Castor* incident in late December 2000/early January 2001 confirmed the absence of an "intervention" framework for the Mediterranean Sea region [36]. The damaged *Castor* tanker was towed around in the Mediterranean Sea for over a month before a place of refuge could be found where a "lightering operation" could be carried out. This raises the question as to whether the Mediterranean Coastal States should have pre-designated places that can provide a sanctuary to vessels in distress and help decline the chances of an accidental spill. Place of refuge is a concept that is considered to be an important part of "intervention." Example of this is ripe in other jurisdictions whereby authorities such as the SOSREP and the MERCOM have been given the power to move a "ship in distress" to a place to prevent pollution or limit the chances of a near spill. Even if there are ongoing efforts to develop a national contingency plan or even regional cooperation with the assistance of REMPEC, the *Castor* tanker event demonstrated the limited farsightedness of the Mediterranean Coastal States.

The Mediterranean Coastal States need not be torn between the definition provided in the International Convention and the definition as provided in the national laws of UK or Australia. The governments are free to define "intervention" based on their own experience with the Mediterranean "ecosystem approach." Whether the governments of the Mediterranean region want to cover only "response" in the "intervention plan or just simply deal with "near spill" needs to be determined sooner rather than later. Undoubtedly, maritime traffic will continue to increase and the shipping industry will continue to use the Mediterranean routes. While operational discharges can be lessened through stringent "zero discharge policy," the chances that accidental pollution will be contained are minimal. The Mediterranean Coastal States need to step up and define a solid action plan to deal with accidental vessel-source pollution before an incident similar to *Torrey Canyon* occurs in that region. Prevention through "intervention" is better than cure through "clean-up."

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The International Maritime Organization and Oil Pollution in the Mediterranean Sea

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Abstract Maritime transportation has diametric personalities. The advancement in global maritime transportation of oil products has resulted in commercial advantages. This advancement has simultaneously led to environmental disadvantages, sporadically leaving the marine environment in a detrimental position. "Commercial advantages" and "environmental disadvantages" are apparently two central issues that emanate from maritime transportation. Although the disadvantages cannot concretely outweigh the advantages, the "pollution" aspect has coastal states, environmentalists, marine biologists, and international organizations worrying whether economic gain is worth destroying the pristine environment. However, some environmentalists are optimistic and state that the marine environment has a form of resistance-capacity and time may heal the human-initiated damage leading to the point where nature will reinstate itself to its original status. However, what has changed today is that with the advancement in global maritime transportation, the impacts on the marine environment are no longer small, localized, and reversible. Incidents both accidental and operational in nature have raised serious environmental concerns. The Mediterranean Sea is no exception to this concern.

Data reveals that maritime activities in the Mediterranean have increased since the late 1900s and this "increase" will reach a higher plateau by 2018. While no major accidents have been recorded so far, the ubiquity, abundance, and broadness of detected operational spills in the Mediterranean have caught the attention of the International Maritime Organization (IMO). Hence, the Mediterranean Sea is

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distinguished as a "special area" and the need to control oil transportation has become a dire need in order to save the region from anthropogenic impacts. Similar to many anthropogenic impacts on natural systems, oil pollution is one that, despite widespread recognition of the problem, is still growing and even if stopped immediately will persist in the marine environment for years to come. Scientists have proven that polycyclic aromatic hydrocarbons, a high molecular weight component (compound) of crude oil, are extremely difficult to clean due to its complex structure. The main problem associated with this component is that they cannot be absolutely degraded by bioremediation efforts. Since the rise in the number of maritime transportation is inevitable, to eradicate problems associated with illegal oil discharge, the Mediterranean Sea area has been designated as a "special area." The question is whether the initiatives of the IMO to establish a "zero discharge policy" are sufficient to control oil pollution in the Mediterranean Sea? This chapter will endeavor to answer that question.

Keywords Crude oil, Illicit discharge, International Maritime Organization, Maritime traffic, Mediterranean Sea, Oil pollution, Oil tanker, Operational pollution, Special area

Contents

1 Introduction

As far as the "dawn of civilization" is concerned, the sea has provided wealth to mankind by facilitating international trade and commerce and providing abundant natural resources. While the sea has been a boon to mankind since time immemorial, increased human activities have over the years placed significant pressure on the health of the marine environment through overexploitation of fisheries and the entry of pollutants from several diverse sources into the sea [1]. Even though land-based pollution is considered by far the greatest source of marine pollution, the United Nations Conference on the Law of the Sea of 1982 (UNCLOS) has also highlighted other sources of pollution, which includes "pollution from vessels," "pollution from installations and devices used in the exploration and exploitation of natural resources," and "pollution from other installations and devices operating in the marine environment" [2].

When it comes to vessel source pollution, "oil" is a category that has alarmed coastal states, environmentalists, marine biologists, and even international organizations. While "oil" can be categorized into many types, the main source of this substance at sea is "ships" that are either engaged with oil shipments or other commercial activities. Although the positive attributes of "oil" are undeniable, this substance in its many various forms is often described as an "endangerment" to sensitive environments, more specifically marine environments that have special oceanographic and ecological feature. The Mediterranean Sea area is considered to be one such environment which is vulnerable to the impacts of the so-called oil pollution and according to studies conducted in the late 1900s, the threats have escalated and in some cases, certain areas are observed to be already contaminated due to operational discharges from these oil tankers and commercial vessels. This chapter is, therefore, an effort to understand the work of the IMO in combating the detrimental effects of oil pollution in the Mediterranean Sea. As such, various primary and secondary sources have been taken into consideration in order to provide an overview of the current status of the Mediterranean Sea and the regulatory instrument(s) that are relevant in deterring illegal oil pollution in that sea region.

2 Definition of "Oil" and "Pollution"

While the list of pollution and pollutants are numerous in kind and type, the one single pollution that has constantly left a form of inimical-stain in the aftermath of any given maritime incident is pollution from the substance commonly known as "oil." It is observed that before setting out the rules and regulations on matters concerning oil pollution, international organizations or the concerned authorities have always made a commendable effort to narrow down the definition of the term "oil." This is quite evident from the fact that the term "oil" has been covered in the "definition" section of different conventions (see Table 1) and it should also be noted that some conventions provide further definitional interpretations of the different types of oil with the objective to outline and delimit the various categories, which the respective convention then proceeds to govern.

When it narrows down to the topic of protection of the marine environment from the detrimental effects of oil pollution, the first question that merits further scrutiny is: what constitutes pollution? The most common definition can be found in the Merriam-Webster dictionary whereby "pollution" has been defined as "the action of polluting especially by environmental contamination, with man-made waste" [3]. In short, it entails the introduction of detrimental contaminants that are outside the norm for a given ecosystem. In any given marine pollution scenario, the main element that tends to act as the central catalyst is man-made waste – in other words,

Table 1 Various definitions of "Oil"

Convention	Definition
International convention on civil liability for oil pollution damage of 1969	Article 1: "Oil" means any persistent oil such as crude oil, fuel oil, heavy diesel oil, lubricating oil, and whale oil, whether carried on board a ship as cargo or in the bunkers of such a ship
International convention relating to intervention on the high seas in cases of oil pollution casualties of 1969	Article 1: "Oil" means crude oil, fuel oil, diesel oil, and lubricating oil
International convention for the prevention of pollution from ships, 1973 as modified by the protocol of 1978	Annex 1, Chapter 1, Regulation 1 (Definitions): Oil means petroleum in any form including crude oil, fuel oil, sludge, oil refuse, and refined products (other than those petrochemicals which are subject to the provisions of Annex II of the present Convention) and, without limiting the generality of the foregoing, includes the substances listed in appendix I to this Annex
The international convention on oil pollution preparedness, response, and cooperation of 1990	Article 2: "Oil" means petroleum in any form including crude oil, fuel oil, sludge, oil refuse, and refined products
International convention on civil liability for oil pollution damage of 1992	Article 1: "Oil" means any persistent hydrocarbon mineral oil such as crude oil, fuel oil, heavy diesel oil, and lubricating oil, whether carried on board a ship as cargo or in the bunkers of such a ship
International convention on civil liability for bunker oil pollution damage of 2001	Article 1: "Bunker oil" means any hydrocarbon mineral oil, including lubricating oil, used or intended to be used for the operation or propulsion of the ship, and any residues of such oil

Definition of "oil" in accordance with international conventions from 1969 to 2001

any unwanted hazardous or toxic element that may disrupt the status quo nature of a certain environment or the marine ecosystem. From an international law perspective a more concise definition of marine "pollution" was developed and incorporated in article 1(4) of the UNCLOS:

> the introduction by man, directly or indirectly, of substances or energy into the marine environment, including estuaries, resulting in such deleterious effects as harm to living resources, hazards to human health, hindrance to marine activities, including fishing, impairment of quality for use of sea water and reduction of amenities. [2]

The aforementioned definition provides an overview of what constitutes marine "pollution" and from the specific wordings as incorporated in article 1(4), it is apparent that the contaminants can be in the form of "substance" or "energy" and in order to determine the types of "substance" or "energy," which are considered to be "pollutants" or contaminants, the precautionary approach and the ecosystem approach may be convenient and useful. Again, based on the definition as incorporated in article 1(4), it can be concluded that marine pollution emanates from a number of sources and the contaminants are numerous and varied in their effects [4]. Although UNCLOS has attempted to consolidate an all-embracing definition of "marine pollution" via article 1(4), scholars of international law stipulate that:

> [a]s this definition suggest, it is not the aim of international law to prevent all substances being added to the sea – many substances are harmless or are rapidly rendered so by the sea – but only those which have or are likely to have deleterious effects. For this reason, the definition has sometimes been criticized for not taking sufficient account of the need to prevent changes in the marine environment as such, and apart from any immediately identifiable possible deleterious effects. [5, 6]

It cannot be concretely determined whether article 1(4) embodies a sufficient definition to help determine the origin and specific nature of marine pollution; it nevertheless illustrates how pollution is generally perceived at the international level. The upside of this ambiguous definition is that it is comprised of the very basic features that enable one to have a general understanding of what constitutes marine pollution.

In simple terms, the commencing point of a marine pollution event in accordance with article 1(4) is that it should first and foremost be a human-initiated phenomenon and any harm via natural causes cannot be termed "human-initiated" and hence, those cannot be deemed as sources of marine pollution. Subsequently, the next step revolves around the impact that a human-initiated phenomenon has on the surrounding sea areas. This so-called impact or effect should be deleterious in nature in order to satisfy the central condition of pollution. Therefore, based on the textual formulation of article 1(4), it can be concluded that the substance or substances so introduced are labeled as pollutants or contaminants, and the harmful effect that these substance or substances have are considered to be what is known as pollution. Subsequently, if the word "substance" is replaced by the word "oil," it encapsulates not just an ordinary term, i.e., "oil pollution," but also hints the "cause and effect" of the term, which has been marked with considerable apprehension by concerned international organizations and expert bodies sponsored by these international organizations. It should be noted that the definition of "marine pollution" adopted by the Joint Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP[1]) is a verbatim copy of the definition as incorporated in article 1(4) of UNCLOS.

A quick observation from the titles of different international conventions (see Table 1) dealing with "oil pollution" gives the impression that oil pollution undoubtedly has a deleterious effect. The keywords used in the title of these conventions are "civil liability," "damage," "oil pollution casualties," and

[1]Established in 1969, is an advisory body comprised of specialized experts nominated by sponsoring agencies IMO, Food and Agricultural Organization of the United Nations, United Nations Educational, Scientific and Cultural Organization, World Meteorological Organization, World Health Organization, International Atomic Energy Agency, United Nations and United Nations Environment Programme.

"preparedness, response and co-operation," which makes it apparent that the substance called "oil" comprised of only three alphabets cannot be treated as a minor issue.

Another important point that needs to be clarified before dealing with "sources of oil pollution" is the difference in the terms "pollution" and "contamination," although the two terms are often used interchangeably to explain the deleterious effects of an oil spill. From a general perspective, "oil pollution" is a term that is found in international conventions and can be distinguished as a direct or indirect act of introducing oil to the marine environment. In short, it can have a "point source," i.e., a direct emission, or a "nonpoint source," i.e., an indirect transmission; as hinted in article 1(4) of UNCLOS. On the other hand, "contamination" is a term used by scientists and environmental experts to define and explain the negative changes brought by "oil" when exposed to the marine environment. In short, it refers to the "oil impurities" in water regardless of the source of events and one that alters the natural physio-chemical features that lead to the adulteration of the marine environment. While the "oil pollution" sources can be monitored and controlled, the process of restoring a site that has been contaminated with "oil," e.g., "crude oil, fuel oil, sludge, oil refuse and refined products" can be time consuming, laborious, and complex. As such, the effect oil has on water continues to be a matter of great concern even in the twenty-first century.

The "cause and effect" of "oil pollution" begins to unravel a different face of "oil" even though it is currently considered as the lifeblood of maritime transportation. But the deleterious effects of oil begin to far outweigh its advantages and slowly trigger a number of specific thoughts. A fish, oil soaked and dead, a bird, lifeless and covered with oily substance, or a sandy beach, the sand grains of which are engulfed by the darkness of black oil are the instant images that flash across the eyes whenever one dwells upon the topic of oil pollution at sea. While the manifold effects of oil in water have been demonstrated via quantitative research studies, the one area that needs to be thoroughly investigated is the source of oil pollution at sea. The question is when it comes to the marine environment, what are the main sources through which oil is introduced to the marine environment?

3 Sources of Oil Pollution at Sea

Although the world has a reservoir of over $1.3 \times 1018\ m^3$ of water [7], it has been acknowledged that the large volume of water cannot sponge up and absorb all the deleterious substances or wastes without any side effects. The problem factor is that the so-called substances or pollutants do not disperse evenly in the waters and the problem is more pronounced and discernible in enclosed seas, for example, the Mediterranean Sea. Since the Mediterranean Sea is mainly enclosed by land, Greenpeace estimates that the waters of the Mediterranean take more than 100 years to clean and renew themselves and quite often, the waters do not easily or quickly recover from pollution [8]. The United Nations Environment

Programme/Mediterranean Action Plan (UNEP/MAP) has also estimated that the Mediterranean Sea receives inter alia 129,000 t of mineral oil per year and due to its geographical position, the warm waters take more than 80–90 years to clean up. Based on these quantitative quotes, the time it takes (whether 80–90 or 100 years) to renew and revert to the status quo leads to a higher form of concentration of toxic pollutants [8].

The anthropogenic impact, which is commonly known as the cumulative manifestation of various human activities resulting in obvious or surreptitious disturbances to the marine ecosystem, is beginning to take its toll on sensitive areas and enclosed seas such as the Mediterranean. The sensitive ecosystem of the Mediterranean has undergone many changes over the years and the temporal trends are indicative of the fact that overexploitation and habitat loss are the central human-initiated drivers of these many changes. From an UNCLOS perspective, the sources of "ocean pollution" are divided into six main categories: (a) land-based and coastal activities; (b) continental-shelf drilling; (c) potential seabed mining; (d) ocean dumping; (e) vessel source pollution; and (f) pollution from or through the atmosphere. Although the contribution of vessel source pollution is relatively minor compared to land-based pollution, which accounts for more than 80% of overall marine pollution [1], oil pollution is so perceptible that the topic often tends to gain more public attention than land-based pollution.

The Mediterranean Sea links a significant number of countries with unbreakable and multi-directional links. Increased commercial shipping in the Mediterranean region has grown exponentially and has added more weight to the human-initiated changes. In this context, authors suggest two reasons for considering pollution as the most far-reaching and dangerous factor of anthropogenic impact on the hydrosphere [9]. According to authors, the first reason is based on the fact that pollution is accompanied by most kinds of human activities, which includes offshore oil, gas production, and marine oil transportation [9]. The second reason is founded on the idea that compared to the land ecosystems; pollutants in water environment tend to disperse very rapidly over large distances [9].

Based on the aforementioned reasons, Patin distinguishes three main sources through which pollutants may enter the marine environment: (a) "direct discharge of effluents and solid wastes into seas and oceans; (b) "land runoff into coastal zone"; and (c) atmospheric fallout of pollutants transferred by the air mass onto the sea's surface" [9]. From an UNCLOS perspective, the sources of marine pollution are encapsulated in article 1(3), which includes inter alia: (a) land-based sources; (b) pollution from vessels whether accidental, intentional, or unintentional; (c) pollution from installations and generic devices; and (d) pollution from other installations and devices operating in the marine environment [2]. However, in the context of oil pollution at sea, the effects ramify into different branches depending on the type of source and the nature of the pollution. The most commonly identified sources of oil pollution at sea include: (a) natural sources; (b) offshore oil production; (c) maritime transportation; (d) the atmosphere; (e) waste, i.e., municipal and industrial; (f) urban and rural run-off; and (g) ocean dumping.

3.1 Operational Pollution and Accidental Pollution

"Operational pollution," also known as operational discharge, in a way refers to the release of pollutants from vessels in the general operation of the ship, which is also known as "intentional discharge" [9]. These operational activities include emissions from a vessel engine, the chronic discharge of sewage, tank residues, bunker oils and garbage, etc. It is generally understood that a ship is allowed to leave a permanent stream of oily water in its wake for several hours, or even several dozen hours, so long as the concentration of oil in the discharged waste does not exceed 15 parts per million (ppm) [9, 10]. If the discharge remains within the given amount, then the operational pollution is legal in nature. On the other hand, if the amount exceeds 15 ppm, then it will fall outside the scope of "operational or intentional discharge" facet [9]. In short, the difference between legal and illegal spill in terms of operational discharge is considered to be subtle. Rightly, it has been pointed out that:

> . . .it can also be argued that an "intentional oil pollution" can be defined as an unlikely and unrealistic scenario, whereby the vessel in question discharges oil with the full intention to destroy the marine environment. This is as opposed to the small amount of oil released, which accedes the given international standards, and it may or may not be done with the specific intention to cause harm to the environment. This may be coupled with the lack of proper surveillance. Nevertheless, the observation is that "illegal oil pollution" has not been defined in any of the international conventions. The only definition that is observed in major international conventions that deal with oil pollution is a definition, which establishes the criteria which constitute pollution at sea where the discharge of oil is the central character [9]

On the other hand, accidental pollutions are the result of maritime collisions, unwanted contacts with external objects, accidental groundings, explosions, cargo-transfer failures, sinking, or loss of cargo [11]. Unlike operational pollution, accidental pollution cannot be sub-divided. The term "accidental pollution" is quite self-explanatory from the title in so far as the repercussion of the accident is unwanted and in some instances, unplanned. The examples that have dominated the concept of accidental pollution are mainly oil tanker incidents, which have led to thousands of tonnes of crude oil being spilled. While operational or intentional discharges can be controlled via strict regulations and inspections, accidental pollutions revolve around risks, probabilities, and chances, which make it significantly hard to predict and control. Oil pollution has also been termed as the greatest offshore threat and despite numerous efforts by international actors to improve ship safety and stringent regulations on ship routes, improved routeing systems and designs, and management practices, it is submitted that accidental pollution will continue to occur [12].

3.2 *Effects of Vessel Source Pollution*

While the "source of oil pollution at sea" is an assorted collection of random human-initiated occurring sub-divided into different types, vessel source pollution, as a significant subdivision, is observed to be a notorious source that has always gained notable attention at the international level for the damaging effect it has on the marine environment. It is also understood that incorporating stricter international regulations to regulate vessel source pollution has led to a global decline of oil pollution inputs in the marine environment [13]. However, the strikingly high volume of oil's input reported for some regions, presumed to be hundreds of thousands or even millions of tonnes of oil [14], have overturned the environmental optimism and compelled concerned environmentalists to look beyond the facade of protection in paper [13]. These high volumes of oil's input are recorded for different regions inter alia, the Northern part of the Indian Ocean, the Caribbean basin, and the land enclosed Mediterranean Sea. The recorded data of oil pollution input for those regions vary in terms of calculation [13]. For example, some researchers indicate that annual oil pollution input may reach 7.3 million tonnes, which is less than the amount estimated by other researchers, i.e., 20 million tonnes [14, 15, 16]. Researchers further note that about 6,500 large tankers transport more than 1.2 billion tonnes of oil and oil products per year, the veracity of which has not been refuted thus far. What is also confirmed is that oil spills are comprised of: (a) release of crude oil from tanker ships whether from a maritime incident or operational discharge from ship operations; (b) offshore platforms; (c) drilling rigs and wells; (d) spills of refined petroleum products, e.g., gasoline, diesel, and their by-products; (e) heavier fuels, e.g., bunker fuel used by large ships; (f) the oily white substance refuse; and (g) waste oil [17]. While the oil types may differ in terms of component and structural formula, they are considered to be toxic to marine life whereby polycyclic aromatic hydrocarbons (PAHs), a high molecular weight component (compound) of crude oil, are extremely difficult to clean due to the fact that they cannot be absolutely degraded by bioremediation efforts and thus, the effects last for many years in the sediment and marine environment [17, 18].

Numerous oil-shipping disasters have captured the attention of international actors and the outcry of the affected coastal state communities has compelled governments to develop immediate response and intervention tools to combat the detrimental effects of oil pollution. Whether it is accidental or operational discharge, when oil washes up on beaches and is sequestered in the sediments, the bioavailability is said to reduce dramatically thus, slowing down or even preventing biodegradation [19]. The PAHs of crude oil play an important role here since they are quite resistant to microbial degradation by virtue of the aromatic ring and its intrinsic stability [19]. Resistance to microbial degradation means they continue to remain in the same form and when in contact with marine species or aquatic plants – the adverse effects of crude oil begin to unravel.

Although many authors debate that accidental pollution accounts for only a part of the annual global release of crude oil and that much of the global release comes from intentional or operational discharge [19], some authors (including organizations) have gravitated towards accidental discharges, e.g., oil tanker incidents, as the major source of oil pollution [12, 20]. Examples are ripe from the large amount of oil discharges in the aftermath of a number of maritime incidents following the *Torrey Canyon* disaster in 1967. While the *Torrey Canyon* spilled around 118,000 tonnes of crude oil, some of the other accidents have led to the release of much larger quantities of oil. These include the *Amoco Cadiz* in Portsall, France (Spill: 223,000 tonnes); the *Atlantic Express* in Venezuela) (Spill: 300,000 tonnes); the *Castillo de Belver* in Cape coast, South Africa (Spill: 200,000 tonnes); the *Exxon Valdez* in Blight Islands, Alaska (Spill: ten million gallons), and the *Haven* in Genoa (Spill: 140,000 tonnes) [12].

The harmful effects of oil on the marine environment have been substantiated via substantial evidence followed by excruciating details in the work of various authors, researchers, concerned government agencies, and international organizations of that field and does not require further quantitative reiteration [21]. It is also noteworthy that aspects that influence oil spill consequences are myriad and depend on diverse factors, such as the physical features of the region, weather conditions and seasons, the type of oil released, the promptness and efficiency of cleanup operations, and the biological and economical characteristics of the area [22]. While the consequences are deemed to be diverse, scholars of marine biology have concluded that individually marine ecosystems are unique and are structured in complex ways and, therefore, each ecosystem response to oil depends upon both direct and indirect impacts on the species [22]. But whether or not oil has a direct or an indirect impact on species and whether or not their biological response to oil is similar in nature, one thing is certain and that is these species have different toxicity pathways through which they are exposed to injuries, such as "ingestion of oil, accumulation of contaminants in tissues, DNA damage, impacts to immune functioning, cardiac dysfunction, mass mortality of eggs and larvae, e.g., in fish, loss of buoyancy and insulation for birds, and inhalation of vapors" [22–28].

On top of the direct or the direct impact of oil, the species also suffer from the toxicity of oil dispersants whereby researchers have demonstrated that oil dispersants escalate the exposure and uptake of PAHs by fish, more specifically "fishes that live throughout the water column of coastal areas, the oceans and the lakes" [29]. In short, while the marine environment tries to eliminate oil through the natural long-term process of biodegradation, oil and spill dispersants begin to take its toll on the marine environment and cause irreversible damage to marine habitats (such as marine organisms, planktonic organisms, benthic organisms and invertebrates, coral reefs, and fish) within that period of resistance and elimination. While the sources of oil pollution have been explained and the effects have been substantiated in various research works conducted over a period of several decades, it is important to give specific attention to Sea areas that considered to be extremely sensitive to chronic pollution (including oil) and deemed "special" due to its oceanographic, ecological and environmental nature. One such Sea area that requires further investigation is the Mediterranean Sea.

4 Oil Pollution in the Mediterranean Sea

The region enclosing the Mediterranean Sea envelops portions of three continents, i.e., "Europe and its Southern peninsulas to the North, South-western Asia to the East, and the Maghreb region of Northern Africa to the South" [30]. From a geographical perspective, 23 countries have a coastline in the Mediterranean Sea and the Sea itself has a surface area of approximately 2,510,000 km^2. Two major basins are said to comprise the Mediterranean, namely Eastern and Western, separated by the Sicily Channel. The Eastern basin, 4,000–5,000 meters (m) in depth, includes the Adriatic Sea, Aegean Sea, Ionian Sea, and Levantine Sea [31]. On the other hand, the Western basin, 2,500–3,500 m in depth, includes Alboran Sea, Balearic Sea, Ligurian Sea, and Tyrrhenian Sea [31]. In retrospect, the Mediterranean region has always been crowded by intense "human-initiated" commercial shipping activities.

4.1 An Overview of Mediterranean Maritime Traffic

The first documented shipment of petroleum is said to have taken place in the year 1539, when a Spanish ship entitled "*Santa Cruz*" commenced its journey to transport petroleum from Venezuela during the reign of Emperor Charles I [32]. Oil was later discovered in 1859 in the USA and as history goes, the first cargo of oil was transported from the USA to Great Britain in barrels in the holds of the 224 tonne brig "*Elizabeth Watts*" [33, 34]. It was during the First World War that oil, as a source of energy, was in high demand and after the Second World War, oil became an important contributing factor to the world's economy and it is during that time the demand for increased production and supply of oil can be marked by a sharp increase [35]. While the systems pertaining to the production and supply of oil began to ameliorate, the problem concerning oil pollution, especially the ecosystems in semi-enclosed seas such as the Mediterranean, began to increase at a dramatic pace [36].

Issues associated with oil pollution began to emerge during the late 1970s mainly due to the increased traffic in the Mediterranean Sea by large oil tankers involved in oil transportation. The enlargement of the Suez Canal, development of new oil terminal stations, and innovation in offshore oil and gas production have also acted as catalysts. Today there exist a number of ship routes for maritime trade between states bordering the Mediterranean Sea and the rest of the world. What is also apparent is that "all trade takes place between the entire European Union (EU) and countries of Asia and the Middle East via the Mediterranean Sea" [37]. In this context, the numerous dimensions of maritime traffic in the Mediterranean have been considered on three main levels:

- "As a 'maritime route' that, as such, is one of the world's major trade routes, through which nearly a third of world trade 'passes', from the mouth of the Suez

Canal to the Straits of Gibraltar or the Bosporus, from the Atlantic to the Black Sea;

- As a "crossroads" of continents – European, Asian and African – whose trade is growing with globalization;
- As a "landlocked sea" through which coastal countries develop their trade" [37].

A stark "traditional economic sector" in the Mediterranean is considered to be maritime transport [30] and relevantly, "busiest waterway" is a term commonly used to define the Mediterranean. Studies have revealed that from the 1900s, merchant vessels operating within and through the Mediterranean have increased in size [30]. This is evident from the projections made by the Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea (REMPEC) through quantitative research data [38]. While the quantitative data showed that overall vessel activity within the Mediterranean has risen steadily since the late 1900s, it was also projected that this rise will increase by a further 18% from 2009 to 2018 [38]. So by now the increase by 18% has likely become a reality. The numbers crunched by REMPEC with regard to merchant vessels showed that there were more than 325,000 voyages in the Mediterranean Sea in 2007 and in 2013, the Mediterranean Sea accounted for 15% of global shipping activity by number of calls and 10% by vessel deadweight tonnes (dwt.) [30].

Out of the 325,000 voyages accounted for in 2007, two-thirds were internal (Mediterranean to Mediterranean); one-quarter was semi-transit voyages, mainly by large vessels traveling between non-Mediterranean ports through the Mediterranean's various straits, e.g., Straits of Gibraltar, the Straits of the Dardanelles, and the Suez Canal [38]. In addition, the Short Sea Shipping (SSS) of goods between main EU ports and ports situated in the Mediterranean came to a total of 582 million tonnes in 2014. SSS statistics from 2014 also reveal that the "Mediterranean was followed by the North Sea and the Baltic Sea, with shares of close to 26% and 22% of the total EU short shipping tonnages, respectively" [38]. With specific reference to "seaborne trade" REMPEC further highlights that:

> Littoral States with coastlines bordering the Mediterranean account for around 19 per cent of world seaborne trade by volume, which in 2006 amounted to 7.5 billion tonnes. Seaborne trade between Mediterranean littoral States, which is relatively underdeveloped, represents 18 per cent of the total Mediterranean littoral States' trade, which in 2006 amounted to 1.4 billion tonnes. By contrast, intra north European seaborne trade represents over a third of total North European seaborne trade [38] (Fig. 1)

While the Mediterranean is at a stage where vessel activity has increased by 18% since 2009 (amounting to 1.4 billion tonnes in 2006), "port callings" in the Mediterranean has simultaneously escalated by 14% and "transits" by 20% between 1997 and 2006 [38]. While "increase" is a term that can be used in describing merchant vessel activity and associated port callings and transits in the Mediterranean, the same word can be applied when describing the size of these merchant vessels, which is considered to be an increase in size on an average by 30% since 1997 [38]. The data provided by REMPEC shows that the size of vessels calling at Mediterranean ports have steadily increased from 11,628 to 15,109 DWT between

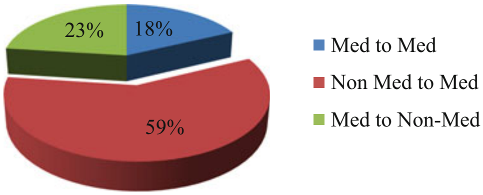


Fig. 1 Mediterranean Littoral States Seaborne Trade (including all French, Spanish, Moroccan, and Turkish Trade) (*Source*: REMPEC 2008; Original *Source*: UN/Lloyd's MIU Analysis)

1997 and 2006, which is an actual increase of 3,481 DWT [38]. For vessels in transit, the increase between 1997 and 2006 is 11,912 DWT, which is nearly four times more than Mediterranean port calls.

4.2 Mediterranean Oil Tankers and Illicit Vessel Discharges

As indicated in the 2008 study by REMPEC, crude oil shipments continue to dominate major traffic lanes within the Mediterranean [38]. These port-to-port routes include "Novorossiysk to Mediterranean destinations and from Sidi Kerir to both Mediterranean destinations and ports West of Gibraltar as well as exports from the Persian Gulf through the Mediterranean via Suez" [38]. A staggering 220 million tonnes of crude oil were loaded at Mediterranean ports in the year 2006 and the highest concentration of crude oil tanker callings is said to be around the ports of Gibraltar, Augusta, Venice, Fos, Algeciras, and Ravenna [38]. While ports around Gibraltar had the highest number of calls, i.e., 534 calls, Algeciras and Genoa ports had the second and third highest number of calls, i.e., 201 and 172 calls, respectively [38]. Two other important facts concerning crude oil trades as highlighted in the 2008 REMPEC study includes

(a) the top 20 Mediterranean crude oil loading ports measured by number of calls accounted for 99% of all crude oil loaded in the Mediterranean; and
(b) the top 20 Mediterranean crude oil discharge ports measured by number of calls accounted for 85% of all crude oil discharged in the Mediterranean.

In terms of loading, Sidi Kerir had a total of 715 loads in 2006, which amounted to 74,339,769 tonnes and is considered to be the highest amount among the Mediterranean ports for that year. On the other hand, Trieste accounted for 33,838,000 tonnes of crude oil from 395 numbers of discharges and is considered to be the highest amount for the year 2006. Furthermore, the given amount of loading and discharging of crude oil in the Mediterranean ports is said to have increased since 2006. This is mainly due to port developments and growth in the Mediterranean, therefore, leading to increased number of port callings coupled with a rise in the amount of crude oil loads and discharges:

> The pattern and volume of crude oil, product and LNG throughput at ports is also changing. Exports from Caspian oil producers via Black Sea ports are increasing, but eastern Mediterranean ports have also become the focus for routes to markets, which avoid transiting the Bosporus. Importing countries in the Mediterranean are also developing new terminal facilities to enable greater diversity in sourcing, particularly in natural gas. New oil pipelines feeding into the Black Sea and eastern Mediterranean and the development of new LNG import terminals on the northern coast of the Mediterranean will alter tanker deployment in the region [38].

Although serious tanker accidents have not been reported in the Mediterranean Sea, the European Commission (EC) Directorate-Generals (DG) Joint Research Centre in collaboration with the EC DG-Environment conducted an oil spill surveillance study in the Mediterranean Sea in 1999 that provided a comprehensive picture of the dimension of operational oil spill related problems, which mainly emanate from routine ship operations [40]. The report of the study published in 2001 showed that enhanced spill concentrations were visible along major maritime routes, such as those crossing the Ionian Sea towards the Adriatic Sea, towards the Messina Straits, towards the Sicily Straits, along maritime routes in the Ligurian Sea, and the Gulf of Lion as well as very close to the East coast of Corsica [40]. The illicit vessel discharges detected on the European Remote Sensing (ERS)-1 and ERS-2 Synthetic Aperture Radar (SAR) images showed that the total spilled area (of the 1,638 detected spills) was estimated to be 17,141 km^2 [40]. Even though patrol operations usually focused on control over known maritime routes, the ERS-1 and ERS-2 SAR images indicated that the spills appeared to be both localized and frequent, leading to the hypothesis that the vast majority of the detected spills may be termed as "offences," i.e., illegal in nature [40].

5 IMO and the Mediterranean Sea

UNCLOS mainly serves as an umbrella of all significant treaties concerning the use of the sea and refers to the work of competent international organizations in part XII. In article 197 of Part XII, states are suggested to cooperate directly or through these international organizations to formulate international rules, standards and recommended practices, and procedures for protection and preservation of the marine environment [2]. In other words, Part XII provides a foundation for international organizations to formulate rules and standards so that states can continue their commercial activities at sea while minimizing, to the fullest extent possible, the release of toxic, harmful, or noxious substances into the marine environment. In short, these rules and standards are implemented so that there can be a balance between "commercial activities" and "marine environmental protection."

The relationship between UNCLOS and IMO instruments has been further explained in a study by the Secretariat of the IMO. The study specifically mentions that "while UNCLOS defines flag, coastal and port State jurisdiction, IMO instruments specify how those State jurisdiction should be exercised so as to ensure compliance with safety and shipping anti-pollution regulations" [41]. This relation is further strengthened by the usage of very specific terms, e.g., "generally accepted international regulations,", "applicable international instruments," "generally accepted international rules and standards," in various parts of UNCLOS [2]. Therefore, when it narrows down to marine pollution, it is undoubtedly clear that the IMO serves as a platform through which concerned states of a certain region may cooperate with each other and subsequently, bind themselves by the rules and regulations as implemented by IMO. These international rules and regulations are also binding on other member states, which seek commercial advantages through transits and continue to pursue their own objectives. UNCLOS has, therefore, stressed on the importance of international rules and standards set by competent international organizations whereby countries signatory to the convention are called upon in article 211 to:

> ... establish international rules and standards to prevent, reduce and control pollution of the marine environment from vessels and promote the adoption, in the same manner, wherever appropriate, of routeing systems designed to minimize the threat of accidents which might cause pollution of the marine environment, including the coastline, and pollution damage to the related interests of coastal States. Such rules and standards shall, in the same manner, be re-examined from time to time as necessary [2].

The IMO, known as the Inter-Governmental Maritime Consultative Organization until 1982, is a specialized agency of the United Nation (UN) charged with the responsibility on matters relating to the safety and the protection of the marine environment from vessel source pollution. In order to satisfy its objective and fulfill its responsibilities, this specialized agency implements international treaties otherwise known as "conventions" and since its inception in 1958, the IMO has adopted a significant number of international conventions related to protection and preservation of the marine environment [42]. One such noteworthy IMO convention is the International Convention for the Prevention of Pollution from Ships, 1973 as Modified by the Protocol of 1978 (MARPOL 73/78). MARPOL 73/78 marks the first milestone on the pathway of recovery and protection against vessel source pollution, i.e., oil pollution, chemical pollution, sewage, garbage, and pollution from air emission.

Annex 1 of the MARPOL 73/78 Convention entered into force on 2nd October 1983 and contains a number of regulations for the prevention of pollution by oil. The prevention regulations as embodied in Annex 1 applies to a number of important regions, e.g., Mediterranean Sea, Baltic Sea, Black Sea, Red Sea, Antarctic area, and North West European Waters, which are marked by an annual increase in maritime traffic in various research related studies. When analyzing the contents, it is observed that MARPOL 73/78 maintains the "oil discharge criteria" prescribed in the 1969 amendments to the International Convention for the Prevention of Pollution of the Sea by Oil of 1954 without any substantial changes [43].

Moreover, IMO has strengthened the level of protection by designating the Mediterranean Sea as a "special area," which has been in effect since 2nd October 1983 [44]. Annex I "Regulations for the Prevention of Pollution by Oil" establishes the Mediterranean Sea area, i.e., "the Mediterranean Sea proper including the gulfs and seas therein with the boundary between the Mediterranean and the Black Seas constituted by the 41ºN parallel and bounded to the west by the Straits of Gibraltar at the meridian of 5º36′ W" as a "special area" in which, "for technical reasons relating to their oceanographic and ecological condition and to their sea traffic, the adoption of special mandatory methods for the prevention of sea pollution is required" [45]. Pursuant to IMO Resolution A.927 (22), the three conditions which must be satisfied for an area to be a "special area" are: (a) oceanographic conditions; (b) ecological conditions; and (c) vessel traffic characteristics [46]. Therefore, the regulations concerning operational discharges of oil as incorporated in Annex 1 will unquestionably apply to the Mediterranean Sea since that region is a particularly sensitive area in terms of chronic pollution and has been under the designation of "special area" for more than two decades. One of the important regulations for the Mediterranean Sea is Regulation 34 of Annex 1, which allows operational discharges of oil from tankers subject to the following conditions:

1. the tanker is not within a special area;
2. the tanker is more than 50 nautical miles from the nearest land;
3. the tanker is proceeding en route;
4. the instantaneous rate of discharge of oil content does not exceed 30 L per nautical mile;
5. the total quantity of oil discharged into the sea does not exceed for existing tankers (delivered on or before 31 December 1979) 1/15,000 of the total quantity of the particular cargo of which the residue formed a part, and for new tankers (delivered after 31 December 1979) 1/30,000 of the total quantity of the particular cargo of which the residue formed a part; and
6. the tanker has in operation an oil discharge monitoring, control system, and a slop tank arrangement [44].

Major maritime nations of the Mediterranean region (except Bosnia and Herzegovina) have ratified Annex 1 of MARPOL 73/78, which gives the Governments of the Mediterranean coastal states the impetus to develop national legislation for prosecuting offenders that are guilty of oil discharge. However, one of the important prerequisites of a "special area" designation, as incorporated in IMO Resolution A.927 (22), is that there must be adequate port reception facilities for oil tankers since they are not allowed to discharge any amount of oil pursuant to Regulation 34. In this context, the Governments (port State authorities) are under an obligation to ensure that a port authority or a terminal operator provides a "reception facility" according to the needs of oil tankers. But the status quo absence of adequate waste reception facilities can be seen as a major hindrance in the development of an overall "zero oil discharge policy" in the Mediterranean region that defeats the very objective of Regulation 10 and 12 of Annex 1 of MARPOL 73/78 and undermines the efforts of IMO. Prominent authors tersely explain that:

> . . . the entire Mediterranean has been designated a MARPOL Special Area under Annexes I and V, but the absence of adequate waste reception facilities has not enabled the Special Area provisions to come into effect, to the consequent detriment of the particularly

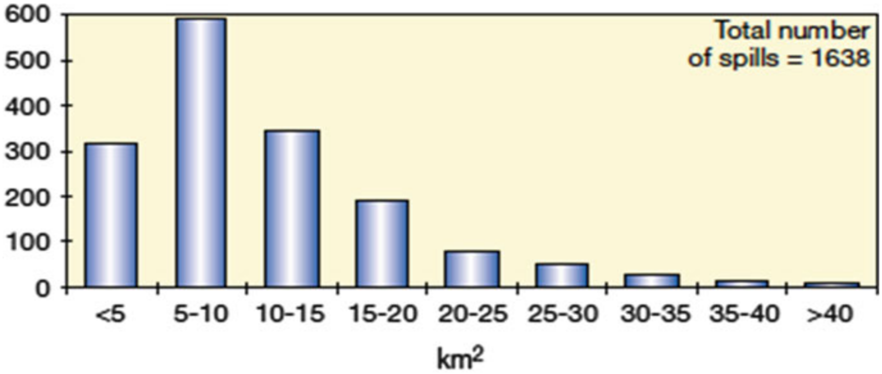
> vulnerable marine environment of the Special Area. Achieving compliance by MARPOL parties with this requirement is a long-standing problem of such apparent intractability...that it has attracted the formally expressed concern of the UN General Assembly [47].

Consistent with the UN General Assembly Resolution 58/240, IMO acknowledges the importance of port State controls (PSC) in developing and promoting the effective enforcement by flag States of generally accepted international pollution standards [48]. In this context, IMO has helped nine regions to develop PSC regimes, i.e., the Paris Memorandum of Understanding (MoU) (1982), Viña del Mar Agreement (1992); Tokyo MoU (1993); Caribbean MoU (1996); Mediterranean MoU (1997); Indian Ocean MoU (1998); Abuja MoU (1999); Black Sea MoU (2000); and the Gulf Co-operation Council (Riyadh) MoU (2004) [48]. The participants of the MoUs mainly cooperate in coordinating PSC whereby the objective is to inspect within a given year a minimum number of foreign ships calling at their ports [47]. By inspection of foreign vessels, the maritime authorities of each participating country determine whether they comply with the international treaties as listed in the respective MoU [47].

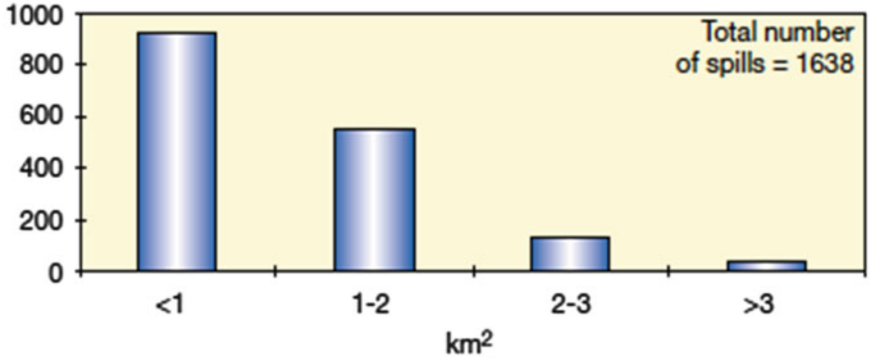
The Mediterranean region is mainly covered by two MoUs, namely the Mediterranean MoU (1997) and the Paris MoU (1982). The Mediterranean MoU participants are Algeria, Cyprus, Egypt, Israel, Jordan, Lebanon, Malta, Morocco, Syria, Tunisia, Turkey, and the Palestinian Authority [49]. The "text of the Mediterranean MoU" is comprised of 10 sections and includes "inspection procedures, rectification and detention" in section 3 of the MoU text [49]. The Mediterranean MoU includes MARPOL 73/78 and its annexes as "relevant instruments" for conducting PSC and the participants aim to inspect 15% of ships calling at their ports per annum (section 1(1.3): Commitments):

> Each Authority will achieve, within a period of 3 years from the coming into effect of the Memorandum an annual total of inspections corresponding to 15% of the estimated number of individual foreign merchant ships, hereinafter referred to as "ships", which entered the ports of its State during a recent representative period of 12 months...[49].

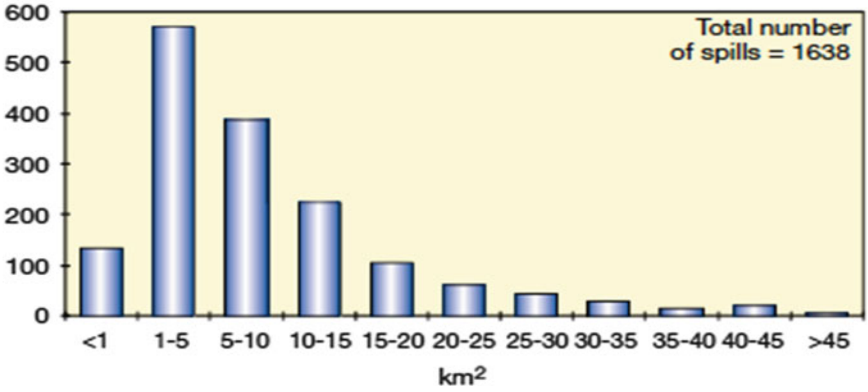
As for the Paris MoU, the list of participating countries from the Mediterranean region include Croatia, Cyprus, France, Greece, Italy, Malta, Slovenia, and Spain. The Paris MoU ports take great pride in the high number of "foreign ship inspections" per year, which is considered to be more than 18,000 [50]. Similar to the Mediterranean MoU, the Paris MoU lists MARPOL 73/78 as a "relevant instrument" among 16 other international instruments [50]. The text of the Paris MoU is comprised of 9 sections and 12 Annexes and compared to the Mediterranean MoU, the Paris MoU annual ship inspection target is 25%, which has been termed as complex yet "ambitious" by some authors [47]. Although IMO has acted within its competency to provide the Mediterranean Region a higher level of protection by designating the Mediterranean Sea area as a "special area" and by assisting the Mediterranean Region to develop a PSC MoU, the European Commission report of 2011 reveals a different picture and shows traces of illegal oil discharges, which are mainly operational in nature [40] (Fig. 2). Since the Paris MoU was developed in



Above: Histogram of length sizes of detected Spills



Above: Histogram of width sizes of detected Spills



Above: Histogram of spilled area sizes of detected Spills

Fig. 2 Histograms of detected spills in the Mediterranean. Histograms of length sizes, width sizes, and spilled area sizes of detected spills; *Source*: On the monitoring of illicit vessel discharges: A reconnaissance study in the Mediterranean Sea. EC DG-Joint Research Centre in collaboration with EC-DG Environment, European Commission

1982 and the Mediterranean MoU was developed in 1997, the European Commission Report of 1999 shows traces of illegal discharges, which is 17 years after the former and 2 years after the latter MoU came into being. The question is – how can these illicit oil discharges be explained?

Regulation 10, Annex 1 of MARPOL 73/78 is very clear about the discharge limits of oil by both oil tankers, ships larger than 400 Gross Tonnage (GT) and ships less than 400 GT [44]. MARPOL 73/78 provides an explicit ban of oil or oily mixture from oil tankers and the same restriction applies to engine room waste discharges from all ships larger than 400 GT [44]. Small ships remain outside the scope of these restrictions. However, discharges are permitted only when the oil content of the discharged effluent does not exceed 15 ppm [44]. Since small ships, i.e., ships less than 400 GT other than oil tankers, are allowed to discharge a certain amount of oil, it can be argued that the detected spills as shown on the histograms do not necessarily fall within the category of illicit or unauthorized oil spill [40]. But the argument tends to weaken if the two other conditions are taken into consideration, i.e., (a) the oil content of the discharged effluent is less than 100 ppm; and (b) the discharge is made as far as practicable from the land, but in no case less than 12 nautical miles (nm) from the nearest coast. Firstly, the 100 ppm discharge restriction "means that even if the full volume of such a small ship is engine effluent (i.e., 400 t), the amount of oil content within it should not exceed half a barrel" and "half a barrel" of oil is not sufficient to create a spill as large as one square kilometer [40]. But the histogram on "spilled area sizes of detected spills" shows that nearly 600 oil spills spread across 1–5 km^2 have been recorded in 1999. Therefore, the spills detected certainly fall within the ambit of "illegal oil discharge." Secondly, the European Commission through the 1999 study revealed that the oil spills detected in some parts of the Mediterranean Sea are quite broad. While some spills are beyond the 12 nm limit, other spill, such as the dark concentration along the East Coast of Corsica "represents overlapping of many spills of different sizes, remain just on the 12 nm limit boundary" [40].

6 Conclusion

While shipping is albeit an important source of marine pollution, tanker accidents are not the only most important source of oil entering the sea from all shipping activities. Due consideration must be given to operational discharges whether it is oil tankers, ships greater than 400 GT or ships less than 400 GT. Whilst on a Mediterranean regional scale the amount of oil entering the marine environment as a result of tanker accidents may be considerably low or even close to zero, the current amount of detected spills from operational discharges, which remain just on the 12 nm limit boundary, need to be taken into account due to the fact that this amount (estimated in the European Commission report of 2001) is likely to increase. This hypothesis is based on: (a) the current trend, i.e., the Mediterranean is currently a major trade route through which nearly 1/3 of the world traded passes;

and (b) projections that maritime traffic in the Mediterranean Sea is increasing due to increased commercial activities between the EU and Asia/Middle East. Therefore, the number of "port callings" has increased in the Mediterranean region and crude oil shipments still dominate major maritime traffic lanes as illustrated by REMPEC.

In order to control the problems associated with spills from oil "loading and discharging," the Mediterranean coastal states have to depend on the work of IMO. This is broadly due to the fact that these oil shipment and generic commercial activities are international in nature and as such, it is only the rules and standards of international law that can put a cap on oil discharges or limit the amount of discharges altogether. But this has already been done by IMO whereby the limits of operational discharges are implemented in the regulations of Annex 1 MARPOL 73/78.

IMO has gone as far as to consider the Mediterranean Sea area, i.e., the Mediterranean Sea proper including the gulfs and seas therein with the boundary between the Mediterranean and the Black Sea, as a "special area." The reasons that contribute to this title are several. Apart from the projected increase in maritime traffic, symptoms of oil impact have been taken into consideration whereby the Mediterranean Sea is considered to be the first marine region to react greatly and "show the symptoms of oil impacts" [51]. Compared to other regional seas, the petroleum tars on the surface of the Mediterranean Sea are considerably higher [52] and according to some authors the factors that contribute to this problem are numerous:

> . . . the particular hydrographical conditions of the basin are such that oil entering or discharged there has little chance of leaving; it will stay and accumulate until it is degraded. Moreover, the cyclonic drift of the water circulation tends to deposit the oil on the shores or to accumulate it at certain exposed points. The oil handling activities brought in the area, and specially the tanker traffic, are, in turn, quite important . . . Finally, a lenient legislation has been unable to prevent intentional pollution [51].

It has been noted that one of the implementation criteria of a "special area" is that the coastal states should provide adequate port reception facilities to the foreign vessels. Unfortunately, the status quo situation with regard to port reception facilities in the Mediterranean region is far from adequate. IMO can do only so much as to provide a higher protection status, but in order to realize that "higher protection" – the coastal states have an equal duty to satisfy the conditions as stipulated in IMO Resolution A.927 (22) before they can enjoy the privileges that come with the title "special area." Again, providing adequate port reception facilities to foreign vessels is something reciprocal in nature, i.e., flag state vessels stop operational discharges within special areas and coastal states help take care of the oily substance that needs to be discharged and have been stored on board. Apart from this issue, another important drawback is observed. Not all Mediterranean states are a part of the Mediterranean MoU or the Paris MoU. These states include Bosnia and Herzegovina, Libya, Monaco, and Montenegro. It is submitted that in order to control oil pollution in the Mediterranean Sea, there needs to be a strong regional cooperation among the states, which is lacking due to the absence of a 100% participation by all coastal states in the Mediterranean.

Although the Mediterranean MoU is commendable based on the texts of the MoU and the inspection targets aimed by the participants, the annual reports of 2014 and 2015 have not been shared on the Mediterranean MoU homepage. This makes it hard to justify whether the Mediterranean MoU has achieved its desired goals in the last two consecutive years, i.e., 2014 and 2015. While IMO has provided significant input in developing MoUs including the Mediterranean and the Paris MoU, the annual reports are not in good order and, therefore, it is not possible to conclude whether the PSC investigation targets have been satisfied and whether there has been any amelioration in the Mediterranean regional PSC system. In the absence of adequate port reception facilities, updated information of annual PSC, and lack of regional statistics on illegal oil discharge activities – it can be assumed that the Mediterranean region is lagging behind other regions declared as "special area," i.e., Baltic Sea and the North West European Waters. The reports of studies conducted by the European Commission between 1991 and 1992 and in 1999 show that a number of sub-areas are subject to higher pressure due to "intense local spilling activity." Whether the Mediterranean Sea will see the light of a "zero tolerance policy" depends on the political will of the coastal states, especially parties to MARPOL 73/78. The Mediterranean coastal states need to consider, acknowledge and respect the work of IMO, and develop stronger regional cooperation based on the existing MoUs. With the projected increase in maritime traffic, especially oil tanker shipments, this should be done with more wisdom and care than ever before.

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The Barcelona Convention and Its Role in Oil Pollution Prevention in the Mediterranean Sea

Angela Carpenter and Tafsir Johansson

Abstract An oil spill, whether via dumping from ships and aircraft, from operational or accidental discharge, from land-based sources or from offshore commercial activities, is an event that has been portrayed by both academics and environmental specialists as a form of "disaster" that causes irreparable damage to the marine environment. The Mediterranean region, like other regions of the globe, is considered to have unique marine features that make the region particularly vulnerable to oil pollution, and hence, there is a dire need for a framework that can assist the coastal states to combine their efforts when trying to prevent, abate, combat and eliminate all potential and actual threats from oil pollution. With the burgeoning concern regarding pollution caused by oil and generic substances, the Barcelona Convention and its Protocols appear as a legislative "soft law" tool that has the full potential, if implemented at the national level, to tackle oil pollution from all potential sources. There is a certain cadence in the way the Barcelona Convention and its Protocols have emerged over time, inevitably forming the most appropriate basis for the coastal states of the Mediterranean Sea area to take actions from a platform that can be labelled as "collaborative". As such, the Barcelona Convention and the Protocols relevant to oil pollution speak to those states as beginning with the notion that efforts to deal with oil pollution need to be combined. They also prescribe how those states can limit and intervene promptly. This prescription is also coupled with a form of recognition that there ought to be a consistent approach when dealing with an element that has a diametric personality, i.e. advantageous when used for operational purposes and disadvantageous when there is a spill. This chapter provides an overview of the Barcelona Convention and proceeds with an incisive

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examination of the Protocols that provide guidance to states on how to protect and preserve the Mediterranean marine environment from oil pollution.

Keywords Barcelona Convention, Mediterranean Action Plan, Mediterranean Sea, Oil pollution, Oil spill prevention, UNEP Regional Seas Programme

Contents

1 Introduction

Human activities and economic development of the Mediterranean can have a significant impact on the environment and on coastal and marine ecosystems. A major source of pollution entering the Mediterranean comes from industrial activities such as mining, heavy industry, manufacturing activities and coastal harbours [1]. Industrial sectors that were responsible for the highest number of pollutant discharges in 2003 were food packing industry (15% of all recorded discharges), energy production (12%), manufacture of metals (10%) and the manufacture of cement (7%). Inorganic chemicals, oil refining and organic chemicals accounted for 5% of recorded discharges of pollutants [1]. Environmental hot spots resulting from the various industrial activities can affect the most productive areas of the marine environment, including estuaries and shallow coastal waters, and are distributed widely around the Mediterranean Sea [2]. There are also more than 40 refineries and petrochemical installations around the Mediterranean, while oil and gas reserves are situated in the waters of Algeria, Cyprus, Italy, Lebanon, Libya and Syria [2]. These produce a wide range of substances including methanol, naphtha, butane and aromatics, for example.

Maritime transport is, however, the main source of petroleum hydrocarbon (oil) and polycyclic aromatic hydrocarbons (PAHs) entering the marine environment of the Mediterranean, including crude oil discharged through tank washing operations, and oil releases from loading/discharging, bunkering and dry-docking operations and discharges of bilge oil [3]. Fishing vessels, cruise ships and leisure craft, together with fixed vessels (e.g. oil exploration and drilling platforms), also contribute to oil inputs to the sea, while a lack of adequate reception facilities, where vessels can discharge oily wastes generated during a voyage, results in the release of oily wastes in the open sea [4]. Larger oil inputs can result from shipping accidents, for example, with 14 such accidents resulting in the release of approximately 180,000 t of oil into the Mediterranean between 1970 and early 2016 [4]. Spills are distributed along the main shipping routes running west to east between the Strait of Gibraltar, through the Sicily Channel and the Ionian Sea, and then on to various locations in the Eastern Mediterranean, and in the Northern Adriatic, to the east of Corsica, in the Ligurian Sea and in the Gulf of Lion, where there are major oil discharge ports [3].

In recognition of the need to protect the environment of the Mediterranean Sea (together with other seas and oceans around the globe), the United Nations Environment Programme (UNEP) established a Regional Seas Programme in 1974. The Mediterranean region subsequently was the first to adopt an action plan (MAP) in 1975, and this provided a framework for countries in the region to cooperate in addressing common challenges in protecting the marine environment of the region [5]. The *Convention for the Protection of the Mediterranean Sea against Pollution* (Barcelona Convention) [6] was subsequently adopted in February 1976, while seven Protocols, and amendments to the both the Convention and those Protocols, have been developed over the last four decades. It is these developments – the UNEP Regional Seas-MAP and the Barcelona Convention and its Protocols – that are examined in this chapter.

2 The UNEP Regional Seas Programme and the Mediterranean Action Plan

In 1974, the United Nations Environment Programme (UNEP) established its Regional Seas Programme to coordinate activities to protect the marine environment at the regional level and to tackle common environmental issues through joint coordinated action by governments in that region. In 1975, the Mediterranean region was the first to adopt an action plan (MAP), the initial focus of which was on marine pollution control. At the time of its inception, 16 Mediterranean countries and the European Community (now the European Union, EU) approved the MAP as the institutional level framework for cooperation in addressing common challenges to protect the marine environment of the region [5]. Work relating to the MAP is undertaken by the Coordinating Unit for the Mediterranean Action Plan – Barcelona Convention Secretariat (see http://www.unep.org/unepmap/who-we-are/mediterranean-action-plan).

The initial objectives of the MAP were to assist Mediterranean governments both in the assessment and control of pollution and in the development of national marine environmental policies [5]. However, it was quickly recognized that socio-economic problems and poor management and planning of development in the region both contributed to the environmental pressures facing the Mediterranean [7], and so, in 1995, contracting parties (CPs) decided to revise both the MAP and the Barcelona Convention, discussed in Sect. 3. As a result, the *Action Plan for the Protection of the Marine Environment and the Sustainable Development of the Coastal Areas of the Mediterranean* (*MAP Phase II*) was adopted in 1995 [8]. It had, as its main objectives:

– Ensuring the sustainable management of natural marine and land resources, and integration of the environment in social and economic development, and land-use policies
– Protecting of the marine environment and coastal zones, through prevention of pollution and by reduction and, as far as possible, elimination of chronic or accidental pollutant inputs
– Protecting nature and protecting and enhancing sites and landscaped of ecological or cultural value
– Strengthening solidarity among Mediterranean coastal statement in the management of their common heritage and resources, for the benefit of both present and future generations
– Contributing to the improvement of quality of life [8]

2.1 MAP Regional Activity Centres

There are seven regional activity centres (RACs) with responsibility for implementation of the various components of MAP II. These are outlined in Table 1, together with the main objective of each component.

2.2 Mediterranean Pollution Assessment and Control Programme (MED POL)

Two of the RACs have relevance to marine pollution, including pollution by oil. The first of these is MED POL which assists 21 countries bordering the Mediterranean Sea to implement 3 of the 7 Protocols to the Barcelona Convention [9]. These are the *Protocol for the Prevention of Pollution in the Mediterranean Sea by Dumping from Ships and Aircraft* (Dumping Protocol [10]), discussed in more detail in step 1 of Sect. 3.2; the *Protocol for the Protection of the Mediterranean Sea against Pollution from Land-Based Sources* (LBS Protocol [11]), discussed in more detail in step 2 of Sect. 3.2; and the *Protocol on the Prevention of Pollution of the Mediterranean Sea by Transboundary Movements of Hazardous Wastes and their Disposal* (Hazardous Wastes Protocol). For further details of all the Protocols to the Barcelona Convention, together with discussion of those with specific relevance to pollution by oil, see Sect. 3.2.

Table 1 Components of MAP II and their main objectives

Component name	Main objective
Mediterranean Pollution Assessment and Control Programme (MED POL)	Prevention and elimination of land-based pollution of the Mediterranean
Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea (REMPEC)	Preventing and reducing pollution from ships and combatting pollution in case of emergency
Plan Bleu Regional Activity Centre (PB/RAC)	Raising awareness of Mediterranean stakeholders and decision makers concerning environment and sustainable development issues in the region
Priority Actions Programme Regional Activity Centre (PAP/RAC)	Sustainable development of coastal zones and sustainable use of their natural resources
Specially Protected Areas Regional Activity Centre (SPA/RAC)	Protection and preservation and sustainable management of marine and coastal areas of particular natural and cultural value and threatened and endangered species of flora and fauna
Regional Activity Centre for Sustainable Consumption and Production (SCP/RAC)	Pollution prevention and sustainable and efficient management of services, products, resources, etc.
Regional Activity Centre for Information and Communication (INFO/RAC)	Collecting and sharing information, raising public awareness and participation and enhancing decision-making processes at regional, national and local levels

Source: UNEP coordinating unit for the Mediterranean Action Plan [8]

As noted in Table 1, MED POL's main objective is to contribute to preventing and eliminating land-based pollution of the Mediterranean. In addition to assisting CPs with planning and coordination of initiatives that meet their obligations under the Barcelona Convention and the Protocols, it also assists by facilitating National Action Plans to address land-based pollution and by assessing the status and trends of pollution of the Mediterranean Sea, including health-related aspects of marine pollution, identifying hot spots in coastal areas and collecting, analysing and disseminating data [8].

Pollution monitoring and assessment work have been undertaken under four phases. Phase I of the *Coordinated Mediterranean Pollution Monitoring and Research Programme* was launched in 1975 and ran until 1980. Phase II, the *Long-term programme for pollution monitoring and research in the Mediterranean*, was launched in 1981 and ran until 1995. Phase III, the *Programme for the Assessment and Control of Pollution in the Mediterranean Sea*, was adopted in 1996 and ran until 2015. The Phase IV programme (with the same name a Phase III) was launched in 2006 and ran until 2013. MED POL collects pollution data from CPs, and that information contributes to implementation of the Dumping, LBS and Hazardous Waste Protocols.

With specific reference to the work conducted by MED POL in respect of LBS pollution, a Strategic Action Plan (SAP-MED) was developed and adopted by CPs in 1997 for the reduction and elimination of land-based pollution [9]. SAP-MED has 33 targets covering the sectors of urban environment, industrial development and physical alterations and destruction of habitats. This targets a wide range of toxic, persistent and liable to bioaccumulate, heavy metals, hazardous and other substances [9]. Under SAP-MED [12], oil is included as a priority substance under the category of hazardous waste from industrial development – oil in this categorization is identified as *used lubricating oils*. While petroleum hydrocarbon emissions were in the top pollutants by emission values in 2003 and 2008, the levels were lower than those for oil and greases (organic) in the same years; petroleum hydrocarbons do not appear in the top pollutants in 2013 however, while oil and grease levels appear to be much lower in that year [12, p. 24].

2.3 Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea (REMPEC)

The second RAC with specific relevance to marine pollution from ships is REMPEC, administered by the International Maritime Organization (IMO) in cooperation with UNEP, and based in Valetta, Malta [8]. Originally named the Regional Oil Combatting Centre (ROCC), this RAC was established in 1976 to facilitate cooperation between CPs to combat massive pollution by oil. However, the Centre's remit changed over time to address emerging issues including preventing pollution from ships [13], and its name was changed to the Regional Marine Pollution Emergency Response Centre in 1989.

REMPEC's main fields of action are in the prevention of pollution of the marine environment from ships and the development of preparedness for and response to accidental marine pollution and cooperation in case of emergency. These actions include strengthening the capacities of the coastal states to prevent pollution of the marine environment from ships and ensure effective implementation of the international rules relating to the prevention of pollution from ships; developing regional cooperation in the field of the prevention of pollution of the marine environment from ships and facilitating cooperation among Mediterranean coastal states in order to respond to pollution incidents including discharges of oil or other hazardous and noxious substances where emergency actions or other immediate response is required; assisting coastal states to develop their own national capabilities for response to pollution incidents, including facilitating exchange of information, technological cooperation and training; and providing a framework for the exchange of information on operational, technical, scientific, legal and financial matters and promoting dialogue aimed at conducting coordinated action at the national, regional and global levels for the implementation of the Prevention and Emergency Protocol [14].

REMPEC also assists CPs to mobilize regional and international assistance in the event of an emergency under the Offshore Protocol of the Barcelona Convention [15] which deals with pollution resulting from exploration and exploitation of the Continental Shelf and the seabed and its subsoil of the Mediterranean [8] (discussed in more detail in step 3 of Sect. 3.2). That pollution includes accidental releases of oil or the accumulation of small operational discharges or oil or other harmful substances from offshore activities.

Finally, REMPEC has responsibility for implementing the Regional Strategy for the Prevention of and Response to Pollution from Ships, a strategy that was required to implement the 1976 Emergency Protocol. Work to develop the Regional Strategy commenced in 2002 with the Strategy being agreed in 2005 [16]. An extended discussion of REMPEC appears in this volume at [17].

3 Overview of the Barcelona Convention and Its Key Components

This section outlines the timeline for development of the *Convention for the Protection of the Mediterranean Sea against Pollution* (Barcelona Convention) [6] and summarizes its various Protocols, from the Convention's initial adoption in February 1976, and including revisions to the Convention which resulted in it being superseded by the *Convention for the Protection of the Marine Environment and Coastal Regions of the Mediterranean* (the revised Barcelona Convention) which entered into force in 2004 [18]. This section also details the key elements of the Barcelona Convention as they relate to oil pollution.

3.1 The Barcelona Convention

In 1976, at a "Conference of Plenipotentiaries[1]" of the coastal states of the Mediterranean held in Barcelona, Spain, the *Convention for the Protection of the Mediterranean Sea against Pollution* (Barcelona Convention) was adopted on 16 February 1976 [6]. That Convention entered into force on 12 February 1978.

In 1995, the Convention was revised by amendments adopted at a further "Conference of Plenipotentiaries" and was renamed the *Convention for the Protection of the Marine Environment and the Coastal Regions of the Mediterranean* [18]. While that amendment was adopted on 10 June 1995, it did not enter into force until 9 July 2004 when it finally replaced the 1976 Convention. In January 2008 the CPs adopted an ecosystem approach, which strengthened previous commitments within the framework of the MAP, including commitments to assessment and control of pollution and marine pollution indicators, for example [1].

[1]Plenipotentiary – a person, especially a diplomat, invested with the full power of independent action on behalf of their government, typically in a foreign country Source: Oxford English Dictionary at https://en.oxforddictionaries.com/definition/plenipotentiary (Last accessed 10 August 2017).

Article 1, para. 1, of the Barcelona Convention defines the geographical coverage if the Convention as being the “the maritime waters of the Mediterranean Sea proper, including its gulfs and seas bounded to the west by the meridian passing through Cape Spartel lighthouse, at the entrance of the Strait of Gibraltar, and to the East by the southern limits of the Strait of the Dardanelles between Mehmetcik and Kumkale lighthouses” [6]. Para. 2 further notes that the defined area does not include internal waters of the CPs, unless specifically provided for in any of the protocols to the Convention. A map setting out the geographical area covered by the Convention and the countries which have ratified it is set out in Fig. 1.

The main objectives of the Barcelona Convention are to assess and control marine pollution, ensure sustainable management of natural marine and coastal resources, integrate the environment in social and economic development, protect the marine environment and coastal zones through prevention and reduction of pollution and as far as possible eliminate pollution (land- or sea-based), protect the natural and cultural heritage, strengthen solidarity among Mediterranean coastal states and contribute to improvement of the quality of life [6].

CPs to the original Convention and to the amendment of 1995 are set out in Table 2. This included the European Community (EC) as a signatory to the original Convention, subsequently appearing as the EU. All CPs ratified the original Convention although Bosnia and Herzegovina have yet to accept the 1985 amendments and notification had not been received from Lebanon by November 2016.

3.2 *Summary of the Protocols to the Barcelona Convention*

The Barcelona Convention has seven Protocols which address specific aspects of environmental conservation of the Mediterranean Sea [19]. These are:

1. The Protocol for the Prevention of Pollution in the Mediterranean Sea by Dumping from Ships and Aircraft (Dumping Protocol) which was adopted in 1976 [10]; this was renamed the Protocol for the Prevention and Elimination of Pollution of the Mediterranean Sea by Dumping from Ships and Aircraft or Incineration at Sea following amendments adopted in 1995. The amended Dumping Protocol [20] has not yet entered into force.
2. The Protocol Concerning Cooperation in Combatting Pollution of the Mediterranean Sea by Oil and Other Harmful Substances in the Case of Emergency (Emergency Protocol) [14] which was adopted in 1976. It was subsequently amended to be the Protocol Concerning Cooperation in Preventing Pollution from Ships and, in Cases of Emergency, Combating Pollution of the Mediterranean Sea (Prevention and Emergency Protocol), with the revised Protocol being adopted in 2002 [21].
3. The Protocol for the Protection of the Mediterranean Sea against Pollution from Land-Based Sources and Activities (LBS Protocol) [11] which was adopted in 1980. It was subsequently amended in 1996, retaining the same name as the original Protocol [22].

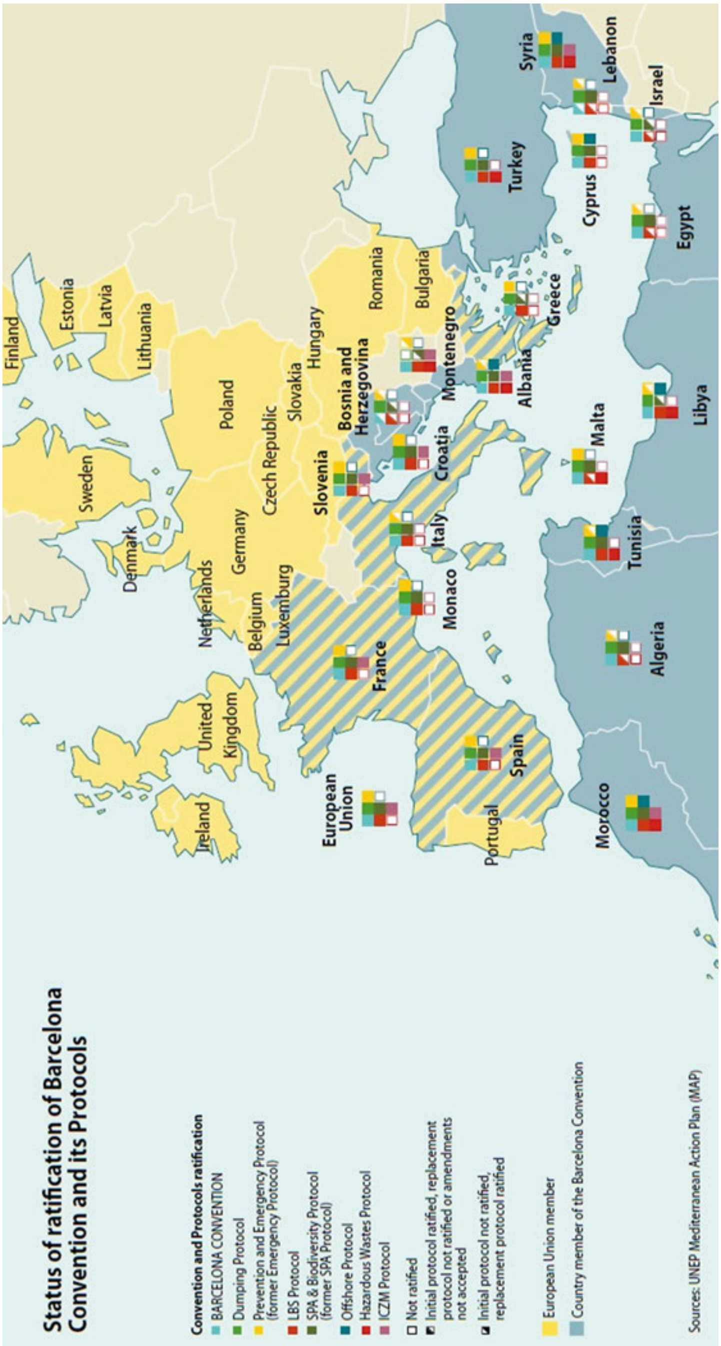

Fig. 1 Map showing status of ratification of the Barcelona Convention and its Protocols. Source: GRID-Arendal. Available at https://www.grida.no/resources/5911

Table 2 Status of signatures and ratifications of the 1976 Barcelona Convention and its 1995 amendments, as at 30/11/16

	1976 Barcelona Convention			
Contracting parties	Signature	Ratification	Acceptance of 1995 amendments	Entered into force
Albania		30.05.90/AC	26.07.01	09.07.04
Algeria		16.02.81/AC	09.06.04	09.07.04
Bosnia and Herzegovina		22.10.94 (SUC)	–	–
Croatia		12.06.92 (SUC)	03.05.99	09.07.04
Cyprus	16.02.76	19.11.79	18.07.03	09.07.04
EC (now EU)	13.09.76	16.03.78/AP	12.11.99	09.07.04
Egypt	16.02.76	24.08.78/AP	11.02.00	09.07.04
France	16.02.76	11.03.78/AP	29.03.01	09.07.04
Greece	16.02.76	03.01.79	10.03.03	09.07.04
Israel	16.02.76	03.03.78	29.09.05	29.10.05
Italy	16.02.76	03.02.79	07.09.99	09.07.04
Lebanon	16.02.76	08.11.77/AC	[a]	[a]
Libya	31.01.77	31.01.79	12.01.09	11.02.09
Malta	16.02.76	30.12.77	28.10.99	09.07.04
Monaco	16.02.76	20.09.77	11.04.97	09.07.04
Montenegro	–	19.11.07	19.11.07	19.12.07
Morocco	16.02.76	15.01.80	07.12.04	06.01.05
Slovenia	–	16.09.93/AC	08.01.03	09.07.04
Spain	16.02.76	17.12.76	17.02.99	09.07.04
Syria	–	26.12.78/AC	10.10.03	09.07.04
Tunisia	25.05.76	30.07.77	01.06.98	09.07.04
Turkey	16.02.76	06.04.81	18.09.02	09.07.04

Source: UNEP [A word document showing the Status of Signatures and Ratifications of the Barcelona Convention and all its Protocols at 30 November 2016 is available at http://www.unep.org/unepmap/who-we-are/legal-framework/status-signatures-and-ratifications (Last accessed 10 August 2017)]
AC accession, *AP* approval, *SUC* succession
[a]Pending notification from Depository country

4. 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) which was adopted in 1994 [15].

5. The Protocol Concerning Specially Protected Areas and Biological Diversity in the Mediterranean (SPA Protocol) which was adopted in 1995, while its Annexes were adopted in 1996 and subsequently amended in 2009 and 2013.
6. The Protocol on the Prevention of Pollution of the Mediterranean Sea by Transboundary Movements of Hazardous Wastes and their Disposal (Hazardous Waste Protocol) [23], which was adopted in 1996.
7. The Protocol on Integrated Coastal Zone Management in the Mediterranean (ICZM Protocol) which was adopted in 2008.

Protocols 1 to 4 above have direct relevance to oil pollution, and these are discussed in more detail in Sect. 4.

3.3 Key Components of the Barcelona Convention

As noted previously, Article 1 sets out the geographical coverage of the Barcelona Convention, and that coverage also applies to the various Protocols to the Convention.

Article 2(a) of the modified Barcelona Convention defines pollution as "the introduction by man, directly or indirectly, of substances or energy into the marine environment, *including estuaries*, which results, *or is likely to result* in such deleterious effects as harm to living resources *and marine life*, hazards to human health, hindrance to marine activities, including fishing *and other legitimate uses of the sea*, impairment of quality for use of seawater and reduction of amenities" [18]. This definition is much more detailed than the original, and the words which were added to the original definition [6] are shown in italics.

Article 3, General Provisions, notes that all CPs are required to act in conformity with international law, and may enter into agreements bilaterally or multilaterally, regionally or subregionally, that promote sustainable development and protect and conserve the Mediterranean Sea environment and its resources. However, any such agreements must be consistent with the Convention and its Protocols (Article 3, para. 2), although these do not prejudice the right of states under the 1982 UN Convention of the Law of the Sea (Article 3, para. 3) [18]. This Article differs considerably from the original Convention which was written at a time when the Law of the Sea was still being developed and codified [6]. The more recent Article is much broader in scope (with five paragraphs instead of two) and includes a note that sovereign immunity applies to warships and other state-owned or state-operated ships, although CPs are to make sure that such vessels – and aircraft – comply with the Convention and its Protocols [18].

General obligations of CPs are set out under Article 4 and include taking measures to prevent, abate, combat or eliminate pollution and protect and enhance the Mediterranean Sea area for both the Convention and any of its Protocols to which they are a party (para. 1) [18]. Not all CPs are parties to all of the Protocols. For example, in respect of the Offshore Protocol [15], only six CPs and the EU have both signed and ratified that Protocol, and it has entered into force in six states plus the EU. Eight states have signed but not ratified the Protocol, and seven states have neither signed nor ratified it (see Sect. 4.4). Other general obligations include, at para. 3 under 5 subparagraphs (a–e). This includes requirements for (a) application of the precautionary principle so that lack of full scientific certainty does not prevent action from being taken to prevent environmental damage as a result of pollution taking place, and (b) application of the polluter pays principle so that any costs of prevention, control or reduction measures are borne by the polluter [18].

At this juncture, it is important to stress that the Barcelona Convention is founded on the so-called polluter pays principle deriving from international standard of civil environmental law, which requires the costs of the pollution be borne by the polluter or the source of the pollution. In this context, Article 4 (3) obliges CPs to:

> [P]romote cooperation between and among States in environmental impact assessment procedures related to activities under their jurisdiction or control which are likely to have a significant adverse effect on the marine environment of other States or areas beyond the limits of national jurisdiction, on the basis of notification, exchange of information and consultation [18].

It is also important to note that latter proposals concerning the establishments of residual liability and Inter-State Compensation Fund as a part of the Barcelona Convention liability and compensation framework (discussed in Sect. 3.3.1 of this chapter) were devised to cover costs that cannot be borne by the polluter.

Articles 5–11 are mainly related to pollution from different sources. Within this group of Articles [18], the Convention requires CPs to take appropriate measures to prevent, abate, combat and, to the fullest extent possible, eliminate pollution of the Mediterranean Sea from the following sources:

- 5 – dumping from ships and aircraft or incineration at sea (incineration at sea was not mentioned in the original Convention [6])
- 6 – from ships, in this case discharges rather than dumping of materials at sea
- 7 – from exploration and exploitation of the continental shelf, seabed and its subsoil
- 8 – from land-based sources
- 11 – from transboundary movements of hazardous wastes and their disposal

Article 8 covers cooperation in dealing with pollution emergencies, and Article 10 covers conservation of biological diversity [15]. Articles 10 and 11 did not exist in the original Convention under which Article 10 covered monitoring and Article 11 covered scientific and technical cooperation [6]. These are Articles 12 and 13 in the revised Convention [15].

In respect of monitoring, Article 12 required CPs to establish monitoring programmes and designate the competent authorities responsible for pollution monitoring. This is in conjunction with Article 8 of the LBS Protocol, for example, which identifies that monitoring programmes should:

– Systematically assess, as far as possible, the levels of pollution along CP coasts, in particular regarding specific sectors of activity including oil, and provide information in that respect.
– Evaluate the effectiveness of action plans, programmes and measures implemented under the LBS Protocol to eliminate to the fullest possible extent pollution of the marine environment [11, 22].

This is an example of how the various Articles of the Barcelona Convention interact and work with the various Protocols to combat pollution. For example, Article 5 of the Convention interacts with the Dumping Protocol [10, 20] and Article 7 with the Offshore Protocol [15]. Transboundary pollution (Article 11) is considered under both the LBS and Offshore Protocols, in addition to the 1996 Protocol on Hazardous Wastes, although there is a brief mention of waste mineral oils unfit for their original use, and to waste oils/water, hydrocarbons/water mixtures, emulsions as being hazardous wastes under Annex I – Categories of waste subject to this protocol.

3.3.1 Liability and Compensation Framework for Pollution: The Backdrop

The legal framework applicable to marine pollution in the Mediterranean is faced with new challenges as new technology allows more ventures and projects to be developed. Against this backdrop, state parties to the Barcelona Convention shouldered the development rules of state responsibility and liability for damage to the marine environment [24]. Prior to amendments in 1995, the Barcelona Convention is considered to have contained a *pactum de contrahendo*, i.e. binding legal instruments under international law giving rise to legal obligations, provision in the manner in which Article 12 of the pre-amended Convention was drafted, i.e.:

> The Contracting Parties undertake to co-operate as soon as possible in the formulation and adoption of appropriate procedures for the determination of liability and compensation for damage resulting from the pollution of the marine environment deriving from violations of the provisions of this Convention and applicable protocols [6].

As is observed in the amended Barcelona Convention of 1995, Article 16 that encapsulates the "liability and compensation" provision has apparently left out the words "as soon as possible". It has been identified that a delegate advanced this proposal "who remarked that the lapse of almost twenty years had not been sufficient to finalise what the parties in 1976 had undertaken to do 'as soon as possible'" [25]. Despite this amendment, from a comparative viewpoint, Article 16 of the Barcelona Convention embodies traits similar to other important existing regional conventions such as the Convention on the Protection of the Marine Environment of the Baltic Sea Area of 1992 (Article 25), and the Convention on the Protection of the Black Sea Against Pollution of 1992 (Article XVI) [26, 27].

When examining the history of the development of the liability and compensation framework, it is important to commence with the first initiatives that took place 2 years after the implementation of the Barcelona Convention of 1976. Following the 1978 initiatives by UNEP-MAP to commission a study on the subject matter of compensation and liability, the CPs to the Barcelona Convention in 1997 gathered the UNEP-MAP Secretariat and government-designated legal and technical experts in a meeting held in Brijuni, Croatia, to address the appropriate procedures for the determination of liability and compensation for damages resulting from pollution in the Mediterranean marine environment [25]. In retrospect, the basis for this joint discussion was a text draft prepared by the UNEP-MAP secretariat, aptly considered as being "too ambitious" due to its far-reaching purpose [25]. It has been explicitly indicated that the far-reaching ambition of the draft included, inter alia, a three-tier regime of liability [25]:

1. Liability Standard (p. 8): An effective liability regime under the Barcelona Convention system should be based on strict liability. Unlike the fault-based liability, strict liability requires no proof of fault (which may be very difficult or even impossible to obtain) that the conduct of the operator was intentionally or negligently in violation of the law. Strict liability only requires that the damage was caused as a result of the conduct of the operator and that the damage is not permissible under the Barcelona Convention or the liability regime. At the same time, strict liability is more flexible than absolute liability because it allows a narrowly defined range of exemptions.
2. International Liability and Compensation (residual liability) (p. 14): The establishment of the residual liability for the state is supplementary to the application of the "polluter pays principle" because it operates only when the private operator cannot pay the entire cost of the required compensation and reparation. The basis of the residual state liability is broadly conceived, in the sense that it derives from the fact that the state has jurisdiction and control over the dangerous or potentially dangerous activities through permits (e.g. Dumping Protocol), authorisations or regulations (e.g. LBS Protocol, Offshore Protocol), notifications (e.g. Hazardous Wastes Protocol) or granting exemptions (SPA Protocol). This broadly conceived residual state liability is of particular importance in relation to those dangerous or potentially dangerous activities which cause significant adverse effect on the marine environment of other states or areas beyond the limits of national jurisdiction.
3. International Liability and Compensation [Mediterranean Inter-State Compensation Fund (MISC Fund)] (pp. 14–15): The contracting parties may establish the Mediterranean Inter-State Compensation Fund (hereinafter, as MISC Fund) for two purposes: (a) for compensation only to the extent that compensation for damage under the civil liability regime is inadequate or not available (in case of

unknown polluters) and (b) for the implementation of reasonable preventive measures in emergency situations (after the occurrence of the incident) [28].

Other than the far-ranging and expansive purpose, the 1997 text draft received "lukewarm" acceptance by the CPs due to the fact that it was based on the Convention on Civil Liability for Damage Resulting from Activities Dangerous to the Environment of 1993 (Lugano Convention[2]) [25].

3.3.2 Guidelines on Liability and Compensation

Following the 1997 effort to develop a liability and compensation regime, a meeting comprised of non-governmental experts was convened on 21 April 2003 in Athens [29]. The objective was to discuss the grounds for the development of a legal instrument in the form of a Guideline on the same subject matter [25]. In this discussion, the experts considered the framework of Directive 2004/35/EC since the European Community is an important actor within the UNEP-MAP community [25]. Moreover, adhering to the framework of Directive 2004/35/EC would bring the intended Guideline more in line with European Union policy and would undoubtedly avoid any undesired overlaps.

It is important to note that Directive 2004/35/EC does not stipulate provisions concerning compensation for persons or property [30]. However, the Directive includes "damage caused by airborne elements in far as they cause damage to water, land or protected species or natural habitats" [30]. In the same year, at the 13th ordinary meeting held between 11 and 14 November, the CPs to the Barcelona Convention requested the Secretariat to formulate and provide a "feasibility study" that could not only cover the legal, economic, financial and social aspects pertaining to the intended liability and compensation regime but also avoid overlapping with other existing regimes [25]. Subsequently, recommendations for the establishment of an Open-Ended Working Group of Legal and Technical Experts were advanced in the 14th ordinary meeting held between 8 and 11 November 2005 [25]. The duty of such a Group would be to propose "appropriate rules and procedures for the determination of liability and compensation for damage resulting from pollution of the marine environment in the Mediterranean Sea" [25]. The Working Group held two meetings: the first meeting was held between 7 and 8 March in 2006, and the second meeting was held in the following year, between 28 and 29 June in 2007 [25].

After the conclusion of the first meeting, the Working Group experts requested the UNEP-MAP Secretariat to prepare a set of draft Guidelines that would ultimately result in adoption in the course of the second meeting [25]. With regard to the scope of the Guidelines, it is considered to apply to all actions to which the Barcelona Convention and the broad range of matters that are covered by its seven

[2]For further information on the Lugano Convention, *see Convention on Civil Liability for Damage Resulting from Activities Dangerous to the Environment of 1993*. Available at https://rm.coe.int/168007c079 (Last accessed 24 October 2017).

Protocols as listed in Sect. 3.2 of this chapter [25]. In the context of oil pollution, the Guidelines would apply to liability and damage resulting from oil and other harmful substances.

4 Overview of the Protocols of the Barcelona Convention with Relevance to Oil Pollution

The Protocols to the Barcelona Convention discussed in this section all have some direct relevance to preventing oil inputs into the Mediterranean Sea. For example, the Dumping Protocol includes dumping – the deliberate disposal into the sea – of wastes from ships, aircraft and offshore installations, while the Prevention and Emergency Protocol deals with how to prevent, where possible, or respond to oil pollution from ships, etc. in the event of an accident, for example. Four Protocols are discussed in this section, including details of some of the main Articles.

4.1 The Dumping Protocol and Its Main Requirements

The *Protocol for the Prevention of Pollution in the Mediterranean Sea by Dumping from Ships and Aircraft* (Dumping Protocol) [10] was adopted and entered into force at the same time as the original convention (February 1976 and February 1978, respectively).

The Protocol was amended in June 1995 and was renamed the *Protocol for the Prevention and Elimination of Pollution of the Mediterranean Sea by Dumping from Ships and Aircraft or Incineration at Sea* [20]. While those amendments have not yet entered into force, the majority of CPs have registered their acceptance of them.

Table 3 sets out signatories to the 1976 Protocol together with its Amendments of 1995 as of 30 November 2016. Some of the main Articles of the Protocol and its subsequent amendment with relevance to oil pollution are then outlined. In the case of this Protocol, all states except Montenegro were signatories to the original protocol, and Montenegro has also not accepted the amendments to the Protocol. Algeria, Bosnia and Herzegovina, Lebanon and Libya have also not accepted the amendments to the Protocol.

Article 3, para. 3, of the original Protocol identified dumping as being (a) any deliberate disposal at sea of wastes or any other matter from ships or aircraft or (b) any deliberate disposal at sea of ships or aircraft [10]. However, the amended Protocol provided a new subcategory which was (c) deliberate disposal or storage and burial of wastes or other matter on the seabed or in the marine subsoil from ships or aircraft [20].

Table 3 Status of signatures and ratifications of the 1976 Dumping Protocol and its 1995 amendments as at 30/11/16

	1976 Dumping Protocol		
Contracting parties	Signature	Ratification	Acceptance of 1995 amendments
Albania		30.05.90/AC	26.07.01
Algeria		16.03.81/AC	–
Bosnia and Herzegovina		22.10.94/SUC	–
Croatia		12.06.92/SUC	03.05.99
Cyprus	16.02.76	19.11.79	18.07.03
EU	13.09.76	16.03.78/AP	12.11.99
Egypt	16.02.76	24.08.78/AP	11.02.00
France	16.02.76	11.03.78/AP	29.03.01
Greece	16.02.76	03.01.79	–
Israel	16.02.76	01.03.84	–
Italy	16.02.76	03.02.79	07.09.99
Lebanon	–	08.11.77/AC	–
Libya	31.01.77	31.01.79	–
Malta	16.02.76	30.12.77	28.10.99
Monaco	16.02.76	20.09.77	11.04.97
Montenegro	–	–	–
Morocco	16.02.76	15.01.80	05.12.97
Slovenia	–	16.09.93/AC	08.01.03
Spain	16.02.76	17.12.76	17.02.99
Syria	–	26.12.78/AC	11.04.08
Tunisia	25.05.76	30.07.77	01.06.98
Turkey	16.02.76	06.04.81	18.09.02

Source: UNEP [A word document showing the Status of Signatures and Ratifications of the Barcelona Convention and all its Protocols at 30 November 2016 is available at http://www.unep.org/unepmap/who-we-are/legal-framework/status-signatures-and-ratifications (Last accessed 10 August 2017)]
AC accession, *AP* approval, *SUC* succession

There are some exceptions to what is included as dumping, which are set out at Article 3, para. 4. This includes disposal at sea of wastes or other matter incidental to, or derived from, the normal operations of vessels or aircraft and their equipment, for example [20].

While Article 3 of the original Protocol did not cover incineration at sea, a new para. 5 was added in the amended Protocol which defined incineration at sea as "the deliberate combustion of wastes or other matter in the maritime waters of the Mediterranean Sea, with the aim of thermal destruction and does not include activities incidental to the normal operations of ships or aircraft" [20]. Incineration at sea is prohibited under Article 7 of the revised Protocol [20].

Article 4 of the original Protocol [10] identified that the dumping of wastes or other matter was prohibited under Annex I of that Protocol. In the list of substances outlined in Annex I, "6. Crude oil and hydrocarbons which may be derived from petroleum, and any mixtures containing any of these, taken on board for the purposes of dumping" are prohibited [10].

No other direct mention of oil appears in the original Protocol, and, with the deletion of Annex I in the amended Protocol, oil is not specifically mentioned. However, in a consolidated version of the Dumping Protocol [31], Article 3, para. 1, identifies ships and aircraft to include platforms and other man-made structures at sea and their equipment, while Article 4, para. 2(d), identifies that the dumping of wastes or other matter including platforms and other man-made structures is not prohibited, as long as material capable of creating floating debris or contributing to pollution of the marine environment has been removed (although provisions of the Offshore Protocol, discussed in Sect. 4.4, are mentioned but without specific detail) [31].

Article 8 of the original Protocol notes that provisions of Articles 4, 5 and 6 (a requirement to obtain a permit to dump other wastes from a competent national authority) shall not apply in the case of *force majeure*, i.e. where due to stress of weather or any other cause where human life or the safety of an aircraft or ship is threatened [10]. In such circumstances, any dumping has to be reported, including the nature and quantities of wastes or other matter dumped, so that action can be taken.

Article 11 of the amended Protocol requires each Party to apply its measures to all ships and aircraft registered in their territory or flying their flag, to ships and aircraft loading in their territory any waste or other matter which is to be dumped and to ships and aircraft believed to be engaged in dumping in areas under its jurisdiction [31]. Article 12 further requires each Party to instruct their maritime inspection ships and aircraft and other services to report any suspicious incidents or conditions which suggest that the Protocol has been contravened.

Finally, Article 13 sets out that all parties have the right to adopt other measures to prevent pollution due to dumping, in accordance with international law. In this regard, the consolidated version of the Protocol [31] makes specific mention of the *Convention on the Prevention of Marine Pollution by Dumping of Wastes and other Matter* (London Convention, 1972) and subsequent resolutions under that convention that prohibit the dumping and incineration of industrial wastes at sea. The London Convention, in force since 1975 and amended in 1996 through the London Protocol, was one of the first global conventions to protect the marine environment from human activities and promotes the effective control of all sources of marine pollution [32].

The 1996 Protocol to the London Convention, in its Annex 2 – Assessment of Wastes or Other Matter that may be considered for dumping – requires CPs to develop a national Action List to provide a mechanism for screening candidate wastes and their constituents, on the basis of their effect on human health and the marine environment, and including toxic, persistent and bioaccumulative substances (Para. 9). Among the substances listed, there are petroleum hydrocarbons [33], and so the Dumping Protocol plays a role in preventing oil discharges into the

Mediterranean Sea through, for example, its requirement for permits and also for reporting of suspicious incidents at sea.

4.2 The Prevention and Emergency Protocol and Its Main Requirements

The *Protocol Concerning Cooperation in Preventing Pollution from Ships and*, *in Cases of Emergency*, *Combatting Pollution of the Mediterranean Sea* (Prevention and Emergency Protocol) [21] was adopted at a Conference of the Plenipotentiaries in Malta in January 2002 and entered into force on 17 March 2004. The 2002 Protocol replaced the original *Protocol Concerning Cooperation in Combating Pollution of the Mediterranean Sea by Oil and other Harmful Substances in Cases of Emergency* (Emergency Protocol) [14] which had been adopted in Barcelona in February 1976 and which had been in force since 12 February 1978. The change in name of this Protocol reflects recognition of the need for prevention of pollution from ships, in addition to responding to pollution incidents irrespective of their origin [21].

Table 4 sets out the status of signatories and ratifications of the Prevention and Emergency Protocol at 30 November 2016. The most recent ratification of the Protocol was by Algeria on 14 November 2016, with the Protocol and the Protocol into force for Algeria on 14 December 2016. For this Protocol all parties except Montenegro ratified the original Protocol, although it subsequently ratified the 2002 Protocol. Albania, Bosnia and Herzegovina, Egypt and Lebanon are still to ratify the 2002 Protocol, while Israel and Libya have signed it, but it has not yet entered into force.

A number of changes appear in the Preamble to the Protocol comparing the original to the amended versions, before the specific Articles are considered. For example, the original Protocol considered grave pollution of the sea by oil and other harmful substances and the danger posed to coastal states and marine ecosystems [14], while the amended version goes further and additionally considers hazardous and noxious substances [21], thus broadening the scope of the Protocol.

While the original Protocol makes specific reference to international legislation such as the *International Convention for the Prevention of Pollution from Ships*, *1973* (MARPOL Convention) [34]; the *International Convention relating to Intervention on the High Seas in Cases of Oil Pollution Casualties*, *1969* [28]; and the *International Convention on Civil Liability for Oil Pollution Damage*, *1969* (CLC Convention) [35], no specific conventions were identified in the amended version. Rather the preamble acknowledged the role of the IMO in promoting "adoption and the development of international rules and standards to prevent, reduce and control pollution of the marine environment from ships" [20][3]. In addition, the amended

[3]A comprehensive list of Conventions is available at http://www.imo.org/en/About/Conventions/ListOfConventions/Documents/Convention%20titles%202016.pdf, while an excel chart listing Ratifications by State as of 31 July 2017 is available at http://www.imo.org/en/About/Conventions/StatusOfConventions/Pages/Default.aspx (both last accessed 10 August 2017).

Table 4 Status of signatures and ratifications of the 1976 *Emergency Protocol*, and the 2002 *Prevention and Emergency Protocol*, as at 30/11/16

	1976 Emergency Protocol			2002 Prevention and Emergency Protocol		
Contracting parties	Signature	Ratification	Acceptance of 1995 amendments	Signature	Ratification	Entered into force
Albania	–	30.05.90/ AC	29.06.90	–	–	–
Algeria	–	16.03.81/ AC	15.04.81	25.01.02	*14/11/16*	*14/12/ 16*
Bosnia and Herzegovina	–	22.10.94/ SUC	01.03.92	–	–	–
Croatia	–	12.06.92/ SUC	08.10.91	25.01.02	01.10.03	17.03.04
Cyprus	16.02.76	19.11.79	19.12.79	25.01.02	19.12.07	18.01.08
European Union	13.09.76	12.08.81/ AP	11.09.81	25.01.02	26.05.04	25.06.04
Egypt	16.02.76	24.08.78/ AC	23.09.78	–	–	–
France	16.02.76	11.03.78/ AP	10.04.78	25.01.02	02.07.03	17.03.04
Greece	16.02.76	03.01.79	02.02.79	25.01.02	27.11.06	27.12.06
Israel	16.02.76	03.03.78	02.04.78	22.01.03	10.09.14	10.10.14
Italy	16.02.76	03.02.79	05.03.79	25.01.02	–	–
Lebanon	–	08.11.77/ AC	12.02.78	–	–	–
Libya	31.01.77	31.01.79	02.03.79	25.01.02	–	–
Malta	16.02.76	30.12.77	12.02.78	25.01.02	18.02.03	17.03.04
Monaco	16.02.76	20.09.77	12.02.78	25.01.02	03.04.02	17.03.04
Montenegro	–	–	–	–	19.11.07	19.12.07
Morocco	16.02.76	15.01.80	15.02.80	25.01.02	26.04.11	26.05.11
Slovenia	–	16.09.93/ AC	15.03.94	25.01.02	16.02.04	17.03.04
Spain	16.02.76	17.12.76	12.02.78	25.01.02	10.07.07	09.08.07
Syria	–	26.12.78/ AC	25.01.79	25.01.02	11.04.08	11.05.08
Tunisia	25.05.76	30.07.77	12.02.78	25.01.02	–	–
Turkey	16.02.76	06.04.81	06.05.81	–	03.06.03	17.03.04

Source: UNEP [A word document showing the Status of Signatures and Ratifications of the Barcelona Convention and all its Protocols at 30 November 2016 is available at http://www.unep.org/unepmap/who-we-are/legal-framework/status-signatures-and-ratifications (Last accessed 10 August 2017)]

AC accession, *AP* approval, *SUC* succession

Protocol also acknowledged the contribution of the European Community in relation to "implementation of international standards as regards maritime safety and prevention of pollution from ships" [21].

Looking in more detail at the specific Articles in the amended Protocol, as compared with the original, there are many differences between the two, the amended version being more complex than the original which had 13 Articles [14]. The amended Protocol has 25 Articles including contingency planning (Article 4); cooperation in recovery operations (Article 6 – which covers the loss overboard of hazardous and noxious substances in packaged form); dissemination and exchange of information (Article 7); emergency measures on board ships, on offshore installations and in ports (Article 11); port reception facilities (Article 14); and environmental risks of maritime traffic (Article 15), for example [21]. Several Articles in the amended Protocol are discussed below.

Article 4 considers contingency plans and other means of preventing and combating pollution incidents [21], including putting in place equipment, ships, aircraft and personnel to undertake emergency operations, strengthening the capability of parties to respond to a pollution incident and designating national and other authorities to implement the Protocol, for example (Article 4, para. 1) [21].

At Article 4, para. 3, parties are required to inform the Regional Centre (REMPEC, see Sect. 2.3) of measures taken to implement Article 4 [21]. This is much more comprehensive than Article 4 in the original Protocol [14] which simply required the parties to develop and apply, either individually, bilaterally or multilaterally, cooperative monitoring activities to have precise information relating to situations set out in Article 1, i.e. "grave and imminent danger to the marine environment, the coast or related interests of one of more Parties due to the presence of massive quantities of oil or other harmful substances" [14]. That oil could come from either accidental causes or an accumulation of small discharges [14]. Monitoring activities, in the amended Protocol, are covered by Article 5 [21].

Article 7 covers dissemination and exchange of information [20] and is much more detailed that the corresponding Article 6 in the original protocol. In respect of the latter, Article 6, para. 1, of the original Protocol sets out that parties will inform each other of who is the competent national authority responsible for (a) combatting pollution and (b) receiving reports of pollution. It also sets out, at 1(c) that information will be disseminated on new ways to avoid pollution of the sea by oil and other harmful substances, new measures to combat pollution and also on the development of new research programmes [14]. Article 7 of the amended Protocol [21] goes further, however, by also requiring information to be exchanged on national organizations or authorities responsible for the implementation of port reception facilities and monitoring discharges which are illegal under MARPOL 73/78, for example, at Article 7, para. 1 (d) [36], while 1(e) talks about regulations and other matters with a direct bearing on preparedness and response. 1(f) is consistent with 1(c) in the original Protocol.

The provision of port reception facilities (PRFs) to receive ship-generated waste and cargo residues, in line with various Annexes of the MARPOL 73/78 Convention, is regulated in EU ports under Directive 2000/59/EC [37] and administered by the European Maritime Safety Agency (EMSA)[4] (see [38] for further details on the role of EMSA in oil pollution preparedness and response, etc. in the Mediterranean Sea region).

Article 9 (originally Article 8) deals with reporting procedures [21]. It is much more detailed than the original version. For example, para. 2 makes reference to ensuring that all ships masters operating in the territorial waters of a Party state comply with the requirement at para. 1 to report any incidents where oil or hazardous or noxious substances are discharged, including the characteristics and extent of such spills [21]. Article 9, para. 3, requires each Party to instruct persons in charge of sea ports or handling facilities to report all incidents which result (or may result) in an oil discharge or other hazardous or noxious substances [21]. A link to the provisions of the Offshore Protocol [15] relating to exploration and exploitation is set out at para. 5 covering reporting of discharges of oil, etc. from offshore units by the responsible persons in charge of those units [21]. With these reporting requirements for ships, ports and installations, the result should be that even small pollution incidents (and also potential incidents) are reported to relevant national bodies and to REMPEC.

Article 10 (originally Article 9) covers operational measures. Para. 1 indicates any Party facing a pollution incident can (a) assess the "nature, extent and possible consequences of the pollution incident . . . or the type and approximate quantity of oil . . . including direction and speed of drift of the spillage" and (b) "take every practicable measure to prevent, reduce and, to the fullest possible extent, eliminate the effects of the pollution incident" [21]. Other requirements under para. 1 include (c) informing affected parties and (d) observing and reporting on incidents, in accordance with Article 9. The priorities, when dealing with pollution from a ship are set out at para. 2 as (a) human lives and then (b) the ship itself so that damage to the environment is prevented or minimized, and any action is reported to both the IMO and through REMPEC [21].

Article 11 deals with emergency measures on board ships, offshore installations and in ports [21]. There was no such article in the original Protocol. Under this Article at para. 1, there is a requirement that ships flying the flag of a Party have a Pollution Emergency Plan on board, in line with relevant international regulations. This would, for example, include Shipboard Marine Pollution Emergency Plans that are a requirement under MARPOL Annex I, Regulation 37 for oil tankers of 150 gross tonnage and above and all ships of 400 gross tonnage and above [39]. In terms of operators in charge of sea ports and handling facilities, para. 4 also sets out the requirement for Pollution Emergency Plans or similar arrangements, to be coordinated with national systems [20]. For operators in charge of offshore

[4]For further details relating to EMSA's role in dealing with port waste reception facilities, see http://www.emsa.europa.eu/implementation-tasks/environment/port-waste-reception-facilities/items.html?cid=147&id=101 (Last accessed 10 August 2017).

installations, contingency plans to combat pollution incidents are a requirement at para. 5 [21].

In the event of a pollution incident occurring, Article 12 establishes that any Party that requires assistance in dealing with it can call for it from other parties directly or via REMPEC [21] and that such assistance might be the provision of expert advice or specialized personnel, products, equipment, etc. (para. 1). In the event that parties cannot agree on how to conduct operations to combat pollution, REMPEC can coordinate such activities (para. 2), while measures to facilitate such operations, including ship, aircraft and other transport movements, and the movement of personnel, cargoes, materials, equipment, etc. are set out in para. 3. Detailed arrangements for the reimbursement of costs of such assistance are set out in Article 13 [21].

Article 14 sets out the requirements for port reception facilities to meet the needs of ships using a Party's ports and terminals without causing undue delay to ships using those facilities (para. 1) [21]. Reception facilities are a requirement under MARPOL 73/78 for specific substances such as oil under Annex I – Regulations on the Prevention of Pollution by Oil [36]. All Mediterranean states are signatories to Annex I apart from Bosnia and Herzegovina and also to Annex II – Regulations for the Control of Pollution by Noxious Liquid Substances in Bulk, for example [39]. Also relating to MARPOL 73/78, para. 4 requires parties to take steps to provide updated information relating to that legislation [21].

Article 15 on environmental risks of maritime traffic [21] requires parties to individually, bilaterally or multilaterally take steps to "assess the environmental risks of the recognized routes of maritime traffic" and take measures to reduce the risk of accidents and their environmental consequences. Shipping is a major activity in the Mediterranean Sea region, including the transportation of oil [4] and so preventative measures such as assessing routes could make a significant contribution in protecting the marine environment of the region in the event of a major spill occurring in the future.

The Prevention and Emergency Protocol is very important in terms of trying to reduce or prevent the input of oil from ships and other sources into the Mediterranean Sea. It supports the main objective of REMPEC to prevent and reduce pollution from ships, to combat pollution in the event of an emergency and also to implement the Regional Strategy for the Prevention of and Response to Pollution from Ships [16].

4.3 The Land-Based Sources Protocol and Its Main Requirements

The *Protocol for the Protection of the Mediterranean Sea against Pollution from Land-Based Sources and Activities* (LBS Protocol) [13] was adopted in May 1980 and amended in March 1996 [22]. The amended Protocol entered into force in May 2006.

Table 5 sets out the signatories and ratifications of the LBS Protocol at 30 November 2016. Algeria, Bosnia and Herzegovina and Libya have all ratified the initial Protocol [13] but not the replacement Protocol [22], and they have also not accepted its amendments (see also Fig. 1).

The LBS Protocol was developed in recognition of the danger posed by human activities in the Mediterranean Sea, and the Preamble to the original Protocol noted that "the danger posed to the marine environment and to human health by pollution from land-based sources . . . [was] primarily due to the release of untreated, insufficiently treated or inadequately disposed of domestic or industrial discharges" [13].

While the LBS Protocol deals with a wide range of pollutants from industrial and agricultural activities, for example, it does make some specific mention of oil as a pollutant. For example, used lubricating oils were identified in Annex I of the original 1980 Protocol as being one of the substances of concern based on toxicity, persistence and bioaccumulation [13], while crude oils and hydrocarbons were listed in Annex II on the basis of the fact that they are generally less noxious. In 1996 a survey of pollutants from land-based sources estimated the annual pollution load of oil entering the Mediterranean as being around 120,000 t per annum, all coming from industrial activities in coastal zones [40]. More recently, used lubricating oil was categorized as a hazardous waste, and in 2008 oils and greases (organic) were identified as being the top pollutant by emissions value, although this was no longer the case in 2013 [12; at Fig. 14].

In terms of pollution by oil, the general obligations of the revised Protocol (Article 5) require all parties to eliminate pollution deriving from land-based sources and activities listed in Appendix I [22]. Under Annex I, these include petroleum refining, the waste management industry and transport under A (Sectors of Activity); include substances with transboundary significance and can affect the taste and/or smell of marine products for human consumption, for example, under B (Characteristics of Substances in the Environment); and include polycyclic aromatic hydrocarbons, used lubricating oils and crude oils and hydrocarbons of petroleum origin, for example, under C (Categories of Substances) [22].

Annex II of the revised Protocol now deals with elements to be taken into account in issuing authorizations to discharge waste such as the characteristics and composition of discharges, their characteristics in respect of harmfulness and characteristics of discharge site and receiving environment. Annex III (Annex IV of the original Protocol) deals with pollution transported through the atmosphere, while Annex IV relates to Best Available Techniques and Best Environmental Practice in areas such as limiting discharges, emissions and waste [22].

Other Articles which had relevance to oil pollution include Article 7, Common Guidelines, Standards and Criteria, which requires parties to cooperate with international organizations to develop criteria for (a) the length, depth and position of pipelines for coastal outfalls; (d) control and progressive replacement of products, installations and industrial processes causing significant pollution of the marine environment; and (e) specific requirements on quantities of substances listed under Annexes I and II, for example [22].

Article 8, Monitoring, requires parties to undertake monitoring (and make the findings of that monitoring public) to (a) systematically assess the levels of pollution

Table 5 Status of signatures and ratifications of the 1994 Offshore Protocol, as at 30/11/16

	1980 Land-Based Sources Protocol			
Contracting parties	Signature	Ratification	Acceptance of 1996 amendments	Entered into force
Albania	–	30.05.90/AC	26.07.01	24.03.11
Algeria	–	02.05.83/AC	–	–
Bosnia and Herzegovina	–	22.10.94/SUC	–	–
Croatia	–	12.06.92/SUC	11.10.06	–
Cyprus	17.05.80	28.06.88	18.07.03	24.03.11
EU	17.05.80	07.10.83/AP	12.11.99	29.03.13
Egypt	–	18.05.83/AC	–	11.05.08
France	17.05.80	13.07.82/AP	29.03.01(AP)	–
Greece	17.05.80	26.01.87	10.03.03	–
Israel	17.05.80	21.02.91	19.06.09	11.05.08
Italy	17.05.80	04.07.85	07.09.99	11.05.08
Lebanon	17.05.80	27.12.94	–	11.05.08
Libya	17.05.80	06.06.89/AP	–	–
Malta	17.05.80	02.03.89	28.10.99	11.05.08
Monaco	17.05.80	12.01.83	26.11.96	11.05.08
Montenegro	–	19.11.07(AC)	19.11.07	19.07.09
Morocco	17.05.80	09.02.87	02.10.96	11.05.08
Slovenia	–	16.09.93/AC	08.01.03	–
Spain	17.05.80	06.06.84	17.02.99	–
Syria	–	01.12.93/AC	11.04.08	11.05.08
Tunisia	17.05.80	29.10.81	01.06.98	11.05.08
Turkey	–	21.02.83/AC	18.09.02	11.05.08

Source: UNEP [A word document showing the Status of Signatures and Ratifications of the Barcelona Convention and all its Protocols at 30 November 2016 is available at http://www.unep.org/unepmap/who-we-are/legal-framework/status-signatures-and-ratifications (Last accessed 10 August 2017)]
AC accession, *AP* approval, *SUC* succession

along their coasts as they relate to the sectors of activity and categories of substance from Annex I and (b) evaluate the effectiveness of action plans, programmes and measures to eliminate pollution of the marine environment in this respect [22].

Article 11, Transboundary Pollution, deals with discharges from a watercourse flowing through the territories of two or more parties or forms a boundary between parties, requiring them to (1) cooperate in dealing with marine pollution from that watercourse and (2), if the pollution comes from a non-contracting state, cooperate with that state in applying the Protocol. In the case of the LBS Protocol, as noted previously Algeria, Bosnia and Herzegovina and Libya all ratified the initial Protocol [13] but not the replacement Protocol [22] (see Table 5). However, Article 11 of the original Protocol also covered transboundary pollution, and those states should continue to cooperate in dealing with such pollution.

The main area covered by the Land-Based Sources Protocol is pollution from industrial, agricultural and other sectors that produce substances that can enter the marine environment from watercourses (e.g. rivers, canals and outlets), where those substances can cause damage to the marine environment. Offshore installations are not covered by this Protocol, with Article 4, para. 2, noting that the Protocol applies to mixed man-made offshore structures but that these structures are not involved in exploration and exploitation of mineral resources of the continental shelf, seabed and its subsoil [22]. Oil is a mineral resource and is, therefore, covered by the Offshore Protocol [15] of the Barcelona Convention, discussed in Sect. 4.4.

4.4 The Offshore Protocol and Its Main Requirements

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) [15] was adopted in 1994 and entered into force in 2011.

Table 6 sets out the signatories and ratifications of the Offshore Protocol at 31 July 2015. As can be seen in Table 6 and also Fig. 1, far fewer parties have signed this Protocol than is the case for the Barcelona Convention and the Protocols discussed in Sects. 4.1, 4.2, and 4.3. The Offshore Protocol has only been ratified by and entered into force in six states plus the EU, while eight states have signed the Protocol, but ratification and entry into force have still not occurred. Seven states have neither signed nor ratified the Protocol.

Within the definitions set out in Article 1 of this Protocol, exploration includes seismological activities, surveys of the seabed and its subsoil, sample taking and exploration drilling. Exploitation includes establishing installations to recover resources (solid, liquid or gaseous mineral resources), development drilling; recovery, treatment and storage; transportation to shore by pipeline or ships; and maintenance and repair operations. A wide range of installation types that are fixed or floating structures are covered by the Protocol, which includes oil exploration and drilling platforms [15].

Specific definitions of oil are also outlined in Article 1, which refers to petroleum in any form including crude oil, fuel oil, oily sludge and refined products, for example, while the Appendix to the Protocol sets out a (non-exhaustive) list of oils under eight subcategories [15].

Section III of the Protocol, covering wastes and harmful or noxious substances and materials, is the main section dealing with a range of pollutant types that can be discharged by installations. Article 10 relates to oil and oily mixtures and drilling fluids and cuttings [15]. Drilling fluids are an emulsion of water and other additives such as clays and chemicals which are used to lubricate and cool the drilling bit and to flush out rock and other materials – cuttings – while a well is being drilled. Article 10 sets out specific standards for the disposal of oil and oily wastes 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 (a by-product of oil

Table 6 Status of signatures and ratifications of the 1994 Offshore Protocol, as at 30/11/16

	1994 Offshore Protocol		
Contracting parties	Signature	Ratification	Entered into force
Albania	–	26.07.01	24.03.11
Algeria	–	–	–
Bosnia and Herzegovina	–	–	–
Croatia	14.10.94	–	–
Cyprus	14.10.94	16.05.06	24.03.11
EU	17.12.12/AC	29.03.13	29.03.13
Egypt	–	–	–
France	–	–	–
Greece	14.10.94	–	–
Israel	14.10.94	–	–
Italy	14.10.94	–	–
Lebanon	–	–	–
Libya	–	16.06.05	24.03.11
Malta	14.10.94	–	–
Monaco	14.10.94	–	–
Montenegro	–	–	–
Morocco	–	01.07.99	24.03.11
Slovenia	10.10.95	–	–
Spain	14.10.94	–	–
Syria	20.09.95	22.02.11	24.03.11
Tunisia	14.10.94	01.06.98	24.03.11
Turkey	–	–	–

Source: UNEP [A word document showing the Status of Signatures and Ratifications of the Barcelona Convention and all its Protocols at 30 November 2016 is available at http://www.unep.org/unepmap/who-we-are/legal-framework/status-signatures-and-ratifications (Last accessed 10 August 2017)]
AC accession, *AP* approval, *SUC* succession

and gas production operations) with a limit of 100 mg/l which cannot be exceeded at any time. While the Article sets out these commons standards, and each Party is required to enforce them, they are also permitted to adopt and enforce more restrictive standards [15].

More detailed provisions relating to oil and oily mixtures and drilling fluids and cuttings are set out in Annex V to the Protocol and include details of how spills are to be dealt with, of how wastes are to be transported to shore and that seabed sampling and analysis are required in the case of production and development drilling, for example [15].

There are some exceptions to the standards for oil (and also for sewage and garbage – Articles 11 and 12, respectively). Article 14 notes that the provisions of Section III will not apply in cases where it is necessary to save human life and ensure the safety of an installation or where there is damage to an installation or its equipment (as long as reasonable precautions are taken to minimize the negative effects of such damage) [15].

This Protocol consists of 32 Articles, 7 Annexes and 1 Appendix. Some of the specific articles of the Protocol include Article 16 on Contingency Planning which makes reference to the Emergency Protocol (see Sect. 4.2) with a requirement that CPs require installation operators to have a contingency plan to combat accidental pollution (para. 2 and also Annex VII covering operators contingency plans and national coordination and direction); Article 17 which covers notification of potential and also observed pollution events; Article 18 which covers mutual assistance in case of emergency, noting that a Party can request help from others (either directly or through REMPEC) to prevent, abate or combat pollution; Article 20 on removal of installations which have been abandoned or disused; and Article 21 on specially protected areas [15]. Transboundary pollution is covered in the Protocol at Article 26, with para. 3 noting that if a Party becomes aware that the marine environment is in imminent danger of damage from pollution, it should contact the other parties that are likely to be affected by such pollution and also REMPEC.

As noted previously, a large number of CPs have yet to ratify this Protocol. However, action is being taken to try and change that. At a meeting in 2016, it was highlighted that there was the possibility of significant accidents taking place as a result of increasingly intense offshore activities and that any such accident could have long-term consequences for fragile ecosystems and the biodiversity of the Mediterranean Sea [41]. The remaining CPs were urged to ratify and adopt the Offshore Protocol as soon as possible and also to adopt a Mediterranean Offshore Action Plan developed within the framework of the Protocol. In its Specific Objective 5, the Mediterranean Offshore Plan requires that all CPs provide data on discharges, spills and emissions from offshore oil and gas installations to the Secretariat to the Barcelona Convention; that the Secretariat should publish an inventory of installations, discharges, spills, etc., on a dedicated platform every 2 years; and that it should also produce a consolidated report on the same based on the data submitted to it [41]. This would be an important step forward in making sure data on installations and spills was made publicly available and in improving monitoring of installations and protecting the marine environment.

4.5 *Tabular Comparison with Other Protocols*

Although the scope of the three remaining Protocols, namely, the SPA Protocol, the Hazardous Waste Protocol and the ICZM Protocol, applies to the area of the Mediterranean Sea as delimited in Article 1 of the Barcelona Convention, the Protocols unfortunately do not cover aspects relevant to oil pollution. The SPA Protocol and the Hazardous Waste Protocols were adopted in 1996, whereas the ICZM Protocol was adopted in 2008. This section is an effort to highlight the important dates, including ratification dates by states and entry into force, related to the Protocols. Subsequently, a tabular comparison is provided highlighting the number of ratifications of Protocols covering oil pollution and the aforementioned Protocols, i.e. Protocols not relevant to oil pollution.

1. The *Protocol Concerning Specially Protected Areas and Biological Diversity in the Mediterranean* (SPA Protocol, see Table 7) was adopted in 1995. Amendments to Annexes I and II entered into force in 2015.

2. The *Protocol on the Prevention of Pollution of the Mediterranean Sea by Transboundary Movements of Hazardous Wastes and their Disposal* (Hazardous Waste Protocol, see Table 8) was adopted in 1996.

3. The *Protocol on Integrated Coastal Zone Management in the Mediterranean* (ICZM Protocol, see Table 9) was adopted in 2008.

Table 10 provides a comparative analysis between the total number of states that have ratified the Protocols relevant to oil pollution and the total number of states that have ratified the Protocols that do not govern oil pollution-related aspects.

Table 7 Status of signatures and ratifications of the SPA Protocol, as at 30/11/16

	1995 SPA and Biodiversity Protocol			
Contracting parties	Signature	Ratification	Entered into force	Amendments to Annexes II and III entered into force
Albania	10.06.95	26.07.01	25.08.01	16.04.15
Algeria	10.06.95	14.03.07	13.04.07	16.04.15
Bosnia and Herzegovina	–	–	–	–
Croatia	10.06.95	12.04.02	12.05.02	16.04.15
Cyprus	10.06.95	18.07.03	17.08.03	–
EU	10.06.95	12.11.99	12.12.99	16.04.15
Egypt	10.06.95	11.02.00	12.03.00	16.04.15
France	10.06.95	16.04.01	16.05.01	16.04.15
Greece	10.06.95	–	–	–
Israel	10.06.95	–	–	16.04.15
Italy	10.06.95	07.09.99	12.12.99	16.04.15
Lebanon	–	–	–	16.04.15
Libya	–	–	–	–
Malta	10.06.95	28.10.99	12.12.99	16.04.15
Monaco	10.06.95	03.06.97	12.12.99	16.04.15
Montenegro	–	19.11.07	19.12.07	16.04.15
Morocco	10.06.95	24.04.09	25.05.09	16.04.15
Slovenia	–	08.01.03	07.02.03	16.04.15
Spain	10.06.95	23.12.98	12.12.99	16.04.15
Syria	–	10.10.03	09.11.03	16.04.15
Tunisia	10.06.95	01.06.98	12.12.99	16.04.15
Turkey	–	18.09.02	18.10.02	16.04.15

Source: UNEP [A word document showing the Status of Signatures and Ratifications of the Barcelona Convention and all its Protocols at 30 November 2016 is available at http://www.unep.org/unepmap/who-we-are/legal-framework/status-signatures-and-ratifications (Last accessed 10 August 2017)]

Table 8 Status of signatures and ratifications of the Hazardous Waste Protocol, as at 30/11/16

	1996 Hazardous Wastes Protocol		
Contracting parties	Signature	Ratification	Entered into force
Albania	–	26.07.01	18.01.08
Algeria	01.10.96	–	–
Bosnia and Herzegovina	–	–	–
Croatia	–	–	–
Cyprus	–	–	–
EU	–	–	–
Egypt	01.10.96	–	–
France	–	–	–
Greece	01.10.96	–	–
Israel	–	–	–
Italy	01.10.96	–	–
Lebanon	–	–	–
Libya	01.10.96	–	–
Malta	01.10.96	28.10.99	18.01.08
Monaco	01.10.96	–	–
Montenegro	–	19.11.07	18.01.08
Morocco	20.03.97	01.07.99	18.01.08
Slovenia	–	–	–
Spain	01.10.96	–	–
Syria	–	22.02.11	24.03.11
Tunisia	01.10.96	01.06.98	18.01.08
Turkey	01.10.96	03.04.04	18.01.08

Source: UNEP [A word document showing the Status of Signatures and Ratifications of the Barcelona Convention and all its Protocols at 30 November 2016 is available at http://www.unep.org/unepmap/who-we-are/legal-framework/status-signatures-and-ratifications (Last accessed 10 August 2017)]

5 Summary

The Barcelona Convention developed in the wake of shipping accidents that have resulted in the release of high quantities of oil between 1970 and 2016. One milestone in this development process is the adoption of the MAP in 1975 that is recognized as the "first-ever Regional Seas Programme under UNEP's umbrella". Efforts to protect the marine environment of the Mediterranean started in the following year with the adoption of the 1976 Convention. The 1976 Convention prescribed the roles and responsibilities of the Mediterranean states with a view to developing a form of collaborative engagement in protecting their common heritage from "pollution" introduced by man, directly or indirectly into the marine environment [6]. The definition evidently embodies a broad scope and is deemed to cover aspects concerning pollution from "oil" – a substance that has severely affected other regions of the globe, and the deleterious effects of which have been documented in

Table 9 Status of signatures and ratifications of the ICZM Protocol, as at 30/11/16

Contracting parties	2008 Integrated Coastal Zone Management (ICZM) Protocol		
	Signature	Ratification	Entered into force
Albania	–	04.05.2010/AD	24.03.11
Algeria	21.01.08	–	–
Bosnia and Herzegovina	–	–	–
Croatia	21.01.08	29.01.13/R	28.02.13
Cyprus	–	–	–
EU	16.01.09	29.09.10/AP	24.03.11
Egypt	–	–	–
France	21.01.08	29.10.09/AP	24.03.11
Greece	21.01.08	–	–
Israel	21.01.08	08.04.14/AP	–
Italy	21.01.08	–	–
Lebanon	–	–	–
Libya	–	–	–
Malta	21.01.08	–	–
Monaco	21.01.08	–	–
Montenegro	21.01.08	09.01.12/R-	08.02.12
Morocco	21.01.08	21:09:12/R	21.10.12
Slovenia	21.01.08	01.12.09/R	24.03.11
Spain	21.01.08	22.06.10/R	24.03.11
Syria	21.01.08	22.02.2011	24.03.11
Tunisia	21.01.08	–	–
Turkey	–	–	–

Source: UNEP [A word document showing the Status of Signatures and Ratifications of the Barcelona Convention and all its Protocols at 30 November 2016 is available at http://www.unep.org/unepmap/who-we-are/legal-framework/status-signatures-and-ratifications (Last accessed 10 August 2017)]
AD adhesion, *AP* approval, *R* direct ratification

Table 10 Number of ratifications of Protocols concerning oil pollution vs. number of ratifications of Protocols not relevant to oil pollution

Protocols relevant to oil pollution	Ratification				
	Accession	Approval	Succession	Adhesion	Direct ratification
Dumping Protocol	5	3	2	–	11
Prevention and Emergency Protocol	–	–	–	–	17
LBS Protocol	–	–	–	–	22
Offshore Protocol	–	–	–	–	8
Protocols not relevant to oil pollution	Ratification				
	Accession	Approval	Succession	Adhesion	Direct ratification
SPA Protocol	–	–	–	–	17
Hazardous Waste Protocol	–	–	–	–	7
ICZM Protocol	–	3	–	1	6

scientific and technical literature over a number of decades. With 26 Articles, the1976 Barcelona Convention covers a wide range of areas that should be taken into consideration by the member states when trying to prevent, abate and combat pollution, including oil pollution from intentional or operational discharges.

In 1995, a revised version of the 1976 Barcelona Convention was adopted. At first sight, the 1995 Barcelona Convention surfaces with a slight change in the title, i.e. addition of the words "coastal region". In other words, the geographical coverage of the revised Convention could be extended to coastal areas of the member states. Other than this change in the title, the revised Convention contains 35 Articles that is consistent with the spirit of the UNEP regional seas programme and the MAP. The 1995 amendments have been accepted by a majority of the Mediterranean states (as indicated in Table 2) and are an express indication of their willingness to proactively cooperate among themselves and with competent international organizations for the "protection and enhancement of the marine environment in the Mediterranean Sea Area" [18].

To date, a number of regional conventions on the sea protections, e.g. Convention for Co-operation in the Protection and Development of the Marine and Coastal Environment of the West and Central African Region of 1981, Convention for the Protection of the Marine Environment and Coastal Area of the South-East Pacific of 1981, Regional Convention for the Conservation of the Red Sea and Gulf of Aden Environment of 1982 and Convention for the Protection of the Natural Resources and Environment of the South Pacific Region and related Protocols of 1986, contain prescriptive jurisdictions that can be exercised by member states. However, a distinct feature of the Barcelona Convention is that it attempts to narrow down a liability and compensation framework for pollution. Although the initial text draft was deemed overambitious, the Working Group comprised of legal and technical experts was successful in drafting a Guideline for member states that outlines liability and damage related matters and applies to oil and other harmful substances. Moreover, the three-tier regime of liability comprised of liability standards, residual liability and MISC Fund that was considered to be overambitious can be viewed as a *sui generis* effort that goes beyond the "polluter pays principle". It sets an example of how other regions should act when trying to limit oil pollution from increased maritime commercial activities.

In order to substantiate the role of the Barcelona Convention in oil pollution prevention, it is important to observe the seven Protocols that have been introduced between 1976 and 2008. The Protocols that have direct relevance to oil pollution are the Dumping Protocol, Prevention and Emergency Protocol, LBS Protocol and Offshore Protocol. Table 11 outlines the specific provisions of the aforementioned Protocols that are pertinent in the context of oil pollution:

Finally, when comparing the number of ratifications by member states, it is apparent that the Barcelona Convention Protocols related to oil pollution have gained more acceptance than the other Protocols (as indicated in Table 10). This is evident from the number of ratifications of the LBS Protocol and the Dumping Protocol. From a narrow viewpoint, the number of ratifications of oil-related Protocols mirrors optimism in so far as the member states commit themselves to combating oil pollution through collaborative engagement despite that fact that

Table 11 Barcelona Protocols and compilation of specific provisions dealing with "Oil"

Protocol	Specifics related to oil
Protocol for the prevention of pollution in the Mediterranean Sea by Dumping from Ships and Aircraft (1995 Amendments not in force)	*Article 4:* "The dumping into the Mediterranean Sea area of wastes or other related matter listed in Annex I to this Protocol is prohibited" *Annex I:* "Crude Oil and hydrocarbons which may be derived from petroleum, and any mixtures containing any of these, taken on board for the purpose of dumping"
Protocol Concerning Cooperation in Preventing Pollution from Ships and, in Cases of Emergency, Combatting Pollution of the Mediterranean Sea	*Article 9:* "1. Each Party shall issue instructions to masters or other persons having charge of ships flying its flag and to the pilots of aircraft registered in its territory to report by the most rapid and adequate channels in the circumstances, following reporting procedures to the extent required by, and in accordance with, the applicable provisions of the relevant international agreements, to the nearest coastal State and to this Party: (a) All incidents which result or may result in a discharge of oil or hazardous and noxious substances (b) The presence, characteristics and extent of spillages of oil or hazardous and noxious substances, including hazardous and noxious substances in packaged form, observed at sea which pose or are likely to pose a threat to the marine environment or to the coast or related interests of one or more of the Parties" *Article 10:* 1. Any Party faced with a pollution incident shall (a) make the necessary assessments of the nature, extent and possible consequences of the pollution incident or, as the case may be, the type and approximate quantity of oil or hazardous and noxious substances and the direction and speed of drift of the spillage ..."
Amendments to the Protocol for the Protection of the Mediterranean Sea against Pollution from Land-Based Sources	*Article 7:* "Specific requirements concerning the quantities of the substances discharged (listed in Annex I), their concentration in effluents and methods of discharging them" *Annex I:* "C. Categories of Substances ... 10. Crude oils and hydrocarbons of petroleum origin ..."

(continued)

Table 11 (continued)

Protocol	Specifics related to oil
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	*Article 1:* "(f) 'oil' means petroleum in any form including crude oil, fuel oil, oily sludge, oil refuse and refined products and, without limiting the generality of the foregoing, includes the substances listed in the Appendix to the Protocol" *Article 10:* "1. The Parties shall formulate and adopt common standards for the disposal of oil and oily mixtures from installations into the Protocol Area: (a) Such common standards shall be formulated in accordance with the provisions of Annex V, A (b) Such common standards shall not be less restrictive than the following, in particular: (i) For machinery space drainage, a maximum oil content of 15 mg per litre while undiluted (ii) For production water, a maximum oil content of 40 mg per litre as an average in any calendar month; the content shall not at any time exceed 100 mg per litre (c) The Parties shall determine by common agreement which method will be used to analyze the oil content" *Article 14:* ". . . (b) The discharge into the sea of substances containing oil or harmful or noxious substances or materials which, subject to the prior approval of the competent authority, are being used for the purpose of combating specific pollution incidents in order to minimise the damage due to the pollution" *Article 16:* "1. In cases of emergency the Contracting Parties shall implement mutatis mutandis the provisions of the Protocol concerning Cooperation in Combating Pollution of the Mediterranean Sea by Oil and Other Harmful Substances in Cases of Emergency 2. Each Party shall require operators in charge of installations under its jurisdiction to have a contingency plan to combat accidental pollution, coordinated with the contingency plan of the Contracting Party established in accordance with the Protocol concerning Cooperation in Combating Pollution of the Mediterranean Sea by Oil and Other Harmful

(continued)

Table 11 (continued)

Protocol	Specifics related to oil
	Substances in Cases of Emergency and approved in conformity with the procedures established by the competent authorities" *Article 18:* ". . . For this purpose, a Party which is also a Party to the Protocol concerning Cooperation in Combating Pollution of the Mediterranean Sea by Oil and Other Harmful Substances in Cases of Emergency shall apply the pertinent provisions of the said Protocol" *Annex I:* "A. The following substances and materials and compounds thereof are listed for the purposes of Article 9, paragraph 4, of the Protocol. They have been selected mainly on the basis of their toxicity, persistence and bioaccumulation: . . . 6. Crude oil, fuel oil, oily sludge, used lubricating oils and refined products . . ."

international conventions do not entirely meet the special requirements that the Mediterranean Sea area demands.

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The Role of REMPEC in Prevention of and Response to Pollution from Ships in the Mediterranean Sea

Angela Carpenter, Patrick Donner, and Tafsir Johansson

Abstract With 20% of the global tank ship maritime traffic, and enhanced offshore oil and gas exploration and exploitation activities in the Mediterranean Sea, the risks related to oil pollution, inter alia, from ships are simultaneously increased. Governed by the Contracting Parties of the Barcelona Convention, REMPEC, in turn, assists Mediterranean coastal states in ratifying, implementing and administering conventions and generally accepted international rules and standards implemented by competent international organisations. The intention is ostensibly clear in so far as REMEPEC's mission is to play an important role in mitigating all probabilities and possibilities of pollution from ships. In order to remain in the vanguard of action to prevent and reduce pollution from ships, REMPEC has further committed itself to assisting Contracting Parties of the Barcelona Convention to strengthen preparedness and response capacities through multifarious pragmatic actions, e.g. including remote assistance, on-site assistance, development of contingency planning, development and dissemination of guidelines, training and education and tools. Over the years, there has been a steady increase in the body of general and descriptive literature dedicated to the work of REMPEC. This chapter, however, concentrates on a more specific yet important area. As indicated in the title, this chapter provides an overview of the role of REMPEC pertaining to pollution from ships, with a special focus on oil pollution.

Keywords Barcelona Convention, Marine pollution prevention, Marine pollution response, Mediterranean Sea, Oil pollution, REMPEC

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Contents

1 Introduction

> The contribution of ship-generated pollution should not be disregarded as a serious threat to the health of the oceans in general, and to the Mediterranean Sea in particular [1].

Pollution from ships was one of the highest priority issues considered when a Mediterranean Action Plan (MAP) [2] was created in February 1975, the first such action plan under the United Nations Environment Programme (UNEP) Regional Seas Programme, established in 1974. Pollution from ships was also a high priority when the Convention for the Protection of the Mediterranean Sea Against Pollution (Barcelona Convention [3]) and its Protocol Concerning Co-operation in Combatting Pollution of the Mediterranean Sea by Oil and other Harmful Substances in Cases of Emergency (Emergency Protocol [4]) were adopted by 16 Mediterranean States and the European Community in 1976 [1]. Contracting parties (CPs) to the Barcelona Convention include all 21 Mediterranean coastal states and the European Union.

The high visibility of oil pollution from ships came about as a result of a series of major oil spills in the late 1960s and during the 1970s. In European waters these included the grounding of the *Torrey Canyon* off the Scilly Isles in the UK in 1967, resulting in nearly 120,000 metric tonnes (or 132,277 tons) of oil being spilt; the grounding of the *Jakob Maersk* off Oporto, Portugal, in 1975, resulting in a spill of around 88,000 metric tonnes (97,000 tons) of oil; and the grounding of the *Urquiola* off La Coruña, Spain, in 1976, resulting in a spill of some 73,500 metric tonnes (81,000 tons) of oil.[1] The *Torrey Canyon* spill was highly publicised at the time, with images of attempts to disperse the oil slick (some 25 × 30 miles in size) by using incendiary bombs appearing in newspapers and in the broadcast media [5]. As a result of the *Torrey Canyon* and the publicity surrounding it, two

[1]Source: ITOPF (2014). Available at: http://www.itopf.com/knowledge-resources/data-statistics/gis/ (Last accessed 12 October 2017).

international conventions were adopted in 1969 and 1973; these were the International Convention on Civil Liability for Oil Pollution Damage [6] and the MARPOL Convention [7].

Oil deposits, particularly crude oil and tar balls, are highly visible when they wash ashore, and many deposits could be found on beaches along major shipping lines, including those of the Mediterranean which has a high density of shipping traffic [1]. At the current time, this includes fishing vessels, cruise ships, leisure vessels, military vessels, container ships and tankers and also oil exploration and exploitation "fixed" (i.e. tethered to the seabed) vessels [8]. In the case of oil tankers, these pass from east to west (from the Suez Canal to the Strait of Gibraltar) and from north to the south and back between various refineries and crude oil loading/unloading ports (see Fig. 1; [9]).

Maritime transport has been identified as the main source of petroleum hydrocarbon (oil) and polycyclic aromatic hydrocarbons (PAHs) entering the marine environment of the Mediterranean Sea [10]. Of an estimated 360 million tons of oil and refined products crossing the Mediterranean annually, around 400,000 tons are deliberately dumped every year (2006 figures) [11]. In addition, it was estimated that around 250,000 tons were discharged annually in ports between 1974 and 2006 as a result of deballasting, tank washing, bunkering and discharging bilge oil, for example, with these spills involving small quantities of less than 7 tons [12]. Bilge water containing oil is a particular problem as it is uneconomic to recycle it, unlike waste lubricating oil, and so it is often discharged into the sea, particularly from fishing vessels which have limited space to store waste on board [13].

Accidental spills which generally occur along the main shipping routes and around major oil discharging ports are generally also small in size [10]. The number of large accidental oil spills (over 10 tons) in the region is very small, with only 14 such spills occurring between 1970 and 2015 [8]. The vast majority of spills are

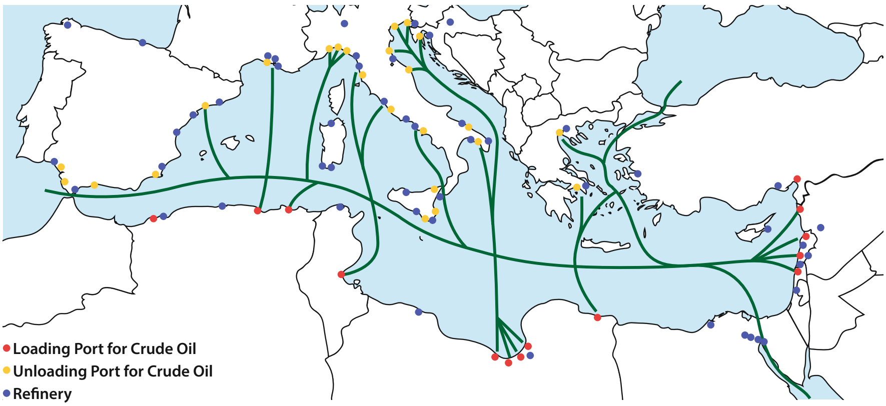

Fig. 1 Oil tanker routes, crude oil loading/unloading ports and refineries in the Mediterranean (Reproduced from One-Europe.net [9])

far smaller in scale and are located along the main shipping routes and around the major oil discharge ports [10].

Between 1977 and 2000, there were 311 reported incidents that caused (or were likely to cause) oil pollution in the Mediterranean Sea [1]. Of these, 156 caused oil pollution and 155 did not cause an oil spill, although incidents likely to cause a spill were not reported [1].

While oil spills can also come from a range of other sources including industrial activities or coastal harbours [10] and from the various refineries, petrochemical installations and oil and gas pipelines located around the region [8], it is the issue of discharges from ships at sea, regulated under the MARPOL Convention [8] and its 1978 amendments [14], that is the main focus of this chapter. The role of REMPEC in contributing to the prevention and reduction of pollution from ships, and in combatting pollution in the event of an emergency, is examined in detail.

2 REMPEC and Its Mandate

The Regional Oil Combatting Centre (ROCC) was established on 11 December 1976 in Malta and was administered by the International Maritime Organization (IMO) and financed by the Mediterranean Trust Fund [1]. The Centre was established in order to strengthen the capabilities of Mediterranean coastal states and facilitate cooperation in combatting oil pollution and dealing with marine pollution emergencies [15]. The ROCC subsequently became REMPEC (the Regional Marine Pollution Emergency Response Centre for the Mediterranean Region) in 1989. REMPEC is based in Valetta, Malta, and is administered by the IMO in cooperation with UNEP/MAP [15].

The mandate of REMPEC has expanded over time to address global developments relating to prevention of pollution from ships and to meet changes in the 1976 Emergency Protocol [4] which subsequently became the *Protocol concerning Cooperation in Preventing Pollution from Ships and, in Cases of Emergency, Combatting Pollution of the Mediterranean Sea* (Prevention and Emergency Protocol 2002) [16].

In addition, a regional strategy – the *Regional Strategy for Prevention of and Response to Marine Pollution from Ships* [17] – was approved by the contracting parties (CPs) in 2005 as a 10-year roadmap for implementation of the Prevention and Emergency Protocol and, since 2006, most of the activities of REMPEC are intended to implement the regional strategy. More recently, the latest regional strategy for the period 2016–2021 [18] also takes into account sustainable development goals in line with the Mediterranean strategy for sustainable development 2016–2021 [19]. In the case of both the Prevention and Emergency and the Offshore Protocols, not all Mediterranean states are CPs. Albania, Bosnia and Herzegovina and Lebanon have neither signed nor ratified the Prevention and Emergency Protocol although all three ratified the 1976 Emergency Protocol; only Albania, Cyprus, the EU, Libya, Morocco, Syria and Tunisia have adopted the Offshore Protocol, while Croatia, Greece, Israel, Italy, Malta, Monaco, Slovenia and Spain have signed but not ratified that Protocol (see [20] for status of ratifications).

REMPEC was the first of seven Regional Activity Centres in the Mediterranean and was established (as the ROCC) under the original Mediterranean Action Plan of 1976. The MAP was subsequently revised, and the new version – the *Action Plan for the Protection of the Marine Environment and the Sustainable Development of the Coastal Areas of the Mediterranean (MAP Phase II)* – was adopted in 1995 [21]. The other Regional Activity Centres are the Mediterranean Pollution Assessment and Control Programme (MED POL), the Plan Bleu Regional Activity Centre (PB/RAC), the Priority Actions Programme Regional Activity Centre (PAP/RAC), the Specially Protected Areas Regional Activity Centre (SPA/RAC), the Regional Activity Centre for Sustainable Consumption and Production (SCP/RAC) and the Regional Activity Centre for Information and Communication (INFO/RAC) (see [22, 23] for further details).

REMPEC has, over its 40-year history (to 2016), made a number of contributions to the Mediterranean Region [24]. These include but are not limited to:

- Providing 15 CPs with assistance in drafting, reviewing and adopting National Marine Pollution Contingency Plans. Those CPs are Albania, Algeria, Croatia, Cyprus, Egypt, Israel, Lebanon, Libya, Malta, Montenegro, Morocco, Slovenia, the Syrian Arab Republic, Tunisia and Turkey. These CPs, together with France and Greece, also have national preparedness and response systems in place, including operational national contingency plans [24].
- Assisting groups of countries to draft and adopt subregional agreements on preparedness and response to spills. Examples of subregional agreements include agreements between Cyprus, Israel and Egypt; between Algeria, Morocco and Tunisia; and between Croatia, Italy and Slovenia [24].
- Assisting countries in emergency situations. In this respect the REMPEC has in place a 24/7 Centre to assist CPs in the case of an emergency and also in areas such as wildlife restoration and pollution drift forecasting [24].
- Compilation of an inventory of port reception facilities in coastal states that are not member states of the EU. In the area of garbage from ships, this assisted in the granting of special status for the Mediterranean under Annex V (Garbage) of the MARPOL Convention [14] and resulted in stricter rules for garbage disposal at sea in the region.
- In the area of illicit discharges from ships, with the recognition that these were taking place on a daily basis despite the Mediterranean Sea also holding special area status under MARPOL Annex I (oily wastes), REMPEC has assisted CPs to the Barcelona Convention in strengthening national legislation on the enforcement of MARPOL, while a Mediterranean Network of Law Enforcement Officials relating to MARPOL (MENELAS) was established in 2013 [24].

REMPEC's main fields of action centre around the prevention of pollution of the marine environment from ships and the development of preparedness for and response to accidental marine pollution and cooperation in case of emergency. These actions are discussed in more detail in Sects. 3 and 4.

3 The Role of REMPEC in Pollution Prevention

REMPEC has a number of roles in relation to pollution prevention in the Mediterranean region, and these are discussed below and are set within the main fields for action of REMPEC [15]. These aspects are among the implementation goals of the 2016 Regional Strategy (see [18], Appendix 1) and include ratification of relevant international maritime conventions related to the protection of the marine environment; ensuring effective maritime administrations; provision of reception facilities in ports; monitoring of delivery of ship-generated wastes, improved follow-up of pollution events as well as monitoring and surveillance of illicit discharges; improving the level of enforcement and prosecution of discharge offenders; the reduction of pollution generated by pleasure craft activities; and establishing procedures for designation of places of refuge to minimise the risk of widespread pollution.

3.1 Effective Maritime Administration Activities

The activities of REMPEC include working with national authorities of coastal states (CSs) to promote ratification of relevant maritime conventions such as international conventions dealing with maritime safety and prevention of pollution from ships (including MARPOL [14]), dealing with combating pollution and dealing with liability and compensation for pollution damage ([25], see also [17]). It also includes a wide range of EU regulations and directives ([25], see also [17]).

In addition, REMPEC assists national authorities to ensure that their maritime administrations in charge of implementation and enforcement of the very wide range of conventions have the knowledge necessary to do so. This activity is in line with one of the main fields for action of REMPEC, i.e. strengthening the capacities of CSs in the region to ensure effective implementation of international measures to abate, combat or eliminate pollution of the marine environment from shipping activities [15].

In order to achieve this, REMPEC provides a range of training courses as well as access to technical and legal expertise [26]. This is also in line with one of the main fields for action of REMPEC, i.e. providing a framework for exchange of information on operational, technical, scientific, legal and financial matters between CSs, in order to achieve coordinated action for implementation of the Prevention and Emergency Protocol [15].

3.2 Activities Dealing with Illicit Discharges of Oil and Other Hazardous or Noxious Substances

Another area where REMPEC has worked since the adoption of the Prevention and Emergency Protocol in 2002 is in setting up marine pollution monitoring and surveillance systems in response to continuing illicit discharges in the region. REMPEC has been involved in a range of activities relating to marine pollution surveillance and monitoring including providing coastal states with technical knowledge on remote sensing systems, participating in pilot projects on satellite monitoring and assisting CSs to establish national monitoring and surveillance systems [26]. These activities are in line with the field of action relating to regional cooperation in preventing pollution from ships and dealing with pollution when oil or other hazardous and noxious substances have been (or may be) discharged at sea and also where a spill requires emergency action or some other immediate response [15].

The requirement for REMPEC to carry out pilot projects was set out in Sect. 4.7 of the Regional Strategy [17] which highlighted a lack of monitoring and surveillance in Mediterranean waters necessary to achieve effective implementation of MARPOL. Only a small number of CSs were already conducting aerial surveillance of their waters (para. 4.7.1). It was recognised that a regular system of national aerial surveillance was necessary if the 2002 Prevention and Emergency Protocol was to be effective (para. 4.7.2). In order to do so, there was a requirement for an enhanced system for satellite surveillance (para. 4.7.3) which would be in addition to the *CleanSeaNet* (CSN) services provided by the European Maritime Safety Agency (EMSA) (see [27] for further details). CSN data was available to all EU Member States, together with beneficiary countries from the Project EuroMed Cooperation on Maritime Safety and Prevention of Pollution from Ships III (Safemed III[2]) and also to REMPEC.

Two projects identified in the Regional Strategy (para. 4.7.4) as being implemented by REMPEC – AESOP and MARCOAST:

– AESOP[3] – the Aerial and Satellite Surveillance of Operational Pollution in the Adriatic Sea Project was carried out between 2005 and 2006 with the aim of testing the reliability and validity of satellite observations compared to those from specially equipped aircraft [26]

[2]Safemed III beneficiary countries included Algeria, Egypt, Israel, Jordan, Lebanon, Libya, Morocco, the Palestinian Authority, and Tunisia. For further details of Safemed III, see: http://emsa.europa.eu/safemed.html (Last accessed 16 October 2017).

[3]For further information on the AESOP Project, see http://rempec.org/admin/store/wyswigImg/file/Information%20resources/Other%20Meetings-Activities/Illicit%20discharges/Technical%20reports/AESOP%20report%20-%20April%202007%20(E).pdf (Last accessed 16 October 2017).

– MARCOAST[4] – the Marine & Coastal Environmental Information Services (European Space Agency funded) Project for Algeria, Morocco and Tunisia was carried out between September 2007 and January 2009 to provide operational satellite monitoring to Southern Mediterranean countries. Each country received data specific to its own waters, but the data was also shared between neighbouring countries so that subregional monitoring and cooperation could occur in the event of an oil spill detected close to the border between two CSs [26].

In relation to aerial surveillance, a number of Western Mediterranean countries also cooperated in the OSCAR-MED operation in 2009.[5] Surveillance aircraft from France, Italy and Spain flew out from the French airport at Hyères during the last week of September 2009. Outcomes of that operation included the detection of three oil spills by satellite (subsequently identified and confirmed by surveillance aircraft), and three ships were caught illegally discharging, including two discharging mineral oil in the French Ecological Protected Zone [26]. Subsequent OSCAR-MED activities took place in 2013 with aircraft from Algeria, France, Italy, Morocco and Spain participating in this aerial surveillance operation in the Western Mediterranean in June 2013. During this operation, 700 vessels were monitored, and three oil slicks were detected, and CSN satellite images were provided by EMSA [26].

Also in the area of illicit discharges, REMPEC has assisted Mediterranean countries to establish appropriate legal frameworks for transposing MARPOL Annex I covering oily wastes into national legislation and has also worked towards promoting a network of prosecutors across the Mediterranean region to facilitate judicial cooperation and potentially establish common procedures for prosecution of polluters [26]. For example, a Regional Seminar on Illicit Discharges from Ships and Prosecution of Offenders was held in France in November 2007 [28] and dealt specifically with legal issues relating to such illicit discharges.

3.3 Activities Dealing with Port Reception Facilities

As noted in Sect. 2, REMPEC has been involved in the compilation of an inventory of port reception facilities in CSs that are not member states of the EU. For example, a 2-year project (the MEDA Project[6]) took place between January 2002

[4]For further information on the MARCOAST Project, see http://www.rempec.org/admin/store/wyswigImg/file/Information%20resources/Other%20Meetings-Activities/Illicit%20discharges/Exercices/OSCAR-MED%20(EN).pdf (Last accessed 16 October 2017).

[5]For further information on OSCAR-MED 2009, see http://www.rempec.org/admin/store/wyswigImg/file/Information%20resources/Other%20Meetings-Activities/Illicit%20discharges/Exercices/OSCAR-MED%20(EN).pdf (Last accessed 16 October 2017).

[6]For further information Activity C of the MEDA Project on Collection and Treatment of Oily Ballast Water from Tankers, see http://rempec.org/admin/store/wyswigImg/file/Information%20resources/

and December 2004 to identify the existing situation and needs for port reception facilities in ports and oil terminals with regard to ship-generated garbage, bilge waters and oily wastes [29]. Ten CSs participated in this project – Algeria, Cyprus, Egypt, Israel, Lebanon, Malta, Morocco, Syria, Tunisia and Turkey. Cyprus and Malta joined the EU on 1 May 2004, and so at the commencement of the project they were not EU member states.

This project found that while a number of ports and terminals did not have facilities to collect and treat oily wastes, almost all ports did have adequate facilities for receiving garbage from ships [29]. As a result, recommendations were provided on optimum solutions for collection, treatment and disposal of solid and liquid ship-generated wastes and standard designs were also proposed for such facilities [29].

3.4 Guidelines for Pleasure Craft and for Places of Refuge

More recent work in the area of prevention includes *Guidelines concerning Pleasure Craft Activities and the Protection of the Marine Environment* [30] and *Guidelines on the decision-making process for granting access to a place of refuge for ships in need of assistance* [31], both adopted by a meeting of CPs in January 2008. The guidelines on pleasure craft activities were developed in response to serious concerns about the potential harm that the increasing density of boats and yachts may cause to the Mediterranean environment [30].

In the case of the places of refuge, this is particularly important in providing sheltered areas where assistance can be provided in the event of, for example, a fire on board a vessel, or where cargo has shifted on board, or where there has been a pollution event ([31], para. 13). The guidelines on places of refuge are in line with Article 16, Reception of Ships in Distress in Ports and Places of Refuge of the Prevention and Emergency Protocol [16], and are an important element in minimising the risk of widespread pollution from ships in need of assistance [31].

4 The Role of REMPEC in Marine Pollution Response and Preparedness

REMPEC has a number of roles in relation to marine pollution response and preparedness in the Mediterranean region [32], and these are discussed below. In terms of the main fields for action of REMPEC [15], these activities relate mainly to assisting CSs in the development of their own national capabilities for pollution response and assisting CSs, in the event of an emergency, if they require direct

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Other%20Meetings-Activities/Port%20reception%20facilities/Technical%20Reports/Activity%20C%20-%20Final%20Report%20Consolidated.pdf (Last accessed 16 October 2017).

assistance or assistance from other parties. If such assistance does not exist within the Mediterranean region, REMPEC should help CSs obtain international assistance from outside the region.

In respect of the implementation goals of the 2016 Regional Strategy (see [18], Appendix 1), those with relevance to REMPEC's role in marine pollution response are ensuring that adequate emergency towing capacity is available throughout the Mediterranean to assist vessels (including tankers) in distress; enhancing levels of prepositioned spill response equipment under the direct control of Mediterranean CSs; improving the quality, speed and effectiveness of decision-making processes in case of marine pollution incidents (development and introduction of technical and decision support tools); increasing the level of knowledge in the field of preparedness and response to accidental marine pollution by oil and other harmful substances; revising existing recommendations, principles and guidelines and developing new ones to facilitate international cooperation and mutual assistance within the framework of the 2002 Prevention and Emergency Protocol; and strengthening the capacity of individual CSs to respond efficiently to marine pollution incidents through development of subregional operational agreements and contingency plans.

4.1 Response Activities of REMPEC

Article 12 of the Prevention and Emergency Protocol [16] identified that any party requiring assistance to deal with a pollution incident may call on other parties – directly or through REMPEC – starting with those parties that are most likely to be affected by such pollution. In respect of this Article, assistance can include expert advice or those other parties making available specialised personnel, products, equipment, etc. to help deal with that pollution. Where there is disagreement between CPs on the organisation of such an operation, REMPEC may coordinate these activities, as long as all the parties agree [32]. Article 12 also requires that each party shall take the necessary legal and administrative measures to facilitate the arrival, use and departure from its territory of ships, aircraft and other transport that has been used, for example, in responding to the pollution incident or transported personnel, cargoes, materials and equipment, for example [16].

Any CP can request assistance from REMPEC in the event of marine pollution occurring and can do so via the 24/7 Centre mentioned previously. They can also report such an incident using the pollution reporting system (POLREP), a standard alert message recommended by the IMO, which is divided into three parts (see [33] – POLREP form available to download). Part I – Pollution warning (POLWARN) provides initial information or a warning of pollution or the threat of pollution including the data and time and position of an incident. Part II – Pollution information (POLINF) gives detailed supplementary reports and situation reports including characteristics of pollution, its source and cause, wind direction and speed, current or tide, sea state and visibility and drift of pollution, for example. Part III – Pollution facilities

(POLFAC) is used to request assistance from other CPs and to define operational matters relating to that assistance and includes information on cost of such assistance, prearrangements for its delivery, where and how it is to be delivered and the other states from which assistance has been requested [33]. Where appropriate assistance cannot be found within the Mediterranean region, REMPEC is able to obtain assistance from outside the region [32].

4.1.1 Remote Assistance

REMPEC can provide remote assistance, such as providing information and advice by telephone, communicating on behalf of the state(s) involved in a pollution incident, advising on other sources of information if it is not available from REMPEC and also coordinating regional assistance [32]. As a function of REMPEC, it is required to develop and maintain working relationships with the other Regional Activity Centres of the MAP and with scientific institutions within the region [34]. Under Specific Objective 18 for REMPEC under the Regional Strategy for 2016–2021 [18], REMPEC is required to encourage participation of regional and technical institutions in R&D activities and to facilitate the transfer of technology. In order to do so, REMPEC assists regional institutions and industry in identifying fields of research requiring enhancement of oil spill preparedness and response technologies and techniques, for example, and also assists in dissemination and exchange of results of national R&D activities.

Specific Objective 19 for REMPEC under the Regional Strategy 2016–2021 [18] requires improvement of the quality, speed and effectiveness of decision-making processes in case of marine pollution incidents through the development and introduction of technical and decision support tools, and in this respect, REMPEC cooperates with scientific institutions and industry in the region and has developed specific cooperation agreements [32].

One agreement which entered into force in 2009 was developed between REMPEC and the Mediterranean Operational Network for the Global Ocean Observing System (MONGOOS) under which a virtual MONGOOS Emergency Response Office (ERO) was established to coordinate, evaluate and disseminate information on behalf of MONGOOS members [34]. REMPEC is able to request information from the ERO on meteo-oceanographic data and oil spill simulations to predict the movement of oil at sea and identify areas most likely to be impacted by accidental spills of oil, for example, which can be used to assist in providing information and advice to CPs [34].

Another area where REMPEC cooperates with expert bodies is that of hazardous and noxious substances (HNS). The European Chemical Industry Council (CEFIC) provides assistance in the event of land-based chemical spills through the International Chemical Environment (ICE) network. In the event of HNS spills occurring in the marine environment, REMPEC acts as a liaison Centre between ICE and affected CSs to communicate information on the chemicals involved in an incident and the risks they pose, for example [34].

Finally, in the area of remote assistance, REMPEC works with the Sea Alarm Foundation, a non-profit non-governmental organisation based in Brussels, Belgium, to enhance the capacities of CSs to respond to oiled wildlife incidents [34], and the Foundation also provides on-site assistance, discussed below.

4.1.2 On-Site Assistance

REMPEC is also able to provide on-site assistance, with REMPEC officers or representatives of the Mediterranean Assistance Unit (MAU) providing advice at the site of an accident [32]. The MAU was established in 1993 and offers an expert advice capability when mobilised by REMPEC at the request of a CP in an emergency situation.

The MAU is based on five memoranda of understanding between REMPEC and relevant institutions [35]. Four of those institutions are able to provide on-site assistance: CEDRE (Centre de Documentation, de Recherche et d'Expérimentations sur les pollutions accidentelles des eaux/Centre of Documentation, Research and Experimentation on Accidental Water Pollution), based in Brest, France; FEDERCHIMICA (Federazione Nazionale dell'Industria Chimica/Italian Federation of the Chemical Industry) based in Milan, Italy; ISPRA (Istituto Superiore per la Protezione e la Ricerca Ambientale/the Italian National Institute for Environmental Protection and Research) based in Rome, Italy; and the Sea Alarm Foundation which provides assistance and advice during responses in regard to oiled wildlife incidents.

An example of a request for assistance from the MAU took place in September 2017. Assistance was requested by Greece following the sinking of the oil tanker *Agia Zoni II* off Piraeus on 10 September 2017, following which two MAU experts were mobilised to the accident to provide technical support on sunken oil assessment and removal techniques and on efficient oil removal from sandy beaches [36]. In this case CEDRE and ISPRA provided on-site assistance in dealing with the impacts of this accident.

4.2 Preparedness Activities of REMPEC

One of the most important activities of REMPEC has been to provide assistance to individual CPs in the event of marine pollution incidents. Reliable national systems for preparedness and response are therefore seen as the single most important factor in determining the effectiveness and success of response to such incidents. In the area of response, there are five specific activities of REMPEC: contingency planning, Mediterranean overview, capacity building, government and industry cooperation and guidelines and tools.

4.2.1 Contingency Planning

One aspect of such preparedness is through contingency planning at both national and subregional levels [37]. In this regard, REMPEC provides assistance to competent national authorities to develop National Systems for preparedness and response to marine pollution, which also includes contingency planning. Seventeen Mediterranean CSs have national preparedness and response systems including operational national contingency plans (NCPs). These CSs are Albania, Algeria, Croatia, Cyprus, Egypt, France, Greece, Israel, Italy, Monaco, Montenegro, Morocco, Slovenia, Spain, Syria, Tunisia and Turkey. Bosnia and Herzegovina and Lebanon do not have an NCP, while Libya has an NCP under preparation, and Lebanon and Malta have drafted NCPs, but they have not yet (October 2016) been approved [37].

In addition to National Systems and NCPs, there are also a number of subregional systems for preparedness and for response to marine pollution, including contingency planning. These are the results of bilateral or multilateral operational agreements between neighbouring countries, and their development is part of the mandate of REMPEC. These agreements offer mutual assistance in the case of marine pollution events and allow individual CPs to pool resources and conduct joint operations [37]. There are four such subregional systems:

– The RAMOGE Agreement[7] covering parts of France, Italy and Monaco was signed in 1976. In 1993 the RAMOGEPOL Plan[8] was developed to define operational aspects of joint spill response between the three countries and was subsequently updated in 2005.
– Subregional contingency plan for the southeastern Mediterranean – this plan, which covers Cyprus, Egypt and Israel, has yet to enter into force although some activities have taken place within the framework of this agreement.
– Subregional contingency plan for the south-western Mediterranean – this plan includes Algeria, Morocco and Tunisia. It was signed in June 2005 and entered into force in May 2011.
– Subregional operational agreement and contingency plan for the Adriatic – this plan includes Croatia, Italy and Slovenia and was signed in November 2005 but has not yet entered into force.

4.2.2 Mediterranean Overview

In the case of Mediterranean overview, REMPEC and the Mediterranean Oil Industry Group (MOIG) initiated an assessment exercise to evaluate the level of capacity to respond to a pollution incident across the region. This work commenced

[7]Accord relative a la Protection de l'Environnement Marin et Cotier d'une Zone de la Mer Mediterranee. Available at http://www.ramoge.org/documents/accord.pdf.

[8]Summary of the Plan RAMOGEPOL. Available at http://www.ramoge.org/documents/ramogepol.pdf.

in 2008 and provides regional information on national competent authorities contact list, the status of ratification of relevant conventions and protocols, contingency planning at national and subregional levels and a list of companies offering services in the Mediterranean Sea region [38]. Individual Country Profiles are available via a link from the REMPEC Country Profile page.[9] A synoptic overview of REMPEC related to government and industry cooperation is provided in Sect. 4.2.6 of this chapter.

4.2.3 Capacity Building

Capacity building is required to ensure a prompt and efficient response to an incident, and training and practice form an essential component of such capacity building. At an international level, the IMO has developed a range of training courses in line with Article 6 of the *International Convention on Oil Pollution Preparedness, Response and Cooperation* (OPRC, 1990) [39]. The IMO delivers a range of courses at various levels – from introductory to Level 3 – in relation to responses to oil spills and more recently has developed courses relating to responses to HNS spills [40].

At the regional level, REMPEC has also developed a training programme in line with Article 4 of the Prevention and Emergency Protocol [16] under which parties shall endeavour to maintain and promote a contingency plan, which includes preparation of personnel to deal with emergencies [40]. The REMPEC training programme commenced in the early 1980s and specialised training courses are organised by REMPEC in areas such as characteristics of oil and HNS spills, contingency planning, forecasting modelling, use of dispersants, oiled shoreline assessment and waste management [40].

From 2006 to 2012, the EU-funded SAFEMED II and II projects, which were implemented through REMPEC, provided numerous training opportunities for, among others, vessel traffic systems operators as well as sponsored fellowships for postgraduate studies at the International Maritime Law Institute in Msida, Malta, and the World Maritime University in Malmö, Sweden [41]. These measures are seen to significantly build the capacity of the maritime administrations of the CPs both in the short and longer term.

[9]Country Profile data is available from the website of the International Tanker Owners Pollution Federation Limited (ITOPF) a not-for-profit organisation established on behalf of the world's shipowners to promote an effective response to marine spills of oil, chemicals and other hazardous substances. Available at: http://www.itopf.com/knowledge-resources/countries-regions/.

4.2.4 Guidelines and Tools

The establishment of the Mediterranean Technical Working Group (MTWG) was considered an important item by the Meetings of REMPEC's Focal Points in 2000 [42]. The objective of the establishment of the MTWG was to facilitate the "exchange of technical data and other scientific information" concerning preparedness and response matters pertaining to marine pollution emergencies [42]. It was also determined that the method of work of the MTWG should concur with the purpose of the Guidelines for the Mediterranean Technical Working group:

1. The purpose of establishing the Mediterranean Technical Working Group (MTWG) is to facilitate the consideration of an issue or specific item by the meetings of REMPEC's focal points on the basis of a consolidated report prepared by the Secretariat of the MTWG through consultation by correspondence with interested delegations, international organisations and appropriate entities.
2. The MTWG is also a regional forum through which the contracting parties can contribute to the relevant work carried out at a global level (e.g. IMO OPRC-HNS technical group) [43].

Following the aforementioned development, REMPEC advanced a set of guidelines, decision support tools and a database with a view to providing a broad range of options to the decision-makers of contingency plans [42].

The guidelines also titled "Legal Framework of REMPEC", as delineated in the official home of REMPEC, is a combination of the following:

1. *Protocols*: (a) Protocol Concerning Cooperation in Combatting Pollution of the Mediterranean Sea by Oil and Other Harmful Substances in the Case of Emergency and (b) the amendment adopted in 2002 – Protocol Concerning Cooperation in Preventing Pollution from Ships and, in Cases of Emergency, Combating Pollution of the Mediterranean Sea [16][10]
2. *REMPEC*: (a) Resolution 7 and Annex on the Establishment of a Regional Oil-Combating Centre for the Mediterranean Sea (Barcelona, 16 February 1976), (b) Revised Annex related to the Objectives and Functions of a Regional Centre for Combating Pollution of the Mediterranean by Oil and Other Harmful Substances (Athens, 6 October 1989), (c) Objectives and Functions of a Regional Centre for the Implementation of the Emergency Protocol (Monaco, 14–17 November 2001) and (d) Mandate of the Components of MAP including the Mandate of REMPEC (Marrakesh, 5 November 2009)[11]

[10]Discussed in Sect. 4.2 of the Chapter: Carpenter and Johansson [23].

[11]Discussed in Sects. 3 and 4 of this chapter.

3. *Consolidated version*: Regional Information System (RIS) Part A. Basic Documents, Recommendations, Principles and Guidelines concerning Accidental Pollution Preparedness, Response and Mutual Assistance, as well as Prevention of Pollution from Ships, 2008 [42]

It is important to note that the "consolidated version" contains, inter alia, Recommendations Concerning Sea-based Pollution Prevention and Control and Recommendations Concerning Marine Pollution Prevention and Control aimed at providing guidance to contracting parties on the subject matter of pollution. The aforementioned recommendations are general in nature and are deemed to cover oil pollution prevention and control [44].

Other than the guidelines, REMPEC has developed a number of operational tools available to the contracting member states, which could be used to obtain insights when developing strategies and plans to prevent, abate, combat and eliminate potential and actual threats from oil pollution. To that end, an overview of the operational tools relevant to oil pollution is provided in the following:

1. **Alerts and Accidents Database (Additional Tools)**

Introduction Document

Includes "Accident involving any type of ship, which actually resulted in an oil spill, a spill or release of a hazardous and noxious substance, or in a loss or damage to a container containing HNS; . . . Accident involving one or more oil tankers or chemical tankers (either laden or not); . . . All accidents involving sinking of vessels that had on board any quantity of oil as bunkers". [45];

Statistical Analysis

This document provides an overview of incidents causing or likely to cause pollution by oil and is based on incidents that occurred between 1977 and 2010. The overview contains:

1. Quantities of oil spilled and number of accidents
2. Places of accidents with a release above 100 tonnes
3. Types of accidents for released quantities <700 tonnes and >100 tonnes
4. Age of vessel [46]

Note that the Statistical Analysis is accompanied by a separate document titled "User's guidelines" [47].

2. **MIDSIS TROCS**

Only deals with HNS tools and chemical data, to the exclusion of oil.

3. **Med GIS on Maritime Traffic**

Med GIS on maritime traffic is "[i]n line with Specific Objective 9 of the Regional Strategy for Prevention of and Response to Marine Pollution from Ships, which aims at reducing the risk of collisions by inter alia *identifying the main shipping lanes for vessels carrying oil* and other hazardous and noxious substances in the Mediterranean Sea, and within the framework of the EU-funded

Safemed Project, REMPEC commissioned Lloyd's Marine Intelligence Unit (Lloyd's MIU) to prepare a Study on Maritime Traffic Flows in the Mediterranean Sea . . . [emphasis added]" [48].

4. **Waste Management Decision Support Tool**

> The Tool focuses on oil spill waste, i.e. oil, weathered and/or emulsified oil, oiled material, oiled sediment, oiled equipment, etc. recovered after an accidental oil spill.
>
> The Tool is designed to assist any country of the Mediterranean Sea to develop a complete and operational "Oil Spill Waste Management Plan - OSWMP" covering:
>
> – Preparedness: developing an oil spill waste management plan.
> – Response: choosing the best oil spill waste treatment. [49]

5. **MEDGIS-MAR**

The MEDGIS-MAR platform includes "public data", and "national data including Response Means, Marine Accidents, *Oil Handling Facilities*, and *Oil and Gas Offshore Installations*, provided by the Contracting Parties to the Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean Sea (Barcelona Convention) through the Mediterranean Technical Working Group (MTWG), the Centre de documentation, de recherche et d'expérimentations sur les pollutions accidentelles des eaux (Cedre), the *International Tanker Owners Pollution Federation* (ITOPF) and the *Mediterranean Oil Industry Group* (MOIG) and whose access is currently restricted to the Mediterranean coastal States . . . [emphasis added]" [50].

4.2.5 Involvement of REMPEC in MEDESS-4MS and POSOW

In 2012, REMPEC was involved in a 3-year partnership project titled Mediterranean Decision Support System for Marine Safety (MEDESS-4MS) with 19 partners from 7 countries [51]. With the Department of Merchant Shipping of Cyprus as the main coordinator, the project partners were "dedicated to the strengthening of maritime safety by mitigating the risks and impacts associated to oil spills and aimed at offering a comprehensive and integrated oil spill forecasting multi-model approach" by considering meteorological and oceanographic data, data related to ship traffic, ship operations and sensitivity mapping [51]. It is noteworthy that the development of the MEDGIS-MAR decision support system was overviewed by REMPEC within the framework of Work Package 4 of the MEDESS-4MS [51].

In the following year, REMPEC coordinated the project titled Preparedness for Oil-Polluted Shoreline Cleanup and Oiled Wildlife Interventions Project (POSOW I) that was initiated to support the Mediterranean regional cooperation alliance in the area of marine pollution [52]. Four manuals were produced within the framework of POSCOW I that address aspects related to oil spill volunteers, oiled shoreline cleanup, oiled wildlife response and oiled shorelined assessment [53].

The Preparedness for Oil-polluted Shoreline cleanup and Oiled Wildlife interventions Project (POSOW II) commenced on 1 January 2015 and is a follow-up of POSOW I [52, 54]. Funded by the European Commission's Humanitarian Aid and Civil Protection department (DG ECHO), POSOW II is partnered by REMPEC, Istituto Superiore per la Protezionee la Ricerca Ambientale (Italy), Instituto Portuario de Estudios y Cooperacion de la Comunidad Valenciana (Spain), Arab Academy for Science, Technology and Maritime Transport (Egypt), and General Directorate of Maritime and Inland Waters (Turkey) [55]. The Centre of Documentation, Research and Experimentation on Accidental Water Pollution (Cedre) was responsible for overall coordination [55].

During the first year (2015) of POSOW II, the partners focused on two main themes, i.e. the preparation of training materials and the translation of materials produced as part of POSOW I and POSOW II into Arabic and Turkish [54]. Subsequently, in the second year (2016), the focus of the project was on (a) the organisation of two theories and practical "train the trainer" courses at Cedre, (b) the organisation of national training courses in the seven South Mediterranean countries (Algeria, Egypt, Lebanon, Libya, Morocco, Tunisia and Turkey) and (c) the updating of the database of people trained through the projects POSOW I and II [56]. In terms of "train the trainer" course, it is estimated that 34 participants from the aforementioned South Mediterranean countries received training on (a) volunteer management, (b) oiled shoreline assessment, (c) oiled shoreline cleanup, (d) oiled wildlife response, (e) waste management and (f) fishermen's support in oil spill response [57].

4.2.6 Government and Industry Cooperation

REMPEC plays an important role in the context of government and industry cooperation whereby a noteworthy example is the supervisory role played by the Director of REMPEC [58]. Under the supervision of the Director of REMPEC together with the support of the OPRC Programme Officer, the Volontaires Internationaux Scientifiques (VIS) acts as a liaison officer between REMPEC and the Mediterranean Oil Industry (MOIG) [58]. An important objective of the VIS is to provide assistance and cooperation to REMPEC in its endeavours related to preparedness and response to marine pollution. It is also important to stress that the VIS Programme is established under the French Ministry of Foreign Affairs with a view to supporting and endorsing the cooperation between governments and industry in the Mediterranean.

In 2008, REMPEC and MOIG in cooperation with the International Petroleum Industry Environmental Conservation Association (IPIECA) initiated an assessment exercise [58]. The objective of the assessment exercise was to obtain a national and regional overview of the *status quo* oil pollution preparedness and response from a Mediterranean government and industry perspective [58]. This assessment exercise served as a basis for the conclusions and recommendations drawn in the 2009 Regional Government and Industry Workshop on Co-operation, Preparedness for and Response to Oil Spills in the Mediterranean Sea. The conclusions and recommendations enabled REMPEC and MOIG to prepare "a short, medium and long term joint programme of work" highlighting the grey areas in order to augment and strengthen overall regional cooperation with regard to preparedness and response capacity in the Mediterranean [58]. Some of the important information, as incorporated in the official home of REMPEC, regarding the national and regional overview are provided in the following:

National Overview

Country Profiles:

The Country Profile of each Contracting Party to the Barcelona Convention reports information on the following subjects:

OPRC – Preparedness for and response to marine pollution

- Contact list of national competent authorities
- Conventions and protocols
- National and regional system
- Response strategy
- Risk assessment
- Expertise
- Resources
- Training and follow-up

Prevention

- National competent authorities contact list
- List of ratified international conventions
- Implementation of international conventions [59]

Regional Synthesis:

The section "regional synthesis" compiles automatically in maps, tables and pie charts information from the Country Profile pages and provides a regional overview on the following aspects:

- Directory of competent national authorities (governmental, prevention, OPRC, 24 h, mutual assistance focal points), downloadable in PDF format
- Status of ratification of relevant conventions and protocols
- Contingency planning (national plans and subregional agreements)
- List of companies offering services in the Mediterranean Sea, downloadable in PDF format [59]

Regional Overview

MOIG from its end, based on REMPEC's Country Profile, developed a questionnaire aimed at collecting detailed information on the oil industry operating in the region (offshore facilities, refineries, ports, etc.).

REMPEC's and MOIG's questionnaires were analysed by a steering committee composed of representatives of REMPEC and MOIG and assisted by IPIECA and consultants selected by REMPEC and MOIG to support the preparation and implementation of the Regional Government and Industry Workshop on Cooperation, Preparedness for and Response to Oil Spills in the Mediterranean Sea, which was held in Marseille, from 11 to 12 May 2009. The outcome of the analysis was summarised under the following six themes:

1. Contingency planning
2. Risk assessment
3. Strategy
4. Tier response approach and responsibilities
5. Resources and mutual assistance
6. Training and exercises [38]

5 Summary

The Regional Marine Pollution Emergency Response Centre for the Mediterranean Region (REMPEC) evolved from the Regional Oil Combatting Centre (ROCC), which was established in the mid-1970s to strengthen the capabilities of the coastal states around the Mediterranean in combatting, controlling and responding to oil pollution. Since the formation of REMPEC in 1989, its role and functions have expanded to address wider issues relating to pollution from ships and issues covered by the Prevention and Emergency Protocol 2002 [16]. Most REMPEC activities are now aimed at implementing the Mediterranean Strategy for Sustainable Development 2016–2025, which, in addition to prevention of and response to pollution from ships, also, as the name suggests, takes into account sustainable development goals [19].

Over the years of its existence, REMPEC has played a significant role in providing concrete support to its CPs in building their institutional frameworks for the prevention of and response to pollution from ships. For example, REMPEC has assisted the CPs in drafting, reviewing and adopting National Marine Pollution Contingency Plans, subregional agreements on pollution preparedness and response and in drafting more robust national legislation to give effect to and enforce the MARPOL Convention [24]. In addition to supporting the legal and institutional frameworks, REMPEC has engaged in strengthening the CPs capacity by providing training and arranging funding support for education to ensure that the national maritime administrations have the necessary knowledge and expertise to effectively implement relevant international conventions.

An important measure towards prevention of pollution was the compilation of an inventory of existing port reception facilities in non-EU countries [14]. Knowing where reception facilities exist is important, because it reduces the need, or temptation, to illicitly dump waste at sea, which is very relevant, particularly in view of the ever-increasing number of pleasure craft operating in the Mediterranean Sea region.

In terms of emergency response in case of pollution incidents REMPEC set up a 24/7 Centre through which CPs can request assistance in the form of information, advice and coordination from REMPEC. Under the Pollution and Prevention Protocol 2002, parties to the Protocol can, through REMPEC or directly, request assistance to deal with a pollution incident. Such assistance can be in the form of advice but also equipment and personnel with special expertise, and REMPEC can play an important role in facilitating the administrative measures regarding the arrival, use and departure at the scene of the incident of such personnel and equipment [16].

A most significant role played by REMPEC, which is easily overlooked, is the fact that it provides a common forum for sharing and transferring information between a range of countries, which represent a variety of cultures and states of development. In this role REMPEC is a vehicle for harmonisation of existing legal and administrative frameworks as well as for continuous capacity building in the Mediterranean Sea region.

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European Maritime Safety Agency Activities in the Mediterranean Sea

Angela Carpenter

Abstract The seas and oceans of the EU, together with the more than 12,000 commercial ports located in EU coastal states, play a major role in Europe's economic security. Its seas and oceans are used to transport of goods and people from within and outside the EU, to produce food from fisheries and aquaculture, and to produce energy from both non-renewable (oil and gas) and renewable (wave, wind) energy sources. In order to protect Europe's marine and coastal areas, the European Maritime Safety Agency (EMSA) plays a significant role in monitoring and protecting those maritime regions from pollution and ensuring the safety and security of ships operating in the region. EMSA has, since its establishment in 2002, developed a broad portfolio of operational and implementation services that it offers to the European Commission and EU Member States. For example, it provides a pollution prevention and response (PPR) service that provides operational assistance in the event of an oil spill at sea. It also provides an earth observation service with satellite-based oil spill detection through its *CleanSeaNet* (CSN) Service and vessel tracking through its *SafeSeaNet* (SSN) Service. This enables EMSA to support both identification of pollution at sea and potentially locate the source of that pollution. This chapter provides a broad overview of the activities of EMSA before focussing on specific activities relating to oil pollution in the Mediterranean Sea. It examines the availability of resources, ships and equipment, and different PPR activities taking place in the region. It also examines the availability of satellite imagery as a tool for oil spill detection during the period 2007–2011, for individual EU Member States in the region, together with more general observations post-2011.

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Contents

1 Introduction

The seas, oceans, and coastal regions of Europe, together with more than 12,000 commercial ports located around its coasts, provide a vital link in the transport of goods and people both within the European Union (EU) and globally [1]. Maritime transport in the Mediterranean is a strong economic sector, with 15% of global shipping activity by number of calls (10% by vessel deadweight) taking place in the region, and more than 325,000 vessel movements in 2007 [2, p. 31]. The region is also a major route for transporting oil, with around 18% if global seaborne crude oil shipments taking place within or through the region. The main oil transport route is from the Suez Canal/Dardanelles Strait in the east to the Strait of Gibraltar in the west, with traffic branching off to ports in both the northern and southern Mediterranean [2, p. 31]. The Mediterranean is an important economic resource as a source of food, with more than 800,000 tonnes of sea fish being landed in 2006 and over 1,500 tonnes of aquaculture production in 2004 [2, pp. 58–59]. Other economic activities in the region include energy production (oil and gas installations, for example) and it a major destination for tourists, including the cruise industry.

Twenty-one countries border the Mediterranean, most of which are EU Member States in the north and non-EU states in the south, including Turkey, Syria, Lebanon, and Israel in the eastern Mediterranean.

The European Maritime Safety Agency (EMSA) is the body which facilitates cooperation between EU Member States and the European Commission in a number of areas to monitor and protect Europe's marine environment, and help maintain the safety and security of maritime traffic in the region. As such it plays a major role in the region, alongside other bodies at international and regional levels.

This chapter presents a brief overview of the history of EMSA and the role it plays in the region. It examines some of EMSAs operational activities relating to maritime safety in areas such as pollution preparedness and response and the provision of oil spill response vessels and equipment around the region. It also examines the role of the EMSA Earth Observation Service through satellite imagery for tracking oil pollution at sea, using data from its *CleanSeaNet* (CSN) Service for the years 2007 to January 2011 (CSN First Generation Report [3], and subsequently from February 2011 to the end of 2013. Finally, some conclusions are presented on how levels of *CleanSeaNet* monitoring compare between the Mediterranean and other regions of the EU, and within the Mediterranean itself.

2 History of the European Maritime Safety Agency

The EMSA is based in Lisbon. It was created as a result of growing public concern about the safety of maritime transport and the issue of oil pollution entering the marine environment, particularly from shipping accidents. For example, when the single-hull oil tanker '*Erika*' broke into two and sank around 40 km off the southern tip of Brittany in December 1999, it resulted in pollution along almost 400 km of French coastline, The European Commission responded very rapidly to that event with a series of proposals for measures relating to Europe's maritime safety policy [4]. In March 2000, the Commission adopted the *Erika I* package of measures through a Communication on the Safety of the Seaborne Oil Trade (COM (2000) 142 final) [5]. The *Erika I* package included measures to: step up controls in ports such as banning or refusing entry into EU ports ships that are in poor condition; greater control of the activities of classification societies, private organizations responsible for checking the structural integrity of vessels, for example; and elimination of single-hull tankers through a proposal for a Regulation on accelerated phasing-in of double-hulled oil tankers [4]. That Regulation (No. 417/2002) entered into force in February 2002 [6].

2.1 Establishment of EMSA

The *Erika I* package was followed, in December 2000, by a second set of measures on maritime safety, the *Erika II* package, in a Commission Communication (COM (2000) 802 final) [4]. That package included measures relating to: greater safety in maritime traffic and more effective prevention of pollution by ships; improvements in existing schemes concerning liability and compensation for pollution damage; and, in relation to this chapter, to a Proposal for a Regulation establishing an EMSA [4]. That specialized agency was to provide Member States and the Commission with technical and scientific support to properly apply community legislation relating to maritime safety, and would also monitor implementation of that legislation and assess its effectiveness [7].

EMSA was established in 2002 under Regional (EC) No. 1406/2002 of the European Parliament and of the European Council [8]. Under Article 1 of that Regulation, EMSAs main purpose was to ensure uniform and effective maritime safety and prevention of pollution from ships operating in EU waters. EMSA would therefore be required to provide objective, reliable, and comparable information and data so that Member States could to take steps to improve both maritime safety and prevent marine pollution, as set out under Article 2.

2.2 The Developing Role of EMSA

In addition to oil pollution arising from shipping accidents, there was increasing recognition of the issue of discharges of wastes and residues to sea through operational activities of ships. It was estimated that around 20% of global discharges of wastes and residues to the sea came from shipping and the EU therefore developed a Directive on Port Reception Facilities for ship generated waste and cargo residues (Directive 2000/59/EC; PRF Directive) [9] to try and reduce such discharges. The Directive, published in 2000 with entry into force in December 2002, required ports across the EU to provide adequate reception facilities so that a lack of facilities in ports could no longer be used as an excuse to discharge oil and other substances into the sea [10]. The Directive also supported the requirement for provision of reception facilities under various Annexes of the MARPOL Convention [11].

An early responsibility of EMSA was to establish appropriate information and monitoring systems to identify ships that did not deliver their waste according to the PRF Directive. This included monitoring operational implementation of the PRF Directive, and EMSA continues to do this as one of its Implementation Tasks relating to the marine environment [12].

EMSA has a number of other general Implementation Tasks. These include the investigation of accidents in the marine transport sector as laid out in Directive 2009/19/EC of June 2011, which contains fundamental principles governing those investigations [13]. Paragraph 22 of that Directive identifies that EMSA had the specific task of facilitating cooperation between Member States and the Commission in the development of a common methodology of maritime accident investigation [13].

The types of accidents investigated under the implementation task include capsizing and listing, collisions, fire or explosions, grounding/stranding, and hull failure, for example [14]. Data on maritime casualties and incidents is stored in the European Marine Casualty Information Platform (EMCIP). Between 2011 and 2014, there were 9,180 occurrences reported to the EMCIP, of which two third directly involved damage to a ship and one third were related to accidents to persons on board [14, p. 8]. 251 cases of pollution were reported of which 216 affecting the sea. 165 cases of sea pollution involved the release of the ship's bunkers and other pollutants (e.g. residues, lubricating, or hydraulic oils [14, p. 57].

Implementation Tasks of EMSA relating specifically to the marine environment include: sustainable shipping; air pollution (SOx and NOx; including emission abatement methods); Ballast Water; Greenhouse Gases; and Ship Recycling, for example. In the area of the environment, it has been identified that the European Commission, Member States, and EU maritime industry have to work together towards a long-term objective of 'zero-waste, zero-emission' to meet European environmental and transport policy and EMSA supports the work of the Commission in that respect [15].

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

3 EMSA Operational Tasks

The Operational Tasks[1] fall under the headings of Vessel Reporting Services, Earth Observation Services, Integrated Maritime Services, and Pollution Response Services. Vessel reporting, for example, makes use of Automatic Identification System (AIS) tracking to collect data on ships travelling in European waters under the EMSA *SafeSeaNet* (SSN) maritime data exchange system [16]. SSN provides information on ship type, course, speed, destination, and any hazardous cargo on board, with that information available to all EU Member States, Norway, and Iceland (see Fig. 1). Outside European waters AIS data is also used to track vessels through the EMSA Long-Range Identification and Tracking System (LRIT).

Under the Integrated Maritime Services heading, for example, EMSA conducts a range of activities including traffic monitoring, search and rescue, fisheries monitoring, and pollution monitoring, for example, [17] and for the latter it uses data collected via satellite monitoring under *CleanSeaNet* (CSN), one of its Earth

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

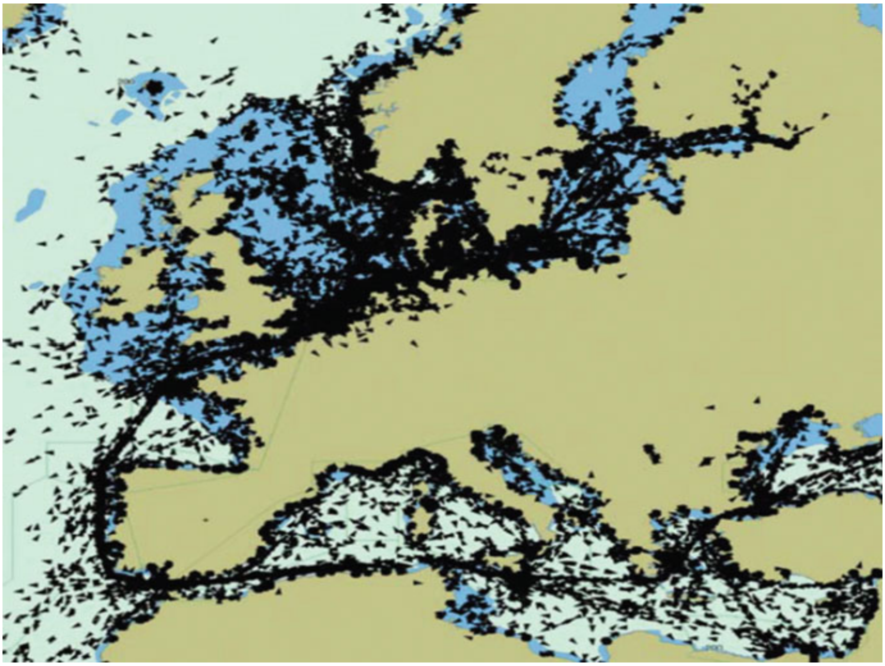

Fig. 1 SSN vessel tracking screenshot from 2011. *Source*: Adapted from [16]

Observation Services which is discussed in Sect. 4. This section focuses on EMSAs Pollution Response Services.

3.1 Pollution Response Service

The EMSA Pollution Response Service provides operational assistance and information to Member States under five main service pillars [18]. The first two pillars, a network of Stand-by Oil Spill Response Vessels located along the European coastline and the CSN satellite-based oil spill and vessel detection monitoring service, are discussed in Sects. 3.2 and 4.2, respectively. The remaining three pillars are: the Marine-Intervention in Chemical Emergencies (MAR-ICE) Information Service which relates to chemical spills at sea; cooperation and coordination with the EU Commission, EU Member States, EFTA/EEA Coastal Countries, Candidate Countries, Acceding Countries, Regional Agreements, and other relevant international organizations such as the International Maritime Organization (IMO); and the provision of information through publications and workshops [18].

Originally the EMSA pollution response service used CSN information to assist in responding to ship-source pollution (both oil pollution and hazardous and noxious substances). Since March 2013, however, EMSA has also had a mandate to respond to marine pollution from oil and gas installations [19]. In response to that requirement, EMSA drafted an Action Plan to establish a framework for its pollution response activities relating to oil and gas installations and, following consultation with relevant stakeholders, the 'Action Plan for Response to Marine Pollution from Oil and Gas Installations' was approved by the EMSA Administrative Board in November 2013 [20, p. 39]. Specific measures were identified to adapt the existing network of Stand-by Oil Spill Response Vessels (OSRVs), to develop monitoring and evaluation tools (including adaptation of CSN), and also measures relating to the use of oil dispersants and provision of specialized equipment [20, p. 39].

3.2 Stand-by Oil Spill Response Vessels in the Mediterranean

Under the first pillar of its Pollution Response Service, EMSA provides Member States with access to a network of Stand-by OSRVs located around the EU's coasts and seas (see Fig. 2).[2] In January 2015 there were 18 OSRVs of which 8 were based in the Mediterranean region [21].

These vessels are commercially operated and can be rapidly converted to oil pollution response activities. In the Mediterranean they range from an offshore supply vessel with a tank capacity of 950 m^3 to an oil tanker with a tank capacity of 7,458 m^3. They have a wide variety of oil spill response equipment on board, including sweeping arms, booms, skimmers, and oil detection equipment. Two vessels are located in the eastern Mediterranean (one of which is based out of Algeciras and one out of Genoa – see Fig. 2), two in the central region (based out of Malta), three in the western region (two out of Piraeus and one out of Limassol), and one in the Adriatic (out of Trieste) [21]. A summary of technical specifications for vessels located in the Mediterranean is provided in Table 1.

In the event of an oil spill, requests for vessels and equipment are channeled through the Emergency Response Coordination Centre (ERCC), with EMSA then providing pollution response resources, as necessary. Those cost of those resources, the network of OSRVs and associated equipment, are covered by EMSA and funded by taxpayer contributions from EU and coastal EFTA states. In 2010, for example, the total expenditure for pollution preparedness and response activities relating to Stand-by OSRVs in the Mediterranean East, Aegean Sea, Atlantic Coast, and Mediterranean West regions (Contract 2010) was over €3,164,000 [20, p. 60]. While Member States as the main beneficiaries of these vessels, they can be made

[2] For further information on the Network of Stand-by Oil Spill Response Vessels and Equipment (Handbook 2014), which includes information sheets on individual vessels and specifications for available equipment, see: http://www.emsa.europa.eu/oil-recovery-vessels/opr-documents/opr-inventories/item/1439-network-of-stand-by-oil-spill-response-vessels-and-equipment-handbook-2014.html (Last updated 20.10.2014).

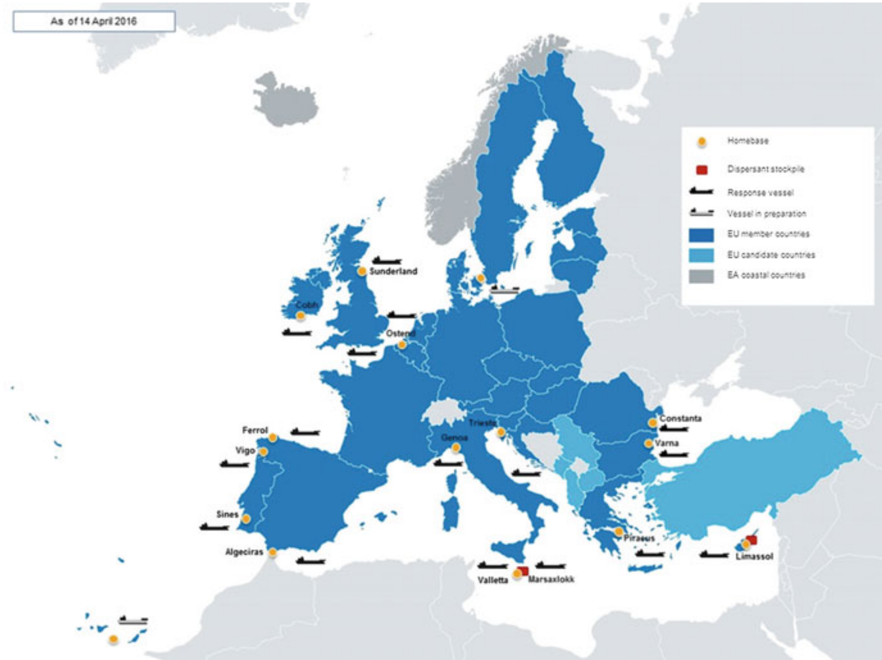

Fig. 2 Locations of EMSA oil spill response vessels and equipment as of April 2016. *Source*: Adapted from [18]. See http://www.emsa.europa.eu/operations/pollution-response-services.html

available to third parties if considered necessary, and all vessels are available to respond to spills anywhere in European waters [22].

In relation to technical cooperation on pollution preparedness and response, EMSA works with international bodies such as the International Maritime Organization (IMO) and is part of the European Commission delegation to the IMO Marine Environment Protection Committee on Oil Pollution Preparedness, Response and Cooperation – Hazardous and Noxious Substances (MEPC OPRC/HNS) [23]. It also works with regional bodies including the Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea (REMPEC) and with the Barcelona Convention, the regional agreement for the Mediterranean Sea [23].

3.3 Pollution Preparedness and Response Exercises in the Mediterranean

A further element of the EMSA Pollution Response Service is the conducting of drills and training exercises for Stand-by OSRVs and their crew. For example,

Table 1 EMSA stand-by oil spill response vessels – technical specifications (at 2015) [21]

Name	Area of operations and equipment depot	Tank capacity (m^3)	Flash point	Oil spill response equipment
Monte Anaga	Mediterranean West Algeciras/Spain	4,096	>60°C	2 × 12 m RSA; 2 × 250 m SPIB; W/BHM; Brush Skimmer; OSDS
Brezzamare	Mediterranean West Genoa/Italy	3,288	<60°C	2 × 12 m RSA; 2 × 250 m SPIB; Weir/Brush/Disc Skimmer; OSDS
Balluta Bay	Mediterranean Central Valletta/Malta	2,800	<60°C	2 × 12 m RSA; 1 × 300 m SPIB; Weir Skimmer; OSDS; DSS
Santa Maria	Mediterranean Central Marsaxlokk/Malta	2,421	<60°C	2 × 15 m RSA; 2 × 250 m Heavy Duty Boom; W/BHM; Weir Skimmer; OSDS
Marisa N	Adriatic Sea Trieste/Italy	1,562	<60°C	2 × 12 m RSA; 2 × 250 m SPIB; W/BHM; Brush Skimmer; OSDS
Aktea OSRV	Mediterranean East Piraeus/Greece	3,000	<60°C	2 × 15 m RSA; 2 × 250 m SPIB; W/BHM; Weir Skimmer; OSDS
Aegis 1 (backup vessel)	Mediterranean East Piraeus/Greece	950	>60°C	2 × 250 m Heavy Duty Boom; Weir/Brush Skimmer
Alexandria	Mediterranean East Limassol/Cyprus	7,458	<60°C	2 × 15 m RSA; 2 × 250 m Heavy Duty SPIB; W/BHM; OSDS; DSS

RSA rigid sweeping arm, *SPIB* single point inflation boom, *W/BHM* weir/brush high-capacity multiskimmer, *OSDS* oil slick detection system, *DSS* dispersant spraying system
Note: All vessels are oil tankers except the *Aegis 1* which is an offshore supply vessel
Source: EMSA – http://www.emsa.europa.eu/oil-recovery-vessels/vessel-technical-specifications.html

acceptance drills take place when a vessel is newly contracted, as was the case of the *Alexandria* which was newly contracted in 2011 and for the *Balluta Bay* and its backup vessel, *Aegis 1* which replaced the *Mistra Bay* and *Aktea OSRV* in the same year [24, p. 13]. Similarly, the *Brezzamare* was newly contracted in 2013 while the *Santa Maria* was re-contracted in the same year [20, p. 16]. In addition to these drills, a series of at-sea operational exercises take place annually and the exercises for 2011 to 2013 are outlined in Table 2 [20, pp. 24–25].

RAMOGEPOL 2013 [20, pp. 30–31] was the largest at-sea training exercise in the Mediterranean between 2011 and 2013, and was the only exercise with participation by multiple countries. The exercise took place in Ajaccio and was organized by the Préfecture Maritime de la Médirerranée. The main goals of the exercise included training staff at the French and Italian Maritime headquarters, verifying and improving national procedures, and improving international cooperation between RAMOGE (an agreement between France, Italy, and Monaco), REMPEC, and EMSA. Under a scenario of a ship collision, with one ship adrift with main

Table 2 At-sea operational exercises in the Mediterranean, 2011 to 2013

Exercise name	Date, location	Participating parties	EMSA vessels
MALTEX 2011	14/09/2011 La Valetta, Malta	Malta, EMSA	*Balluta Bay*
NIRIIS 2011	06.10.2011 Limassol, Cyprus	Cyprus, EMSA	*Alexandria*
NIREAS 2012	06/07/2012 Athens, France	Greece, EMSA	*Aktea OSRV* *Aegis 1*
MALTEX 2012	14/09/2012 La Valetta, Malta	Malta, EMSA	*Santa Maria* *Balluta Bay*
NIRIIS 2012	14/09/2012 Limassol, Cyprus	Cyprus, EMSA	*Aktea OSRV* *Alexandria*
MALTEX 2013	18/09/2013	Malta, EMSA	*Balluta Bay*
RAMOGEPOL 2013	10/10/2013 Corsica, France	France, Italy, Monaco, Spain, EMSA	Monte Anaga

engine and steering gear failure, air and sea assets were mobilized to localize and monitor fuel slicks, while the Stand-by OSRV *Monte Anaga* undertook simulates oil recovery operations. The exercise, which took place in adverse weather conditions, tested the performance of both the *Monte Anaga* and the equipment on board [20, p. 31].

Such exercises, funded through annual vessel contacts between EMSA and commercial operators, provide a valuable tool in maintaining an appropriate level of readiness to deal with a pollution incident at sea. This supports the first pillar of the EMSA Pollution Response Service, an Operational Task of EMSA, which was discussed at Sect. 3.1.

4 EMSA Earth Observation Services

Another Operational Task of EMSA is its Earth Observation Service, which comprises of two elements:

1. Earth Observation for Integrated Maritime Services which includes vessel detection and target activity detection in support of EU maritime border control activities undertaken by FRONTEX, the agency which coordinates and develops European border management, including its maritime borders [25] and anti-piracy activities undertaken by EU Naval Forces (EU NAVFOR) outside of European waters [26]; and

2. *CleanSeaNet,* the European satellite-based oil spill and detection service, which is discussed in more detail in Sect. 4.1.

4.1 CleanSeaNet Service

CSN is the second element of the Earth Observation Service [27]. CSN is a European satellite-based oil spill and vessel detection service which assists participating States in: identifying and tracing oil pollution on the sea surface; monitoring accidental pollution during emergencies; and contributing to the identification of polluters. These tasks are requirements of Article 10 of the 2005 EU Directive on ship-source pollution [28].

A number of satellites including the European Space Agency's ENVISAT and the Canadian Space Agency's RADARSAT's 1 and 2, with their on-board sensors, have provided wide-area surveillance across over 1,000 million km^2 of the EU's maritime area. Satellite imagery has been used to identify potential oil spills at sea, approximately 2,000 satellite images being analysed through the CSN service each year. Once a potential oil spill has been detected, an alert is sent to the country in whose waters it is located.

Between 16 April 2007 and 31 January 2011 the EMSA CSN First Generation service was based on 3 polar orbiting SAR (synthetic aperture radar) satellites (ENVISAT and RADARSAT's 1 and 2) [3]. More recently, images from other satellites (COSMO-SkyMed, for example) have also been used (see Sect. 5.1). 8,866 possible spills were detected between April 2007 and January 2011 with 2,828 possible spills being checked on site and 50% of those checks taking place within 3 h of satellite acquisition. Of the 745 confirmed spills, 80% were mineral oil and 20% were other substances [3]. In 2011 there were 72 authorized users of the CSN service in the 24 coastal states of Europe which included Croatia, Cyprus, France, Greece, Italy, Malta, Slovenia, and Spain in the Mediterranean [3]. Each country has a designated alert area covering its national waters. If a spill is detected on a satellite image the relevant country is alerted and the analysed images are made available to national contact points within 30 min of the satellite passing overhead [3, p. 4].

4.2 CleanSeaNet in the Mediterranean

The western-most limit of the Mediterranean is at 5°50″W while the eastern-most limit is at 36°13″E. Fig. 3 illustrates the CSN satellite coverage for that area with green squares representing satellite detections. Yellow squares are detections checked using aerial surveillance, for example, and red squares are confirmed detections. Only two countries, France and Spain, undertook verification by aircraft less 3 h after detection of a potential oil spill, with one such verification also for

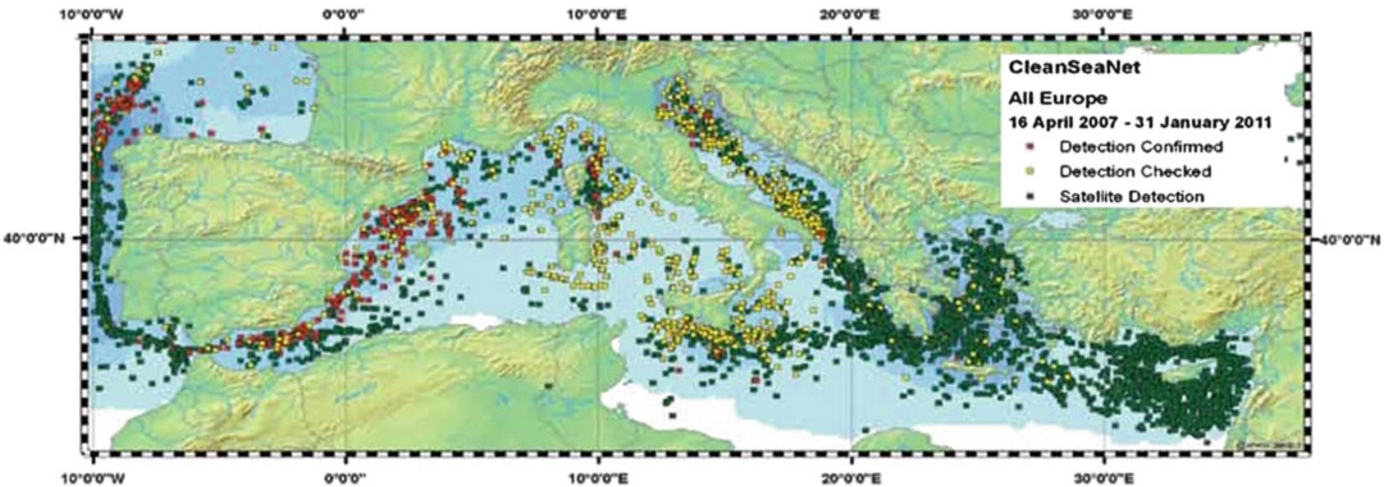

Fig. 3 Sea area coverage of EMSA CleanSeaNet for EU countries bordering the Mediterranean Sea. This figure has been adapted to show the area bordered by Mediterranean Sea states. *Source*: Adapted from [3, p. 8]

Malta. For other countries the confirmed detections (red squared) took place outside that limit.

As can be seen in Fig. 3, the highest proportion of confirmed detections (red squares) is in the western Mediterranean, from the Strait of Gibraltar and around the coasts of Spain and France. The highest concentration of satellite detections which have not been checked (green squares) is in the eastern Mediterranean, around the coasts of Greece and in the Aegean Sea, and also around Cyprus (particularly south of that island).

The highest concentrations of checked detections (yellow squares) are in the Adriatic, around southern Italy and Sicily, and also in the central Mediterranean. In these areas there are very few confirmed detections. A more detailed examination of data by country is presented in Sect. 5.2.

Figure 3 also illustrates that satellite imagery extends into the waters of southern Turkey, Syria, Lebanon, and Israel, with all areas showing high levels of satellite detections. However, for those countries, no information is available on the numbers of detections checked or confirmed.

Table 3 identifies the number of satellite images acquired via CSN annually [3] in each country's alert area. In the case of France and Spain, data on image acquisition covers both the Mediterranean and Atlantic alert areas. In the case of Spain CSN data also includes the area around the Canary Islands in the Atlantic. Slovenia, with a coastline 43 km in length and a single port (Koper), is not included in Table 3 or the subsequent analysis as, from a total of 203 image acquisitions (some of which may have been requested by Italy or Croatia), there were no satellite detections in the Slovenian alert area from the CSN data [3, p. 27].

In terms of total acquisitions, the figures for 2008–2010, the years where 12 months of data is available, show some variability within each country. For example, Cyprus, Greece, and Italy all received around one third less image acquisitions in 2009 compared to 2008, with some increases for Greece and Italy in 2010. For all 7 countries there was a drop in the number of image acquisitions of 31% between 2008 and 2009, before the numbers recovered towards 2008 levels in

Table 3 Annual number of image acquisitions for Mediterranean EU Member States, 16 April 2007 to 31 January 2011

Year / Country	2007	2008	2009	2010	2011	Totals by country: 16.04.07 to 31.01.11
Croatia	3	79	90	102	8	282
Cyprus	77	97	33	24	0	231
France	245	436	371	454	30	1,536
Greece	136	271	191	200	17	815
Italy	58	298	200	249	22	827
Malta	13	73	75	63	4	228
Spain	151	304	332	378	25	1,190
Total acquisitions	683	1,558	1,292	1,471	122	

2010. One problem drawing any clear conclusions here is, however, the lack of specific geographical information on image acquisitions for France and Spain.

Regarding country-specific information, it should also be noted that images ordered by one country may partially cover the alert area of a country bordering it; for example, between Spain and France. An image may therefore be included in the total for a country that did not request it. There is, as a result, the potential for some cross-coverage of image acquisitions presented in Table 3.

France, closely followed by Spain, had the highest number of image acquisitions in all years and for the total period covered by CSN First Generation data [3]. As noted above, however, this is in part explained by those figures also including their Atlantic alert areas. Greece had the third highest number of acquisitions in 2007, but in subsequent years Italy had the third highest number with that data covering both its Mediterranean and Adriatic alert areas. Malta had the lowest number for the first full year of data, 2008, while Cyprus had the lowest in 2009 and 2010, with less than half the number of acquisitions for Malta.

4.3 Satellite Imagery and CSN Post-2011

Only limited information is available on the operational use of CSN for the period since February 2011. No more recent country-specific or region-specific data has been generated by EMSA post the CSN First Generation Report [3].

While the EMSA Pollution Preparedness and Response Reports for covering the years 2011–2013 [19, 23, 24] do make some brief mention of satellite image acquisition, all data is provided for the whole of the EU. For example, 1,641 images were ordered from ENVISAT with 1,456 being delivered between 1 February and 31 December 2011 [23, p. 26]. For RADARSAT-1 the figures were 175 ordered and 129 delivered and for RADARSAT-2 there were 589 images ordered and 524 delivered. Between February and December 2011 there were 2,143 delivered images showing 2,048 possible oil spills detected. 749 of those spills were identified as Class A – most probably oil (mineral or vegetable/fish oil) and 1,299 were identified as Class B – less probably oil [23, p. 28]. Prior to this spills had not been classified.

Similar information was provided for 2012, the main change being that EMSA signed a contract for delivery of COSMO-SkyMed images in 2012 and 14 images were subsequently ordered and 9 delivered that year [29, p. 24]. COSMO-SkyMed discussed elsewhere in this volume [30] comprises of a constellation of four radar satellites with synthetic aperture radar (SAR) sensors on board which can be used for Earth Observation and has been developed by the Italian Space Agency and Italian Ministries of Research and of Defense [31, p. 4].

In 2013, 245 COSMO-SkyMed images were ordered and 137 were delivered [20, p. 41]. Further developments in the availability of satellite images were anticipated with the launch of the European Space Agency's SAR satellite

Sentinel-1 which was expected to launch in 2014 [20, p. 41]. Sentinel-1A subsequently launched on 3 April 2014 and Sentinel-1B on 25 April 2016 [32].

5 EMSA CSN First Generation Data by Mediterranean EU Member State, 2007–2011

This section examines EMSA CSN First Generation data for the individual Mediterranean Sea EU Member states covering the period 16 April 2007 to 31 January 2011 [3]. Table 4 shows the number of satellite detections by Mediterranean EU Member States for the period 16 April 2007 to 31 January 2011 and the average number of spills per image (figure in brackets).

The average number of detections per image by country, for the period 1 January 2008 to 31 December 2010, for the 3 years for which 12 months data is available, is approximated as follows: Croatia 0.45; Cyprus 2.38; France 0.25; Greece 1.51; Italy 1.03; Malta 0.41; and Spain 0.52. For all countries in those years the average number of detections per image is 0.93 in 2008, 0.69 in 2009, and 0.57 in 2010, suggestive of a reducing trend over time.

As noted previously, however, the data for France and Spain includes acquisitions for their territorial waters in the Atlantic as well as the Mediterranean. From maps provided by country, it is possible to draw some conclusions about the Mediterranean detections and spill confirmations for those countries. The CSN

Table 4 Annual number of satellite detections for Mediterranean EU Member States and average number per image, 16 April 2007 to 31 January 2011

Year Country	2007	2008	2009	2010	2011	Totals by country: 16.04.07 to 31.01.11
Croatia	0 *(0.00)*	42 *(0.53)*	36 *(0.40)*	44 *(0.43)*	0	123
Cyprus	139 *(1.81)*	243 *(2.51)*	67 *(2.03)*	56 *(2.33)*	0	505
France	62 *(0.25)*	131 *(0.30)*	92 *(0.25)*	86 *(0.19)*	1	372
Greece	290 *(2.13)*	425 *(1.57)*	303 *(1.59)*	270 *(1.35)*	16	1,304
Italy	25 *(0.43)*	374 *(1.26)*	180 *(0.90)*	218 *(0.88)*	16	813
Malta	0 *(0.00)*	33 *(0.45)*	30 *(0.40)*	23 *(0.37)*	1	87
Spain	135 *(0.89)*	204 *(0.67)*	184 *(0.55)*	136 *(0.34)*	6	659
Total observations	651	1,452	892	833	40	

Note: As the figures for 2011 are for 1 month only, no average number of detections per image is provided. There is also no average number provided for the Totals by country results by EU Member State in the Mediterranean are presented below, from Cyprus in the east to Spain in the west.

5.1 Cyprus

Cyprus [3, pp. 18–19] had one of the lowest numbers for image acquisitions, but had the greatest number of detections per image with an average of 2.51 detections per image in 2008, according to Tables 3 and 4. In all years apart from 2007, when Greece had a higher average than Cyprus, the data suggests that there is a high incidence of detections in Cypriot waters, from a low of just under 2 per image in 2007 to a high of 2.51 in 2008, and remaining over 2 in 2009 and 2010.

While no verification by aircraft less than 3 h after a satellite pass took place in any of the years for which data was available, monthly data identifies 3 detections checked in July 2007 and 2 in July 2009. This is the lowest level of flights to check detections of any EU Member State being examined in Sect. 5. From the map of the Cypriot alert area all of the checked detections were to the south of the island although detections were observed across the whole alert area, apart from a small area to the north of the island at its western end, and the satellite coverage averaged at approximately 1–2 images per month. There were no confirmed detections at any time.

5.2 Croatia

CSN data for Croatia [3, pp. 16–17] identifies that the number of image acquisitions annually is low and the average number of detections per image is less than 0.5 (1 every 2 images) in most years; there was a high of 0.53 in 2008. There were 123 detections in total of which more than half were checked, all checks outside the 3 h limit. Monthly data indicates that in most months from August 2008 onward verification activities took place for a large number of satellite detections.

To illustrate the type of monthly data available in the CSN report [3], the Croatia map and data identify confirmed spills as follows: June and October 2009 (1 and 2 respectively); 1 in each of February and September 2009 and 2 in November that year; and 1 in March 2010. The map shows that 7 of those spills were in northern waters, of which 4 were close to the border with the Italian alert area, and 1 was confirmed in the south. Along most of the Croatian coastline there are large numbers of islands and the majority of detections were located away from coastal waters. Only in the north of the alert area, which received a monthly average of 2–4 images (4–6 in one area), do detections appear closer in to land. In its southern waters, the average number of satellite images was 1–2 per month.

5.3 Greece

For Greece [3, pp. 30–31] there were 1,304 total detections with no confirmations within the 3 h limit. The highest average number of detections per image was 2.13 in 2007, falling to a low of 1.35 in 2010. Monthly data for Greece indicates that a small number of detections were checked in most months from November 2008 onwards (5 or less per month; outside the time limit) and were generally distributed across the entire Greek alert area.

Greece received an average of 1–2 satellite images per month at the southern-most and western-most borders of its alert area. There were higher concentrations averages of (2–4 or 4–6 images per month) closer to the mainland. The highest concentration (6–8 images per month) was in the area south and east of Athens and north of Crete (southern Aegean and Sea of Crete area).

There were only 2 confirmed spills in Greek waters, 1 in March 2009 and 1 in February 2010. There was 1 confirmed spill off eastern Greece in the Ionian Sea and 1 to the north of Crete. It is not possible to link time and location for these spills on the basis of available data. However, it can be concluded that the number of confirmed spills would be much higher if the number of flights to check detections were increased, since only Cyprus undertook less flights.

5.4 Italy

Data for Italy [3, pp. 34–35] indicates that no detections were confirmed within the 3 h limit for 2008–2010. However, it is apparent from monthly data that the vast majority of the total of 813 satellite detections for the data period were checked, from which just under 30 were confirmed as spills between October 2007 and January 2010. The highest number of confirmations was in July 2008 (5 confirmations from approximately 46 detections that month). 2008 was the only year in which the average number of detections per image was over 1 (1.26 in that year).

Almost all detections to the east of mainland Italy in the Adriatic were checked with confirmed spills in both the north and south Adriatic, areas receiving 2–4 or 4–6 satellite images monthly on average; the central Adriatic is received only 1–2. There were also a number confirmed in the waters south of Sicily, while the area to the south-east of Sicily, with 1–2 images per month and close to the Greek alert area, had the lowest level of checked detections anywhere in the Italian alert area.

To the west of mainland Italy there was one confirmed spill east of Cagliari on Sardinia, several more being clustered to the north-east of Sardinia, all locations with an average of 2–4 satellite images per month. There were also a number of confirmed detections in the area north-east of Corsica and along the border between the Italian and French alert areas. The vast majority of detections west of mainland Italy were checked and only a very small proportion of these was confirmed as a spill. Of all the EU Member States in the Mediterranean, Italy had the highest rate of detection checks.

5.5 Malta

Malta [3, pp. 40–41] had one detection confirmed in its alert area of within 3 h of image acquisition, that detection being in September 2010. In total there were 6 confirmed detections to the south of Malta with a further 10 checked in that area between June 2008 and October 2010. The average number of detections per satellite image was less than 0.45, which was the highest average of any country in 2008.

As discussed previously, images ordered by other countries may partially cover the Maltese alert area and therefore may have been included in the totals for Malta. Many of the satellite detections to the north of Malta are identified on or close to the border with the Italian alert area. In the waters closest to the island an average of 2–4 images were produced each month, while the remainder of its area extending towards Tunisia in the west and bordering the south of the Greek alert area in the east, received 1–2 satellite images per month.

5.6 France

The data for France includes detections in both the Atlantic/English Channel and in the Mediterranean [3, pp. 26–27]. The average number of detections per image was less than 0.30 in all years with only 372 detections from a total of 1,536 image acquisitions between April 2007 and the end of January 2011. In 2008 there were 131 detections of which 11 were checked and 8 were confirmed as spills. However it is not identified how quickly those checks took place.

Between 2009 and 2011, a number of detections were checked and verified by aircraft less than 3 h after image acquisition; of these 53% were confirmed as a spill. Of the 92 detections in 2009, for example, 7 were checked of which 4 were confirmed. In 2010 there were 86 detections, 9 checks, and 4 confirmations; in January 2011 there was 1 detection which was checked and confirmed as a spill. The area of French waters with the highest level of satellite images per month was around the coast of Brittany and into the English Channel, with as many as 10–12 images per month in the Channel area. The majority of the Bay of Biscay received 2–4 images per month, the same level as the French Mediterranean alert area.

Focusing on the Mediterranean [3, p. 26], satellite detections were generally distributed across the whole area. There was a fairly concentrated cluster of spills to the east of Corsica and, although the intensity of squares to the east of Corsica makes the map difficult to interpret, there were approximately 5 checked and 5 confirmed detections to the east of Corsica, all close to the border with the Italian alert area. Additionally, there was 1 confirmed detection to the north-west of Corsica and 2 further checked detections.

Around the southern French port of Marseilles there was 1 checked and 1 confirmed detection east of the city, 3 checked south of the city, and approximately 10 checked and 1 confirmed to the west of the city. The remaining checked and confirmed detections in the French alert area were close to the border with the Spanish alert area. In that area there were approximately 6 checked and 5 confirmed detections, with 1 checked and 1 confirmed being very close to the French coastline. As with all the CSN data there is no timeline associated with it, and nor is there any available data on the nature or source of confirmed spills, or the scale of any spill.

5.7 Spain

Spain, across all its alert areas, had the second highest total number of image acquisitions in all years [3, pp. 54–55]. The highest average number of detections per image was 0.89 in 2007, falling to 0.34 in 2010. In 2009, just over 60 of the 184 detections were checked by aircraft in less than 3 h and of these just under 50 were confirmed as spills. In 2010, there were 130 detections, 50 checks and 30 confirmations, while in January 2011 there were 6 detections, 4 checks, and 2 confirmed spills. Over the period 2009 to the end of January 2011, Spain had a confirmation rate of 70%.

Focusing on the Spanish Mediterranean alert area only [3, p. 54] there were large numbers of confirmed detections along the entire southern and eastern coastlines of Spain, an area receiving 2–4 satellite images on average each month. Away from the coastal areas a much smaller proportion of satellite detections were checked and therefore the level of confirmations was also much lower. For example, there was a single confirmed spill to the south of Mallorca in the Balearic Isles, south of which there were only 1–2 satellite images received each month.

Close to the border with the French alert area, and also in Spanish waters north of Barcelona, there were no checked detections or confirmed spills. This is in contrast to France where there were a number of checked and confirmed detections close to the Spain/France border.

6 Conclusions

This chapter has briefly presented an overview of the history and development of the EMSA, the development of its role to support the European Commission and EU Member States particularly in the area of marine environmental protection.

The EMSA *CleanSeaNet* Service, in conjunction with other services such as AIS vessel tracking information provided through *SafeSeaNet*, plays a major role in helping detect oil pollution entering Europe’s marine areas the source of that oil, for example. It also supports EU Member States by providing an emergency response to oil and other spills at sea within 24 h, through a network of Stand-by Oil Spill Response Vessels. Those vessels, together with oil spill equipment on board and stockpiles of equipment located around the EU, can be used to assist in cleaning up accidental oil spills at sea. This has, since March 2013, also included cleaning up spills from oil and gas installations. In the event of an incident taking place in non-EU waters, those vessels may also be made available to third parties and so could potentially be used to support clean-up operations in the southern Mediterranean.

Satellite imagery has been shown to provide an important tool in identifying oil (and other) pollutants on the sea surface. While some satellite monitoring has taken place in the Mediterranean [33–35] there is little information available to draw conclusions about long-term trends in oil pollution, unlike other regions such as the North Sea where more than 30 years of data is available and a clear trend for a reduction levels of oil entering the marine environment has been observed [36, 37].

Very little can be concluded from the CSN images available through EMSA's Earth Observation service for the Mediterranean. For the period 16 April 2007 to 31 January 2011 it is apparent that the intensity of satellite coverage was far higher in northern European waters – English Channel, North Sea, Baltic Sea – than in the Mediterranean [3, p. 8] and that difference is particularly market between northern French waters around Brittany and into the English Channel, compared to the French alert area in the Mediterranean. The majority of the Mediterranean had satellite coverage between 1–2 and 2–4 images per month, while in the English Channel coverage was approximately 10–12 images (possibly as high as 16–20). Some areas of the Baltic Sea received more than 20 images on average each month.

Between 2008 and 2010, the years for which there is a full year's data available, the number of image acquisitions for the 7 EU Member States was quite variable, with Cyprus, Greece, and Italy all receiving around one third less acquisitions in 2009 compared to 2008 (see Table 3). The total number of acquisitions in 2008 and 2009 fell by 31%, from 1,558 to 1,292, before showing an increase to 1,471 in 2010. Since data for France and Spain include their alert areas in the Atlantic and no specific information for their Mediterranean alert areas is not available, this is a limitation of the available data.

During the same period, there was a nearly 40% reduction in the total number of observations for all 7 countries from 1,452 in 2008 to 892 in 2009, with a small additional fall in 2010 when there were 833 observations (see Table 4). As a result of a lack of geographical information for Spain and France, and the non-availability of CSN data since February 2011, it is not possible to draw any conclusions on trends in oil inputs using EMSA data.

What can be concluded, however, is that the low levels of satellite images received across the region, combined with the lack of aircraft verification of acquired images in the eastern Mediterranean, means that the number of spills is likely to be much higher than the data suggests. It is also likely to remain high unless increased satellite monitoring occurs and ships are more likely to be caught illegally discharging oil in the region, and prosecuted for doing so.

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Numerical Modeling of Oil Pollution in the Eastern Mediterranean Sea

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Abstract This chapter presents a summary of major applications in numerical oil spill predictions for the Eastern Mediterranean Sea. Since the trilateral agreement between Cyprus, Egypt, and Israel back in 1997, under the framework of the subregional contingency plan for preparedness and response to major oil spill pollution incidents in the Eastern Mediterranean Sea, several oil spill models have been implemented during real oil pollution accidents and after oil spills that were detected from satellite remote sensing SAR data. In addition, several projects cofinanced by the European Commission addressed particularly issues with oil spill

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modeling, taking the advantage of developments in operational oceanography, as well as collaboration with the Mediterranean Oceanographic Network for Global Ocean Observing System (MONGOOS), with the European Maritime Safety Agency CleanSeaNet (EMSA-CSN), and Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea (REMPEC). Major oil pollution incidents in the Eastern Mediterranean and the oil spill modeling applications carried out are summarized in this work. Three well-established operational oil spill modeling systems – two of them characterized by different numerical tools MEDSLIK, MEDSLIK II, and the POSEIDON oil spill models – are described in terms of their applicability to real oil spill pollution events, the *Lebanon oil pollution crisis* in summer 2006, the case *Costa Concordia* accident, and the spill event associated with the collision of two cargo vessels in the North Aegean Sea in June 2009. Finally, an overview of the present-day capability of Eastern Mediterranean countries in oil spill modeling is provided in this chapter.

Keywords Eastern Mediterranean Sea, Levantine Basin, MEDSLIK, MEDSLIK II, Oil spill models, POSEIDON OSM

Contents

1 Introduction

Oil spills in the Eastern Mediterranean Sea, as with any other seas and oceans around the world, can significantly impact the marine environment and are a concern for civil protection authorities and coastal populations in a time of ever-increasing shipping volumes and hydrocarbon exploration [1] (Fig. 1). The Eastern Mediterranean Sea finds itself as the locus of one of the busiest shipping corridors in the world [2, 3], with variable weather and sea current patterns depending on seasonality, formation of local storms, and bathymetry. These latter factors have, potentially, a significantly impact on oil slick movement.

The probability of a major oil spill incident to occur in the Eastern Mediterranean Sea is relatively high at present due to increasing exploration and exploitation for hydrocarbons in the Levantine Basin [4] (Fig. 2). This increase in interest from exploration companies was particularly recorded after the discovery of significant

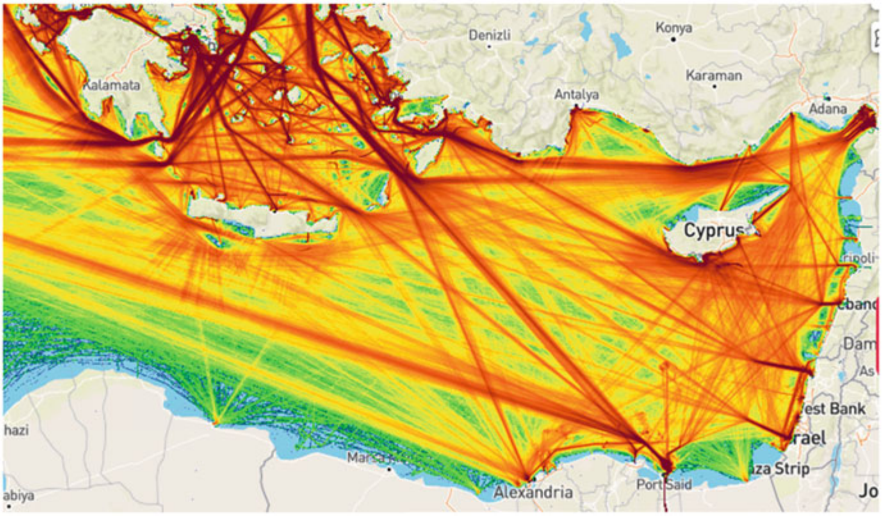

Fig. 1 Marine traffic density in the Eastern Mediterranean Sea (see https://www.marinetraffic.com)

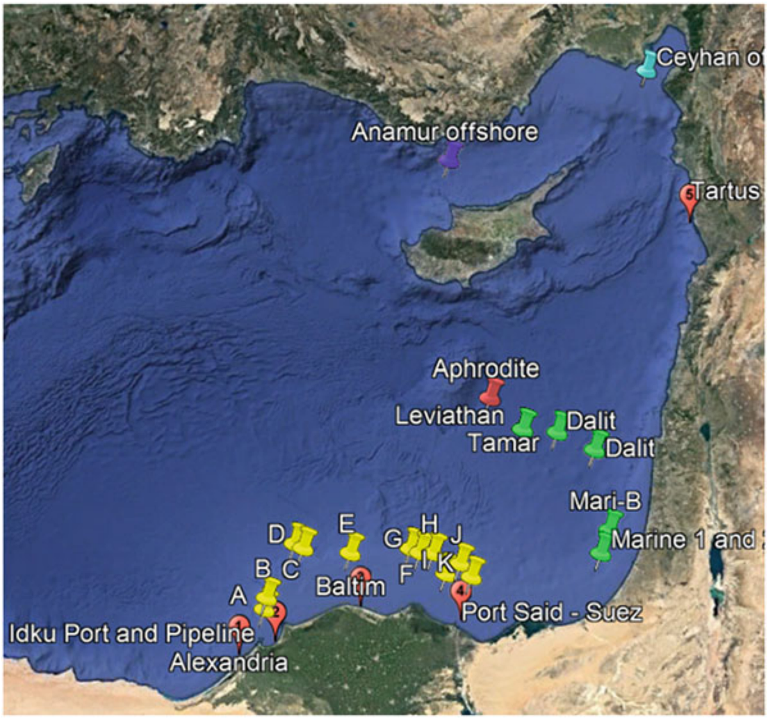

Fig. 2 Major offshore platforms in the Eastern Mediterranean Levantine Basin up to the year 2016

amounts of oil and gas in the EEZs of Israel, Egypt, and Cyprus. In addition, increase risk of an oil spill accident in the Eastern Mediterranean Sea is associated with:

1. The recent enlargement of the Suez Canal in Egypt, which now accommodates tankers up to 550,000 deadweight (dwt) in volume.
2. Refineries and ports have been upgraded to deal with the expected increase in ship tonnage and volumes of hydrocarbons (both oil and gas) to be produced from new offshore fields.
3. No efficient mitigation plans and real-time surveying technology exist to assist response agencies during major oil spill accidents.

Item (3) comprises a major limitation when considering acute pollution events such as the Lebanon 2006 oil spill, so far the largest oil pollution accident that occurred in the region [5], potential collision accidents along major routes for oil and gas tankers from the Middle East to Europe, from offshore platforms, or pollution accidents resulting from well blowouts in deep waters.

The risks potentially associated with the deployment and operation of offshore installations in the Mediterranean Sea prompted, in 2011, the adoption of a new protocol for the protection of the Mediterranean Sea against pollution from oil/gas exploration and exploitation on the continental shelf and the seabed, known as *Offshore Protocol*. This is one of the seven protocols of the *Barcelona Convention*. The *Offshore Protocol* urges riparian countries to develop *Impact Damage Assessments* in order to take into account all elements that may affect the sea and the coast during the deployment of offshore drilling installations. The measures to mitigate and to minimize associated drilling risks include the early detection and control of oil spills, the redistribution of available resources for an efficient combat of oil spills at their early stages, proposals for new response mechanisms to fight oil spills, etc. In order to evaluate the consequences of an oil release from planned offshore platforms, national authorities are required to develop an *Impact Damage Assessment* based on oil spill modeling results. Of crucial importance, in the case of a major oil spill incident, are operational oil spill modeling predictions. These modeled predictions will serve as the initial/forefront tools to assist regional and national contingency plans.

Several initiatives have been developed in the last 5 years to improve the preparedness and response measurements to major oil spill incidents in the Eastern Mediterranean Sea, some of them also addressing oil spill modeling predictions.

The most recent project addressing oil spill predictions in the Mediterranean Sea, using a multi-model approach, was the *Mediterranean Decision Support System for Marine Safety* (*MEDESS-4MS*) (http://www.medess4ms.eu/) funded by the European Commission (EC) throughout the MED Program. Moreover, to address the access of marine data, the European Commission has established the *European Marine Observation and Data Network* (*EMODnet*), which now provides a single entry point for accessing and retrieving marine data derived from the *EMODnet* thematic portals, from the *Copernicus Marine Environment Monitoring Service* (*CMEMS*), and from other initiatives existing at more regional “basin” scales. In order to test and evaluate how comprehensive and accurate are the monitoring and forecasting marine data available through the *EMODnet* and Copernicus thematic portals (http://www.emodnet-mediterranean.eu/), at the scale of the Mediterranean Sea, 11 challenges were defined where the marine data can benefit key downstream applications to foster *BlueMed economies*.

One of the *EMODnet Mediterranean Checkpoint* challenges comprises the *oil platform leaks*, which aims at providing oil spill predictions so that one can determine the likely trajectory of oil slicks and the statistical likelihood that sensitive coastal habitats, species, or tourist beaches will be affected. The *oil platform leak* challenge handles the ability to produce oil spill predictions in the Mediterranean Sea, where the EC generates the oil leak alert online. In the framework of this challenge, oil spill predictions can be connected to existing oil spill monitoring platforms (EMSA-CSN and REMPEC) using the well-established oil spill models MEDSLIK and MEDSLIK II and environmental data from CMEMS, ECMWF, or other met-ocean forecasting systems such as CYCOFOS, POSEIDON, SKIRON, and ALERMO [6–10].

Extensive industrial activities related to shipping and hydrocarbon industry in the Mediterranean Sea, particularly in its eastern region, show the necessity for having in place a reliable, well-tested oil spill modeling system to help response agencies in mitigating any accident. European (EMSA-CSN), regional (REMPEC), and national response agencies, civil protection teams, academia, and industrial and NGO stakeholders have been working in tandem to develop, improve, and operate oil spill models for predicting real and/or potential oil spills, at surface or in the subsurface, forward and backward [4, 5, 11–13]. They have recognized a strong influence of variable oceanographic and weather conditions on the movement of oil in the entire Eastern Mediterranean Sea and have demonstrated a close effect of seafloor bathymetry on regional currents [4, 14]. After modeling real and hypothetical oil spills in key hydrocarbon exploration areas, and shipping lanes in the Eastern Mediterranean Levantine region, [4, 14–16] confirmed that the variability of weather and oceanographic conditions has a crucial effect on oil slick movement (advection) and oil spill characteristics (weathering processes) through time and space.

The general circulation pattern in the Eastern Mediterranean Levantine region is anticlockwise, with several cyclonic and anticyclonic gyres, respectively, the Rhodos gyre and the Mersa Matruh, and mesoscale features such as the Cyprus and Shikmona warm core eddies. Flow jets also occur in the area such as the MMJ transferring the Modified Atlantic Waters offshore across the Levantine region and the Asia Minor Current. This latter current is capable of transferring, along the southern coast of Turkey, the warm and saline waters of the easternmost part of the Levantine Basin further to the north along the eastern Aegean Sea, after passing the eastern Cretan Arc Straits [17–19].

The Eastern Mediterranean Sea is known to be the largest subregion of the Mediterranean and is subdivided geographically as several distinct basins: (a) Aegean Sea, (b) Levantine Basin, (c) Cretan Passage, and (d) the Ionian Sea. The Eastern Mediterranean is chiefly a deep basin with exception of the shallow coastal zones of Egypt and Libya. The Eastern Mediterranean Sea is connected to the Black Sea to the north by the Strait of Dardanelles and Bosporus, to the Red Sea to the southeast via the recently (2016) enlarged Suez Canal, and to the Western Mediterranean to the west through the Ionian Sea and the Sicilian Channel (Fig. 3). These sea passages constitute the main shipping corridors on the Eastern Mediterranean Sea, while on the SE part of the Levantine Basin, on the shallow continental shelf of Egypt as well as offshore the EEZ of Israel and Cyprus, an increase of hydrocarbon exploration has been observed for the last decade.

Technological advances provided by geo-information systems, such as the use of satellite synthetic aperture radar (SAR) and automatic identification system (AIS), made possible the detection of oil slicks and of the sources responsible for oil leakages on the sea (Fig. 4). At present, the coupling of satellite remote sensing systems with oil spill models constitutes an effective monitoring and forecasting tool (Fig. 5) used to discourage illegal operational oil discharges [20–24]. From SAR images collected during the period spanning 1999–2004, up to 2,544 possible oil spills were detected in the Eastern Mediterranean [25]. Similarly, in the NE part of the Eastern Mediterranean Levantine region, more than 1,200 possible oil spills were detected from 2007 to 2011 [11]. The majority of SAR-detected oil slicks followed the main shipping routes in the Levantine region and were the result of routine operations such as degassing, deballasting, and other actions involving illegal discharges of oil, in violation of the EU Directive 2005/35 (Fig. 4).

A common practice for assisting the national and regional contingency plans is to have in place (together with monitoring systems) dedicated tools providing

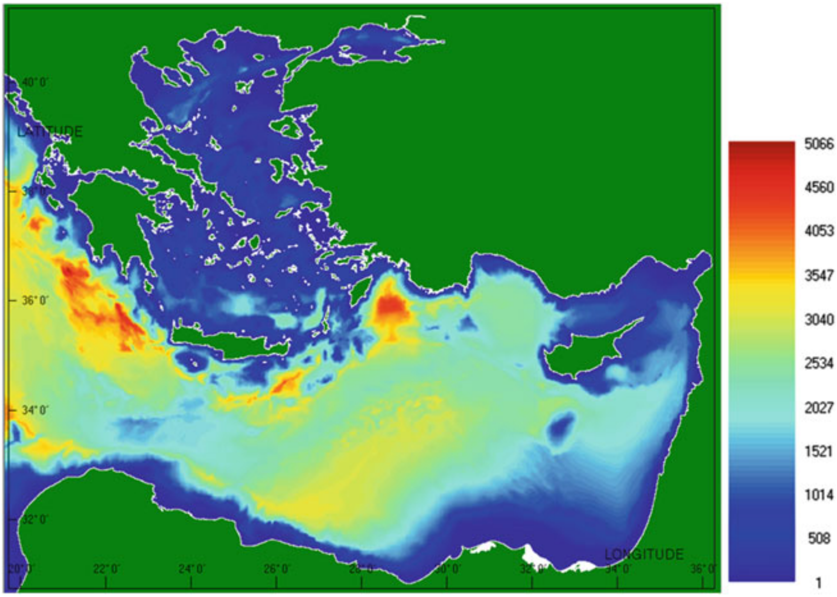

Fig. 3 Geometry and bathymetry of the Eastern Mediterranean Sea

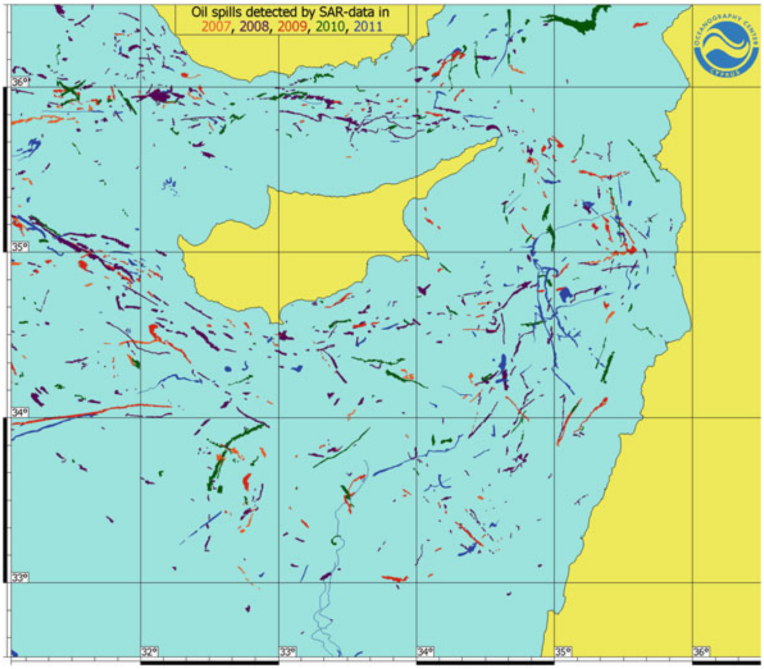

Fig. 4 Possible oil spills detected in the NE Levantine region during the period spanning 2007–2011 (map from Zodiatis et al. [11])

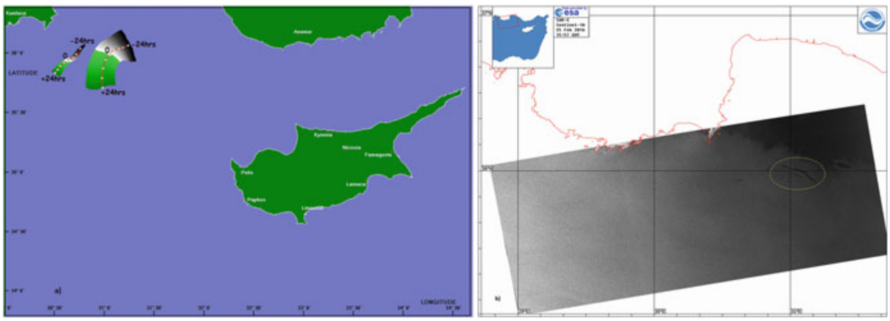

Fig. 5 Example of the detection of oil slicks using ESA Sentinel SAR data and MEDSLIK 24 hour forward and backtracking predictions (date: 25/2/2016). White, initial oil slick position, 0 h (date/time of observation); dark green, forecast +24 h; black, backtracking −24 h

operationally, on a routine basis, high-resolution met-ocean information of the main parameters (sea currents, winds, waves, sea surface temperature, sea water density) affecting the advection and the weathering of the oil spills [11]. The use of this information by oil spill models provides the capability for operational forecasting or hindcast predictions of oil spill advection and weathering (Fig. 5), allowing the agencies in charge to combat oil pollution and the decision-makers to promptly respond to oil pollution crises.

For the last two decades, developments in operational oceanography in Europe made possible for the EC to implement the CMEMS in 2015, which provides daily, reliable, and quality-controlled met-ocean forecasts for the European seas, including the Mediterranean Sea [26]. In the Eastern Mediterranean Sea, several sub-regional met-ocean forecasting systems exist at present; a total of 28 systems downscale the CMEMS regional data to provide high-resolution forecasting and hindcast data for the needs of the oil spill predictions [27]. In order to harmonize the different met-ocean forecasting in terms of oil spill prediction modeling, the EC funded the MEDESS-4MS project to make possible the use of common parameters and formats for input/output data. These data are needed for well-established oil spill models in the region, including those operated in the Eastern Mediterranean Sea: MEDSLIK, POSEIDON OSM, and MEDSLIK II.

The chapter is organized as follows: in Sect. 2 the main oil pollution incidents in the Eastern Mediterranean are briefly reported; in Sect. 3 an overview of major research projects focused on oil spill modeling in the Eastern Mediterranean is summarized; in Sects. 4–6, the three well-established oil spill modeling systems implemented in the Eastern Mediterranean Sea are described: (a) MEDSLIK, (b) POSEIDON OSM, and (c) MEDSLIK II. Their application during real oil spill incidents is briefly explained. At Sect. 7 risk mapping for the Lebanon oil spill crisis in summer 2006 is presented based on the international standard ISO 31000:2009. Finally, concluding remarks are included in Sect. 8.

2 Main Oil Pollution Incidents in the Eastern Mediterranean Sea

Several major oil spill incidents were reported in the Eastern Mediterranean Sea in the past four decades. A brief description of these pollution incidents is documented in the ITOPF (International Tanker Owners Pollution Federation; www.itopf.com) and also in [4] for the wider area of the Levant Basin. The largest oil spill accidents include:

1. The grounding of the *Messiniaki Frontis* (1979) in South Crete. In this accident, a cargo ship was grounded off southern Crete spilling 7,000 tons of crude. Much of the spilled oil dispersed at sea although a limited amount of shoreline cleanup was required.
2. The sinking of the *Irenes Serenade* (1980) in the Pylos Harbor, Peloponnese. This accident was confined to the harbor and was followed by another accident in 1993.

3. The grounding of the *Iliad* (1993) at the same Pylos Harbor, Greece. In this case, cleaning operation was facilitated by mechanical recovery and shoreline cleanup by a private contractor.
4. The collision of the *Geroi Cernomorya* (1992), in which 8,000 tons of crude oil was spilt. In this accident, the abovementioned vessel spilled crude oil into the Aegean Sea following a collision. Most of the oil dispersed naturally, but parts of Mykonos Island were lightly oiled. A contractor undertook the cleanup supervised by the port authority.
5. The collision of *La Guardia* (1994) with pipeline systems of a refinery near Athens. In this accident, supply pipes spilt 400 tons of heavy crude while the vessel was maneuvering out of dock at the Aspropyrgos Hellenic Refinery.
6. The spillage of 300 tons of Arabian light crude oil by the *Kriti Sea* (1996), offshore Isthmia. The vessel was loading at the Motor Oil Refinery Installations at Agioi Theodoroi Port.
7. The explosion of the tanker *Slops* (2000) in the Port of Piraeus, near Athens, while anchored. An unknown but substantial quantity of oil was spilled, some of which burned in the ensuing fire.
8. The spillage of 500 tons of bunker fuel (oil and diesel) in Lefkandi, Central Greece, by the *M/V Eurobulker X* (2000).
9. The Lebanon oil pollution crisis in summer of 2006, which is considered the biggest so far oil pollution in the Eastern Mediterranean Sea, for more details see Sect. 4.1.
10. The 2013 "*Gastria* oil spill incident" in the northern part of the Famagusta Bay, at the east coastal zone of Cyprus, outlined below:

An oil spill, approximately 100 tons of heavy fuel oil (HFO), occurred caused by a Turkish tanker at 0.67 nautical miles from the shore (at the reported location of 3518.61 N–03359.50 E) on 16 July 2013 at 10:00 UTC, while offloaded HFO to an oil terminal for the needs of the nearby "Kalecik" power station, owned and operated by the Turkish "Aksa" energy company in the Turkey, occupied part of Cyprus.[1]

The oil spill was also identified by SAR images provided by EMSA-CSN portal. Within the frame of the Cyprus National Contingency Plan, the MEDSLIK oil spill model provided the predictions of the slick and has shown that due to the very-very weak winds and of the sea currents, the spill needed around 18 h to arrive at the nearby coast. Unfortunately, due to the political situation between Turkey and Cyprus, the Turkish forces denied the offered support and equipment from the Cyprus response agencies to combat the spill while it was at sea. This resulted the beaching of the majority of oil in a relative extended part of the northern shore of the bay. Later on, with the increase of winds and the action of waves, certain amount of the percentage of oil at coast but potentially releasable reentered the sea

[1]See http://www.reuters.com/article/cyprus-spill-idUSL6N0FN1Z320130717 and http://www.hurriyetdailynews.com/40-tons-oil-spilled-into-sea-turkish-firm-admits.aspx?pageID=238&nID=50910&NewsCatID=348.

as small slick parcels, scattered by the currents in the southern part of the bay, both simulated by MEDSLIK and verified by in situ observations.

3 Oil Spill Modeling in the Eastern Mediterranean Sea: A Review

Several initiatives have been carried out in the last decade to improve the preparedness and response measurements to major oil spill incidents in the Eastern Mediterranean Sea. One of these initiatives concerns oil spill predictions.

The major project addressing the issue of oil spill modeling prediction in the region is the *Mediterranean Decision Support System for Marine Safety* MEDESS-4MS[2] (funded by the EC throughout the MED Program). The MEDESS-4MS project is dedicated to the prevention of maritime risks and subsequent strengthening of maritime safety related to oil spill pollution in the Mediterranean Sea. MEDESS-4MS delivered an integrated operational multi-model oil spill prediction service for the Mediterranean Sea [27], connected to existing monitoring platforms (REMPEC, EMSA-CSN, AIS), using well-established oil spill modeling systems, data from the Copernicus Marine Environment Monitoring Service (CMEMS), and national ocean forecasting systems. MEDESS-4MS constitutes a successful joint project between the members of the Mediterranean Oceanographic Network for Global Ocean Observing Systems (MONGOOS) and of several response agencies including REMPEC. MEDESS-4MS uses information on position of the oil slick, links it to four well-established oil spill models in the Mediterranean Sea capable of predicting the movement pollutant, thus providing tailored products to oil spill crisis management users. This workflow contributes substantially to the prevention of maritime risks and to maritime safety.

One of the major goals of MEDES4MS is the improvement of the modeling tools used among different institutional and operational partners, in order to provide an integrated approach to maritime safety, particularly to support the response against oil spill pollution in the Mediterranean Sea. This objective was achieved through interconnecting the different parts of MEDESS-4MS oil spill monitoring and forecasting services with the *network data repository* (NDR) and *user interfaces* (UI) [27].

During MEDESS-4MS, four well-established stand-alone oil spill systems (MEDSLIK, MEDSLIK-II, POSEIDON-OSM, MOTHY) in use in the Mediterranean Sea were interconnected into an integrated multi-model oil spill forecasting network. In order to accomplish this same integrative step, each stand-alone system underwent changes for the implementation of a common data exchange system providing the link between the necessary information that should be available to the oil spill systems, environmental data from the CMEMS, the national ocean

[2] See www.medess4ms.eu/.

forecasting systems, the oil slick data from existing monitoring platforms (REMPEC, EMSA CSN), and the data from supplementary resources such as ESA and AIS.

The main steps toward the implementation of the MEDESS-4MS multi-model oil spill forecasting system were the understanding of existing oil spill forecasting systems, the design of common specifications for the data exchange and interfacing with oil spill data from existing monitoring systems, the implementation of common standards to all MEDESS-4MS modeling system modules, and, finally, the testing of the overall system performance in operational mode.

The *Risk Assessment of Offshore Platforms in the Eastern Mediterranean* (RAOP-MED) project, funded by the EC, provided a holistic study on the risks associated with exploration and production of hydrocarbon in the Eastern Mediterranean Sea. This included the prevention, early detection of oil spills, and reorganization and redistribution of resources available for an efficient combat of oil spills at their early stages. In order to evaluate the consequences of a release of oil from offshore platforms in the Eastern Mediterranean Sea, *Impact Damage Assessment* studies were carried out under the framework of the RAOP-MED project. To this extent, the *Impact Damage Assessment* studies are based on the predictions of the well-established MEDSLIK oil spill model, using downscaled CMEMS MED MFC and CYCOFOS data, as well as wind data provided by SKIRON.

Under the framework of RAOP-MED, long-term oil spill hindcast simulations were carried out for the first time to study weekly, seasonal, and interannual variability in oil spill predictions for the Levantine Basin, using met-ocean data of high spatial and temporal resolution. The hindcast oil spill simulations were initially carried out for 10 planned drilling locations at the southeast EEZ of Cyprus by ENI [14] and also for 19 existing offshore wells located in the Levantine Basin, where hydrocarbon exploration and production are ongoing [4].

The oil spill modeling scenarios for the 10 planned drill sites and for the 19 existing platforms were prepared for week to week conditions for a period of 4 years (2010–2014), presenting the detailed trajectories of hypothetical oil spills. These trajectories were computed together with graphs corresponding to the percentage volumes of dispersed, evaporated, trapped at the surface, first impact at coast, extend of the affected coastline, extend of the sea area affected 1–20 days after the onset of the spill. The modeled spills took into account the release of 55,800 bbls[3] of medium-grade Belayim oil, the common type produced in the Levantine Basin, following the REMPEC MEDEXPOL 2013 exercise [28].

The long-term hindcast oil spill modeling for existing offshore platforms suggests that the most vulnerable areas are those in the eastern part of the Levantine Basin – offshore and coastal Israel, Lebanon, and the Egyptian coastline. The early deployment of response measures, following the established response protocols for large oil spill accidents from offshore platforms, will minimize the impact of any future pollution accidents on the coastal zones. Due to the significant

[3]The standard volume unit for crude oil measurement, the 42-gal barrel (“bbl”).

environmental, social, and economic impacts that oil spills may impose on the Levantine Basin, continuous improvements in the prevention and response capabilities are necessary for the region. This can be achieved by investing in monitoring assets, in situ and remote sensing, in technological innovation and operational oil spill, and in ocean forecasting models.

At present, several institutions and agencies throughout the Eastern Mediterranean Sea, in EC member and nonmember States, implement and operate oil spill models in operational and hindcast modes using downscaled CMEMS met-ocean data, following the developments in EC projects regarding the operational oceanography and the oil spill modeling [15, 27]. Most of downscaled and downstream applications are capable to provide oil spill predictions only at their national exclusive economic zones (EEZ), whereas in the framework of the MEDESS-MS project, the well-established oil spill models (MEDSLIK, MEDSLIK-II, POSEIDON OSM) are applicable to the entire Eastern Mediterranean Sea using any available met-ocean information from the 28 different harmonized regional, subregional, and coastal downscaled met-ocean systems of different resolutions and different surface forcing(s).

4 The MEDSLIK Oil Spill Modeling System

MEDSLIK is a well-established 3D oil spill model that predicts the transport, fate, and weathering of oil spills [11, 13]. It is used by several response agencies and institutions around the Mediterranean Sea.

MEDSLIK was successfully used during the Lebanon oil spill pollution crisis, in summer 2006, considered so far to be the biggest oil spill pollution incident in the Eastern Mediterranean Sea [5, 29].

MEDSLIK has been used operationally for real oil spill accidents and for preparedness in contingency planning within the framework of pilot projects with the Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea (REMPEC) and the European Maritime Safety Agency CleanSeaNet (EMSA-CSN). It was also used in the EC project NEREIDs supported by the European Civil Protection Agency.[4]

The MEDSLIK oil spill model is used by the Cyprus National Contingency Plan and has been used also in the framework of the subregional contingency plan in preparedness and response to major oil spill incidents in the Eastern Mediterranean Levantine Basin between the Republic of Cyprus, the State of Israel, and the Arab Republic of Egypt, a EC project coordinated by REMPEC.

Moreover, the MEDSLIK oil spill model has been used in the framework of dedicated EC-funded projects, for example, the MERSEA-Strand1, MERSEA-IP, MyOcean, MyOcean-2, and MyOcean-FO, promoting the development of the EC

[4] See www.nereids.eu.

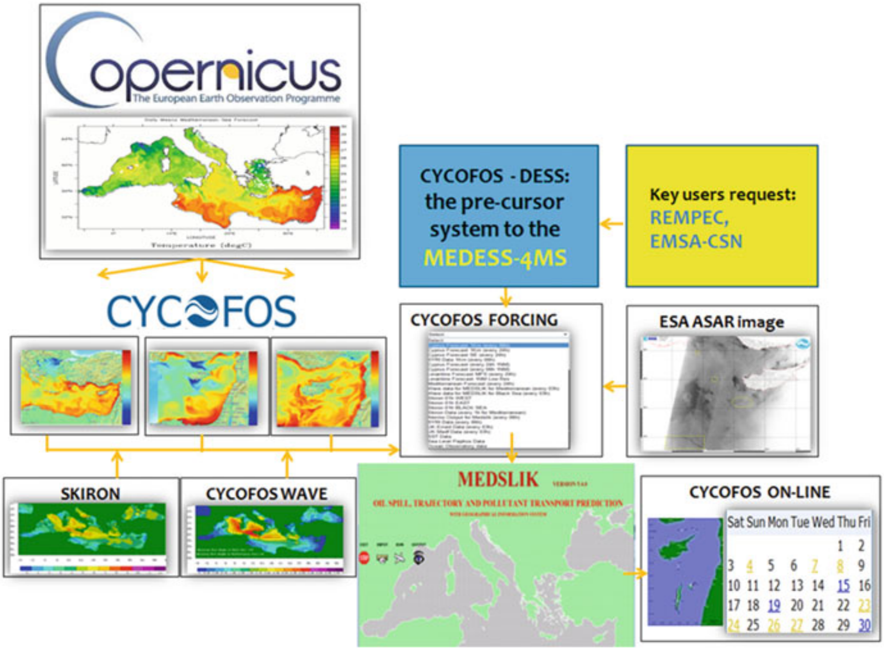

Fig. 6 The MEDSLIK oil spill model uses regional CMEMS MED MFC and the downscaled CYCOFOS met-ocean data and can incorporate emergency warnings from the Mediterranean and European response agencies such as REMPEC and EMSA-CSN. The MEDSLIK oil spill prediction system was used as the precursor service to build the MEDESS-4MS multi-model oil spill prediction service for the entire Mediterranean Sea

CMEMS (Copernicus Marine Environment Monitoring Service), formerly known as the Global Monitoring for Environment and Security (GMES).

The MEDSLIK oil spill model has been implemented in many other EC-funded projects regarding oil spill predictions using the operational ocean forecasts, for example, the MFSTEP, ECOOP, EMODnet Mediterranean Checkpoint, RAOP-MED, and the MEDESS-4MS. At present, MEDSLIK is coupled with CMEMS MED MFC, CYCOFOS, ECMWF, and SKIRON forcing data using the input/output "standards" set in the frame of MEDESS-4MS project (Fig. 6).

The MEDSLIK oil spill model incorporates oil slick at sea surface; evaporation, emulsification, dispersion in water column, adhesion to coast, sedimentation at shallow waters, viscosity changes, oil density, oil thickness, oil slick volume, and the length of the impacted coast are also derived. The oil spill movement is simulated using a Monte Carlo[5] approach. The pollutant is divided into a large number of Lagrangian parcels of equal size. At each time step, each parcel is given

[5]Is a broad class of computational algorithms that rely on random sampling to obtain numerical results that might be deterministic in principle.

a convective and a diffusive displacement. In detail, the oil is considered to have a light evaporative component and a heavy non-evaporative component. Emulsification is also simulated, and the viscosity changes of the oil are computed according to the amount of emulsification and evaporation of the oil. The model simulates slick transport taking into account that the movement of the surface slick is governed by currents, waves (Stokes drift[6]), and wind, while the diffusion of the slick is simulated by a random walk (Monte Carlo) model. The oil may be dispersed into the water column by wave action, while the dispersed oil is moved by currents only. Mechanical spreading of the initial slick is also included. The number of parcels used by the MEDSLIK model to form the oil spill may range from 10,000 up to 500,000, while the water column structure is described by 15 vertical layers which are adjusted to the relevant hydrodynamic/oceanographic forecasts provided with CMEMS, CYCOFOS, or any adapted MEDESS-4MS predictive models.

The MEDSLIK oil spill model prediction length may vary from few hours up to 3 weeks, but by using the "restart" facility of the model oil spill prediction length, it can be extended further depending on the end-user application requirements and the forcing availability.

The operational implementation of the MEDSLIK oil spill model consists of the following modules:

- The setup module for the model domain and required parameters
- The visual interface for input of the spill data
- The run module that performs the simulation
- The visual interface for viewing the output

In parallel, the MEDSLIK oil spill model contains the following features:

- The inclusion of built-in database with 240 different oil types characteristics, provided by REMPEC.
- The switching from coarse- to high-resolution ocean forecasting data when the oil slick passes from a coarse- to a higher-resolution domain.
- The model allows assimilation of oil slick observations, from in situ or aerial, to correct any predictions if needed.
- The effect of deployment of oil booms and/or oil skimmers/dispersants can be examined in order to assist any response measures.
- Continuous or instantaneous oil spills moving or from drifting ships, whose slicks merge, can be modeled together.
- Multiple oil spill predictions can be provided for different locations.
- Backward-backtracking simulations for tracking the source of oil spill pollution.
- The integration with AIS data, upon the availability of this same type of data.
- The simulation of subsurface oil spills at any given water depth, implementing an improved new plume model (Fig. 7).

[6]Is the average velocity of a particle floating at the free sea surface in the direction of wave propagation.

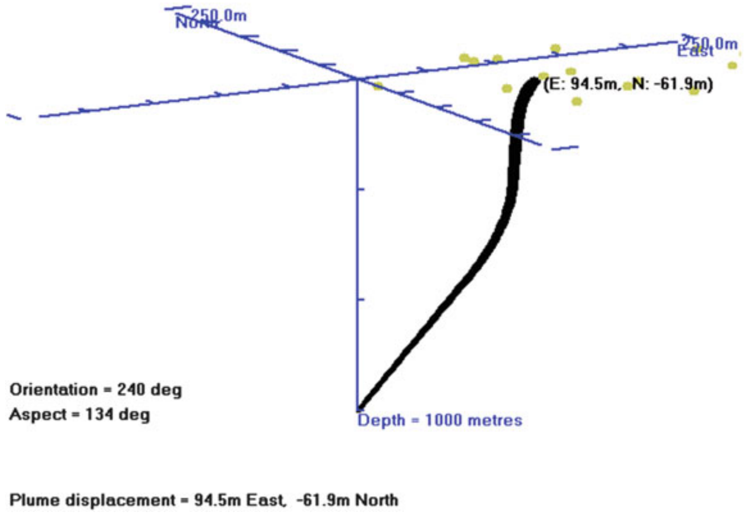

Fig. 7 An example of the horizontal displacement (m) of the oil plume from the MEDSLIK improved oil plume model, with the source of oil leakage at 1,000 m depth

- The coupling with SAR satellite data, any shape of the slick images from EMSA-CSN, as well as with the ESA data (previously from ENVISAT, nowadays from SENTINEL) for forward- and backward-backtracking predictions.
- Includes a simple GIS to allow information on resources.

The MEDESS-4MS standard input/output oil spill prediction format files [27] have been integrated into the MEDSLIK model, where the met-ocean data are in NetCDF files (network Common Data Form). The required atmospheric forcing for the model integration consists of the wind speed and direction. The significant wave height and the wave period are also required to estimate the Strokes drift while the hydrodynamic/oceanographic forcing is defined by the U,V current components at 15 vertical levels, together with the sea surface temperature. Bathymetric data are also required for the model integration.

MEDSLIK was extensively used for the Lebanon oil pollution crisis in the summer 2006 [5, 29]. Similarly, MEDSLIK was used for a smaller oil pollution incident during summer 2013 near the northeastern coastal area of Cyprus. In addition, MEDSLIK is used for operational 24 h forward- and backward-backtracking of oil slick identified by SAR images, either from EMSA CSN dedicated portal or from ESA images. Spanning the period between 2007 and 2012, more than 1,200 possible oil slicks were identified, and oil slick simulations (24 h forward and backward) were carried out with MEDSLIK for each one of these possible oil slicks [11].

Several drifter experiments took place in 2007 in the Eastern Mediterranean Sea to assess the accuracy of the drift component of the MEDSLIK model [30]. The evaluation lasted for more than a month, using various surface drifters (Fig. 8).

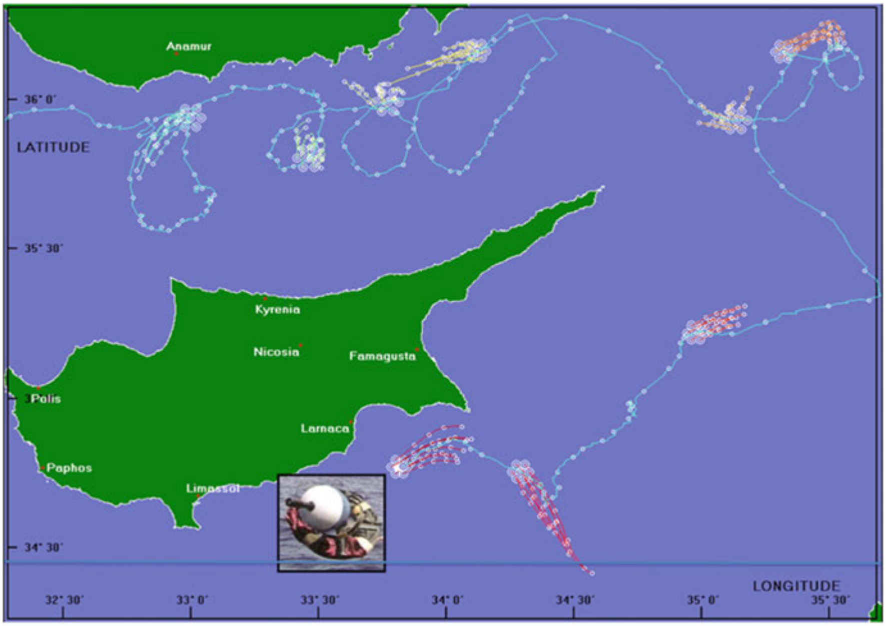

Fig. 8 Example of integrated comparisons between the MEDSLIK multiple virtual floating objects trajectory 24 h predictions and the trajectory of an SVP drifter from February to March 2007, during the ECOOP project. The CYCOFOS and SKIRON forcing data were used in the MEDSLIK models (map after Zodiatis et al. [30])

4.1 The Lebanon Oil Pollution Crisis

A large oil spill occurred in mid-July 2006 at the Jiyeh power plant, located 30 km south of Beirut, Lebanon. The amount of oil spilt was reported as between 15,000 and 20,000 tons, and the type of oil is heavy fuel with an API of about 20. The spill took the form of a continuous leakage of oil from the power plant, starting at 08:00 h on 13 July 2006 [5, 29]. The operational current forecast for mid-July 2006 from the CYCOFOS-Cyprus Coastal Ocean Observing and Forecasting System, which has a resolution of 1 km, showed a northerly flow parallel to and close to the coasts of Lebanon and Syria. Flow velocities were in the range of 20–30 cm/s. It turned out that these features persisted for the next 2 months, apart from the occasional development of eddies behind various headlands. The SKIRON wind forecast showed winds in the vicinity of the spill that varied in direction between southwest and south. This same wind pattern remained steady for most of the ensuing 2 months, with the wind strength varying generally between 2 and 7 m/s.

The oil spill predictions extracted from the MEDSLIK model were consistent with satellite observations (SAR and MODIS): the oil moved northward by the currents and winds, while very large amounts were deposited on the coast adjacent to the Jiyeh power plant and between there and South Beirut. Some of these coastal deposits were subsequently washed back into the water and moved northward. To the north of Beirut, MEDSLIK predicted a significant coastal impact between Beirut and Chekka and both north and south of Tartus, with a relatively smaller coastal impact almost as far north as Latakia (Figs. 9 and 10). These predictions are borne out by the satellite images.

Within 3 days of the start of the incident, due to the high sea surface temperature and moderately strong winds, evaporation of the oil was virtually completed with about 20% of the oil evaporated.

The position of the oil slick after 5 days was predicted by MEDSLIK oil spill model. A large fraction of the oil was driven onto the coast in the immediate neighborhood of the power plant, while some has rounded the headland of South Beirut and had extended to the north of Chekka.

Very heavy concentrations of oil were predicted by MEDSLIK on the coast near the Jiyeh power plant and on the promontory of South Beirut. Moderate concentrations were predicted for the coast between Beirut and Chekka, and extending up to Tartus with some impact almost as far north as Latakia. No oil was predicted north of Latakia. These predictions are consistent with MODIS and SAR images as well as with observation from a United Nations' monitoring mission (Fig. 11).

5 The POSEIDON Oil Spill Model

The POSEIDON OSM is an oil spill model developed by the Hellenic Centre for Marine Research (HCMR) as a standard module of the POSEIDON Operational Oceanography System, implemented and operating in the Greek Seas since 2000. The POSEIDON OSM has been efficiently used in the framework of several European-funded projects concerning the prevention, contingency planning, and preparedness during real oil spill accidents. These projects have been supported by European environmental agencies such as the Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea (REMPEC) and the European Maritime Safety Agency (EMSA).

The POSEIDON OSM has also been used operationally, providing support to the Greek marine authorities during real accidents in 2009, in the North Aegean Sea [31], and also detection services through SAR image analyses. The system has also been used as a forecasting service for the effective management of oil spill incidents in the Greek Seas (ESA funded projects: ROSES, MARCOAST). The POSEIDON OSM has been recently integrated as a standard module of the multi-model Mediterranean Forecasting System implemented during the MEDESS-4MS project [27].

After its first implementation into the POSEIDON system [32], the POSEIDON OSM was further developed and upgraded during several research projects. A major upgrade of the system was completed during the research projects ROSES (Real Time Ocean Services for Environment and Security, 2003–2004) and MARCOAST (Marine and Coastal Environmental Information Services, 2005–2008), funded by the European Space Agency (ESA). These two projects

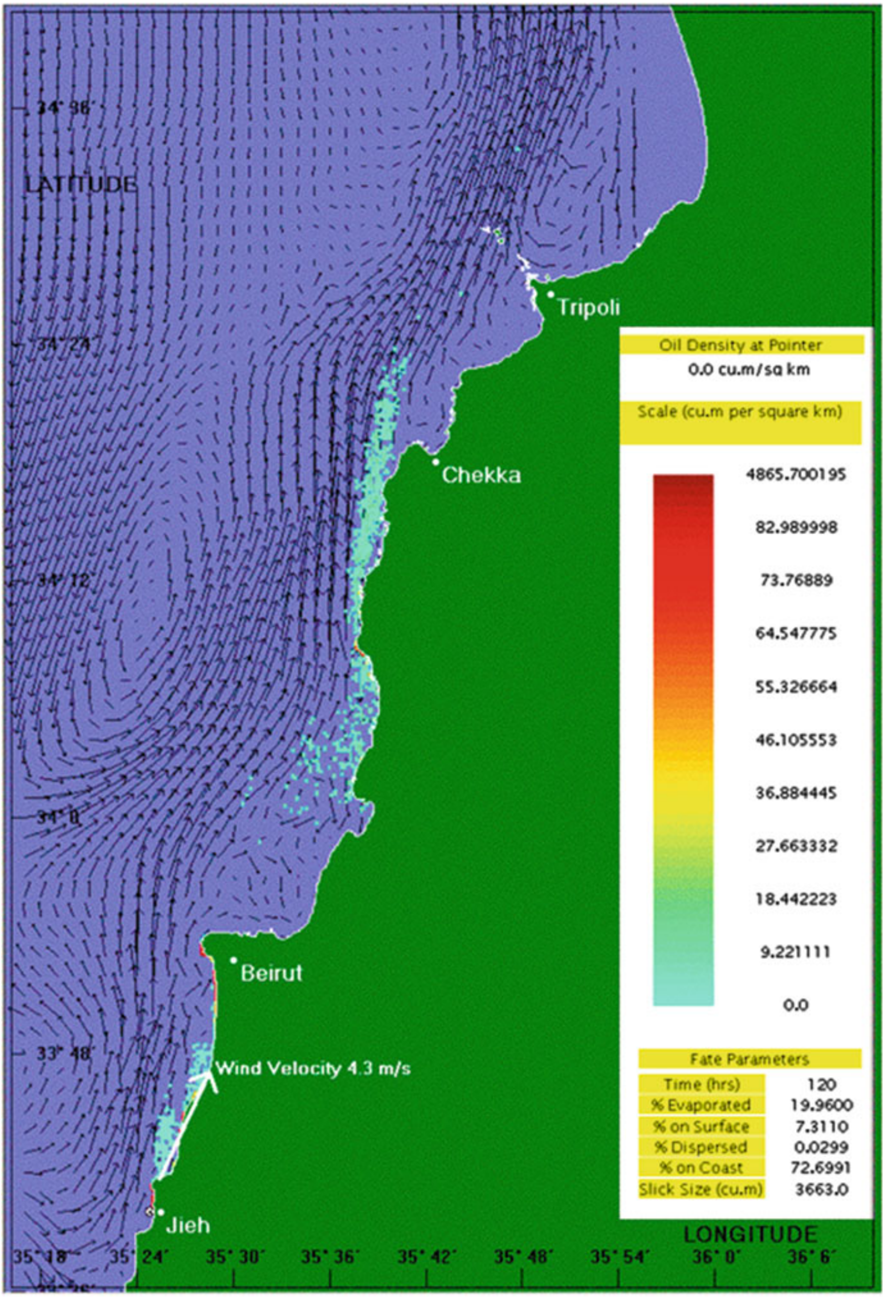

Fig. 9 MEDSLIK predictions for the oil slick 5 days after the onset of the spill (after Lardner et al. [29])

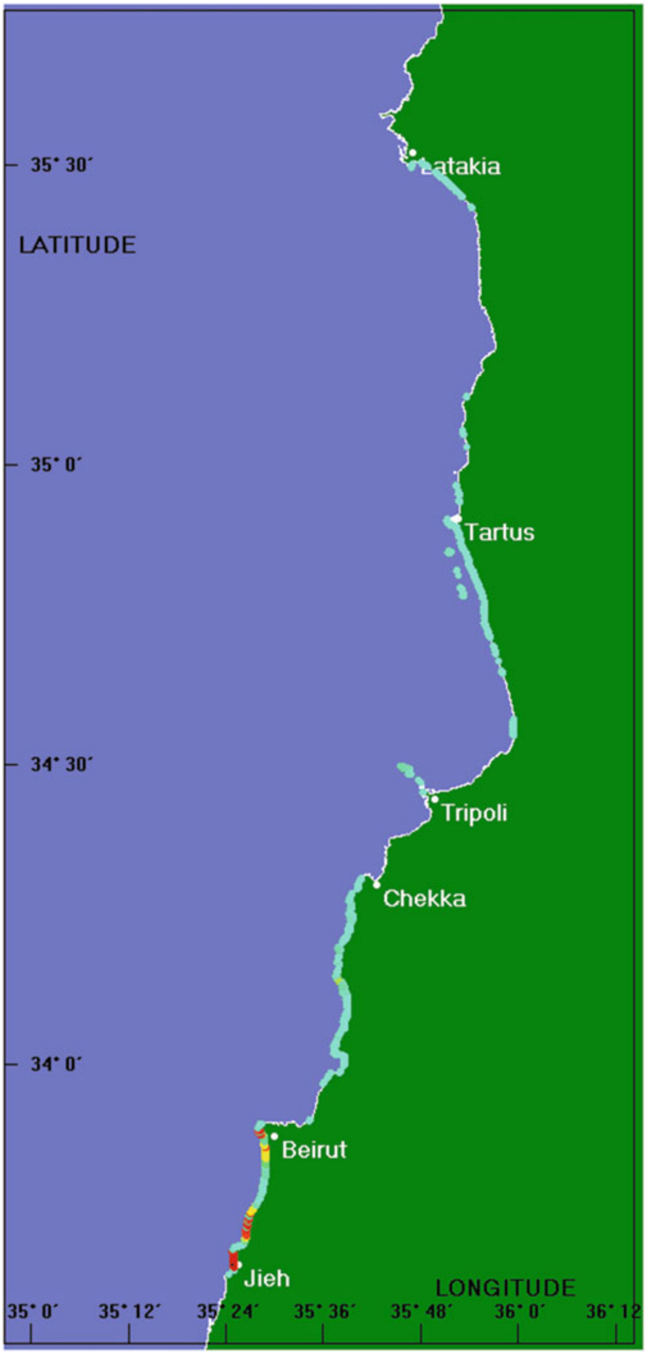

Fig. 10 MEDSLIK predictions of coastal impact 30 days after the onset of the Lebanon spill (after Lardner et al. [29])

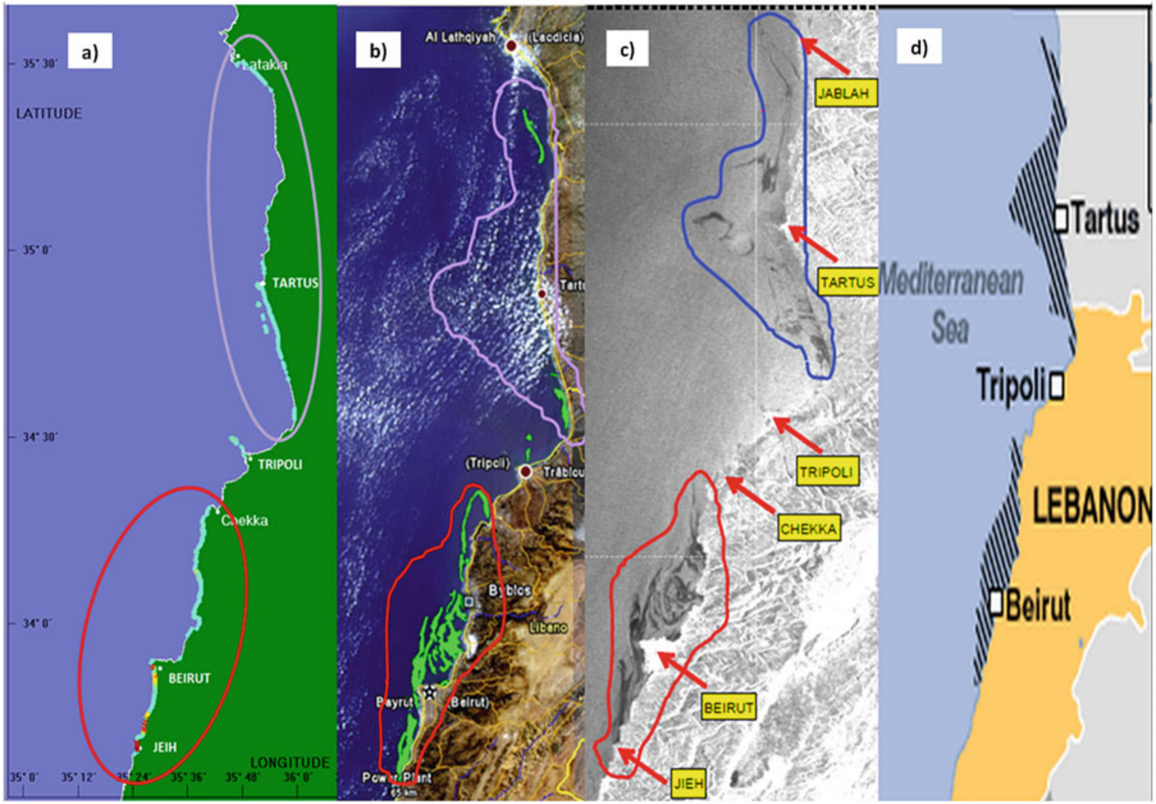

Fig. 11 Intercomparison of oil adhesion to the coast and advection at sea during the Lebanon oil pollution crisis in summer 2006 between: (**a**) oil on coast as modeled by MEDSLIK, (**b**) observed by MODIS, (**c**) observed by SAR, and (**d**) after a United Nations' monitoring mission (maps after Lardner et al. [29] and 'De Dominicis [24])

were part of the European GMES initiative (Global Monitoring for Environment and Security, precursor of the European Copernicus service), which was co-funded by the ESA and EC.

These specific projects were part of the GMES Service Elements (GSE) program, aiming at delivering decision support systems for use by the public and the policymakers, with the capability of acquiring, processing, interpreting, and distributing information related to environment, risk management, and natural resources. The POSEIDON OSM was the forecasting component of the MARCOAST-integrated oil spill service, which was implemented in operational mode during a 3-year period (2006–2008) in the Aegean Sea. This later service was an integration of the oil spill detection processes applied on satellite-based SAR images, together with the forecast of oil spill evolution provided by the POSEIDON oil spill system (Fig. 12). The core user of this service was the Marine Environment Protection Division (MEPD) of the Greek Ministry of Mercantile Marine, which has the responsibility of surveying the Greek Seas. The users received near-real-time (1 h after satellite overpass) synthetic information concerning oil spill detection and relevant forecasts in the Aegean Sea, through a dedicated Web site. Users were also alerted by e-mail/fax/telephone of new information posted to a dedicated Internet site [33].

The POSEIDON OSM was further upgraded into an active element of the European Decision Support System (EuroDeSS) in 2010, as part of the EC-funded ECOOP (European Coastal Sea Operational observing and Forecasting System, 2007–2010) project. This was achieved through the integration of ECOOP standard input and output formats, which extended the systems' interoperability, allowing data exchange and comparison experiments between different numerical models. During the implementation of the Aegean module of DESS, the system was used in operational mode in order to support the Greek marine authorities in their response to a real accident that took place in the North Aegean in 2009 [31].

During the *Mediterranean Decision Support System for Marine Safety* (MEDESS-4MS, 2012–2015) project funded by the MED Program, four different well-established oil spill models (MEDSLIK, POSEIDON-OSM, MOTHY, MEDSLIK-II) were integrated into a combined service running together with high-resolution environmental (meteorological and oceanographic) data from the Copernicus Marine Environment Monitoring Service (CMEMS)[7] and associated national downscaled ocean forecasting systems from the MONGOOS network [27]. Oil slick data from existing monitoring platforms, such as REMPEC and EMSA CleanSeaNet satellite data, were also connected to the MEDESS-4MS service, thus building a complete oil spill response and decision support service.

[7]See www.marine.copernicus.eu.

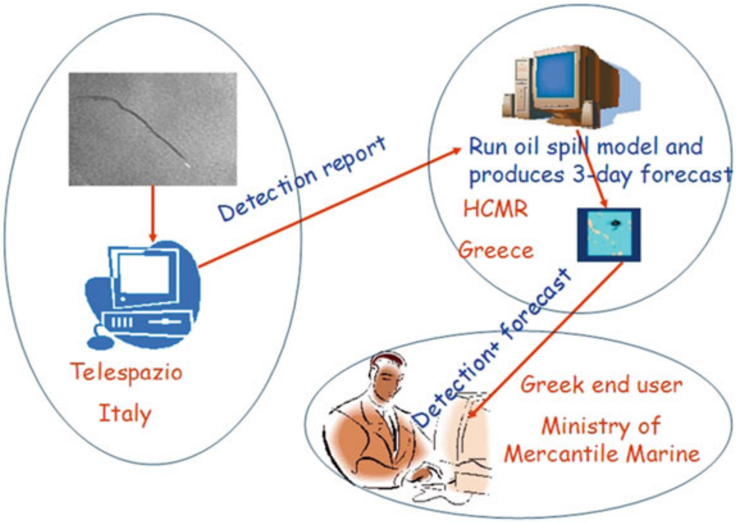

Fig. 12 Schematic representation of the integrated oil spill service in the Aegean Sea between 2006 and 2008

This multi-model oil spill prediction service is helpful to both EU and non-EU members' response agencies and to the key users such as REMPEC and EMSA.

The POSEIDON oil spill model is a fully 3D oil spill model capable of simulating the movement and spreading and aging of oil particles in the 3D space. The whole mass of the oil is represented by a large number of material particles or parcels, each representing a group of oil droplets of like size and composition. The oil transport is described by two modules, the circulation module and the wind-generated wave module. The horizontal displacement caused by advection, and the vertical transport of the oil, are calculated using the output of the oceanographic model. The net current speed caused by linear waves (Stokes drift) is calculated using the wave model output. The horizontal and vertical mixing coefficients of the hydrodynamic model are used to calculate the horizontal and vertical diffusions, while the vertical resolution of the model is tied to the relevant resolution of the hydrodynamic model.

The POSEIDON-OSM is also capable of simulating oil spill weathering transformations in the marine environment such as the evaporation, emulsification, beaching, and sedimentation of oil. The required input information consists of data specifying the event and the oil spill per se: location of the event (Lat/Long), date and time of the event, total volume of the oil released into the sea, number of particles describing the volume, critical density for evaporation and emulsification, retention time (how long an oil particle stays in the beach), evacuation time (instant disposal in the sea or not), and total time of model integration.

In the existing operational implementation of POSEIDON OSM, the model uses atmospheric data from the POSEIDON ETA weather forecasting system [34], wave

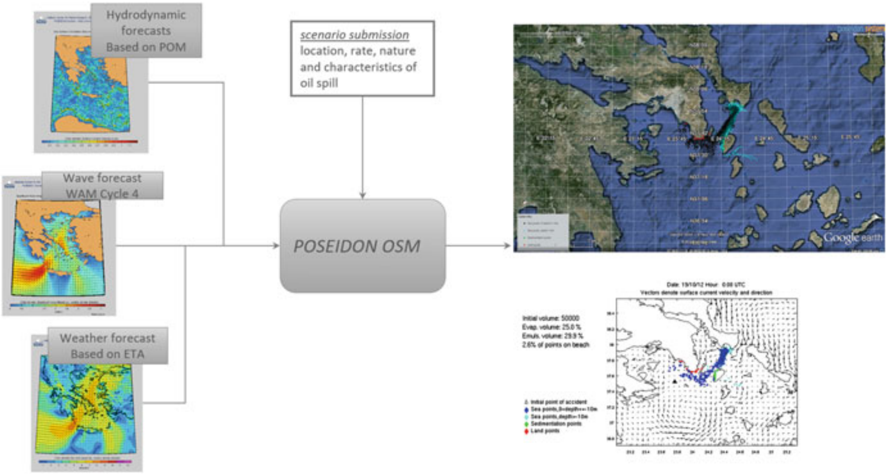

Fig. 13 Schematic representation of the POSEIDON OSM simulation process

data from the POSEIDON WAM Cycle 4 for the Aegean Sea [35], and oceanographic data from the POSEIDON Aegean model [7]. The forecast length extends from few hours up to the present-day availability of the required forcing data (typically 5 days). In Fig. 13, a schematic representation of the POSEIDON OSM simulation process is shown for a hypothetical incident in the Aegean Sea.

The predicted output variables of the model contain the position of each particle in the sea (longitude, latitude, and depth), the evaporated volume of the initial oil, the emulsified volume, the volume remaining on the beach, and the oil volume that reached the sea floor.

Currently, the POSEIDON oil spill model can be triggered through a dedicated Web-based application[8] (see Fig. 14) where the user can specify the parameters of a real or hypothetical event and submit this scenario to the system, receiving the results after a few minutes. There is also the possibility for the user to receive the results in Google Earth format for a more realistic geospatial representation.

5.1 POSEIDON OSM Test Cases

No major oil spill accidental events have occurred in the Greek Seas since the implementation of the POSEIDON OSM in 2000, so that the model could be tested and validated during real-time accidents. Nevertheless, POSEIDON oil spill service has been frequently used as a decision support system under the framework of distinct European projects, as well as to support the Greek marine authorities in the

[8] Available at http://osm.hcmr.gr.

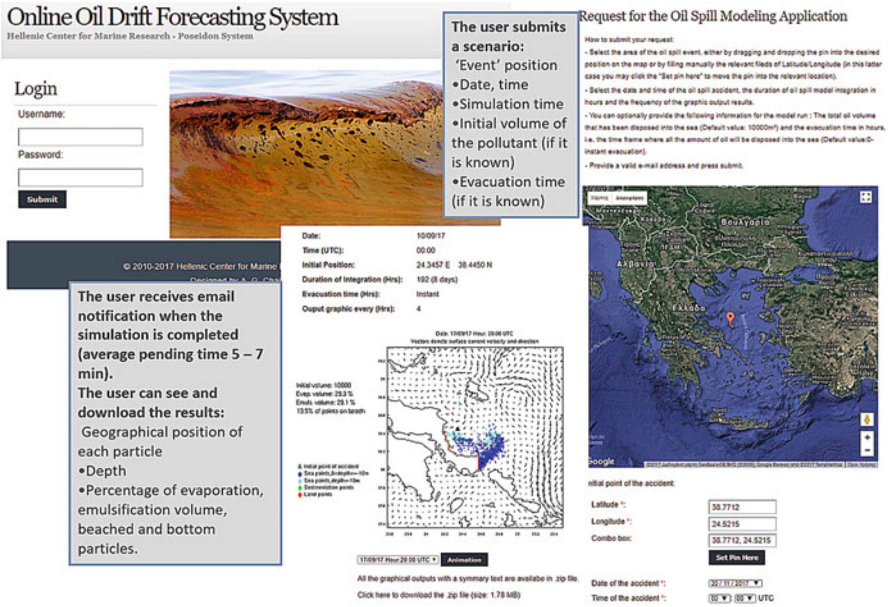

Fig. 14 The POSEIDON OSM Web interface

prevention of pollution in the marine environment during real oil spill and ship collision incidents. A case of a real accident in the North Aegean Sea will be described subsequently, along with some test cases during field experiments completed during the MEDESS-4MS project.

During the implementation of the ECOOP project, the developed Aegean Decision Support System was used in operational mode to support the responsible Greek marine authorities (Ministry of Mercantile Marine, Marine Environment Pollution Division) handling a real accident that took place in the North Aegean area at the end of June 2009 [31].

The accident that alerted the Greek authorities was a collision between two cargo ships in the international waters of the Northeast Aegean Sea during the night of 27 June 2009. Although no significant amount of oil was initially spilled into the sea, the situation remained critical for several days as the two ships were joined together after the collision and they were towed slowly toward the Turkish coasts. The Greek authorities requested (from REMPEC) the activation of the agreement between REMPEC and MONGOOS to assist in preventing and minimizing any possible threat(s) of marine pollution to Greek territorial waters as well as to the Greek islands, resulting from the collision incident.

As a MONGOOS member, the HCMR responded to this request by implementing the new developed Aegean Sea Decision Support System into operational mode. Every day, a complete report with the evolution of the oil spill for the next 2 days was provided to relevant ministries in order to help in planning the possible actions in case of a major release of oil into the sea. For the production of daily forecasting information, the POSEIDON atmospheric and marine background data was converted into the common standard NetCDF format and was then fed into the system, as required by the previously mentioned Aegean DESS specifications. Finally, this alert situation ended without any further events 3 days later – with the safe towing of the two ships onto the Turkish coast.

In the framework of MEDESS-4MS project, two sea field experiments were organized in order to evaluate the performance of the oil spill forecasting service. One of them was conducted in connection with the RAMOGEPol exercise and took place in Portoferraio, north of the Elba Island, between 16 and 17 September 2014. The Italian Ministry of Environment organizes the RAMOGEPol exercise every year in cooperation with relevant authorities in France, Italy, Monaco, and Spain to evaluate the efficiency and organization of each country in the field of preparedness for response to marine pollution from ships.

In September 2014, three OCEANIA Long Range (LR) Buoys, equipped with satellite transmission to track the oil spill at long-range distances, were released by the CEDRE representative from the Italian Coast Guard vessel into an area infused with rice husks, used as pollutant at the hypothetical accident position. The aim of this exercise was to check how efficiently the buoys behave as the pollutant-like substance by showing a similar drift and then to compare their trajectory with the dispersion calculated from the forecasting models. The three buoys remained in the path of the pollutant-like substance throughout the duration of the exercise (6 h), while the POSEIDON OSM was chosen among the other MEDESS-4MS models to simulate the oil dispersion during the exercise. The drift of the satellite transmitting buoys was compared with the drift of the trajectory provided by POSEIDON OSM. Both showed similar southwestward trajectories as illustrated in Fig. 15, and thus it can be assumed that POSEIDON OSM corrected the drift of the rice husks, the pollutant-like substance of the exercise.

6 MEDSLIK-II: A Community Oil Spill Model for the Mediterranean

An oil spill model MEDSLIK-II [12, 24], based on its precursor oil spill model MEDSLIK [11, 36], has been freely available to the scientific community[9] since 2012.

The model is used to predict oil transport and transformation due to complex physical processes occurring at the sea surface. Within the framework of a Lagrangian approach, the oil slick is discretized into constituent particles. Each particle moves due to currents, wind, and waves, whose parameters can be obtained from external basin-scale or subbasin oceanographic and atmospheric models. The oil transformation processes at the surface are calculated by means of bulk formulas

[9]See http://medslikii.bo.ingv.it/.

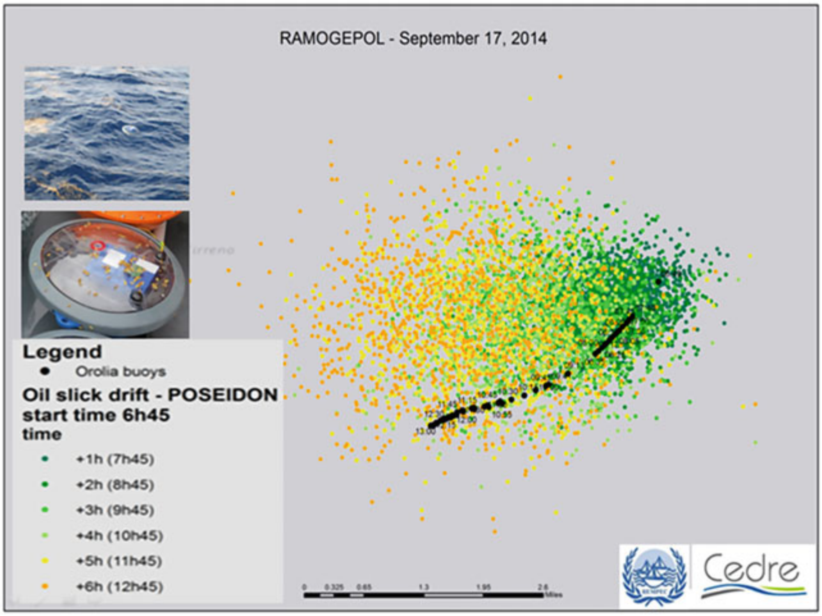

Fig. 15 Map representing the buoys trajectories from 17 September 2014 at 6:45 up to 12:30 compared to the POSEIDON OSM predictions

that describe changes in surface oil volume due to three main processes, known collectively as weathering (evaporation, dispersion, and spreading). The formation of water-in-oil emulsion is also taken into consideration. If oil droplets arrive on the coast, the model is able to simulate the adsorption of droplets into the coastal environment, taking into account the probability that oil may be washed back into the water. As key outputs, MEDSLIK-II provides the oil concentrations at the surface, in the dispersed water-column fraction, and on the coast. Mass balance components of the oil are calculated as a function of time, which allows a time-dependent tracking on the oil weathering.

A scientific consortium was established in November 2012 with the aim of bringing MEDSLIK-II into operation and ensuring its continued, sustainable development and application as a state-of-the-art software suitable for a wide range of users. Currently, the consortium embraces the Istituto Nazionale di Geofisica e Vulcanologia (Italy), the Euro-Mediterranean Center on Climate Change (Italy), the Consiglio Nazionale delle Ricerche – Istituto per lo Studio dell'Ambiente Marino Costiero (Italy), and the MEDSLIK developers from the Oceanography Center at the University of Cyprus (Cyprus) and the Simon Fraser University (Canada), as well as more than 300 active users around the world.

For the period of the consortium activity, MEDSLIK-II has been developed and extensively applied to a wide variety of practical tasks. Primarily, the model's parametric sensitivity was tested, and the accuracy was evaluated against synthetic aperture radar (SAR) and optical satellite images of oil slicks and passive drifter trajectories in different areas of the Mediterranean Sea – including an Algerian case experiment [24].

It was concluded that MEDSLIK-II forecasts largely depend on the spatial-temporal resolution of ocean currents provided by the operational Eulerian models. In addition, key effects on the model were proven for local wind velocity correction and the wave-induced current terms (the Stokes drift velocity). Since then, an empirical JONSWAP wave spectrum computed as a function of wind speed and fetch [37] has been algorithmically incorporated into the model to calculate the Stokes drift components. Recently, MEDSLIK-II was adjusted [38] for the direct use of WaveWatch-III model outputs [39], which seem to be more accurate and computationally efficient than the JONSWAP parameterization.

The new generation of oil spill models requires not only spill forecasts but also the evaluation of uncertainty of such forecasts, which is itself critical for timely, efficient, and cost-effective responses. Uncertainty in the prediction of the oil transport and transformation stems from uncertain environments and sparse data. Due to a large number of parameters that control the oil movement and transformation in MEDSLIK-II, the number of possible uncertainty scenarios is enormous. Currently, MEDSLIK II started to implement both simple and efficient algorithms to quantify uncertainties caused by the initial oil spill conditions [48], ocean currents, and wind [49].

Milestones in MEDSLIK-II research, development, and applications are listed in Table 1.

6.1 *The MEDSLIK II Test Case: The Case of* Costa Concordia

During the *Costa Concordia* emergency, the capabilities of basin-scale, sub-basin, and local relocatable ocean circulation models were tested as the external providers of ocean dynamics data for the MEDSLIK-II oil spill model [40]. On 13 January 2012, only hours after leaving the Italian Port of Civitavecchia, the *Costa Concordia* cruise ship – with more than 4,200 passengers and crew on board – hit a rocky outcrop, ran aground, and rolled onto its side as it sailed off Giglio Island in Italy (Fig. 16). With 2,500 tons of fuel in her tanks, the *Costa Concordia* was immediately considered a high-risk accident in terms of possible oil spills.

The Coast Guard and Civil Protection authorities immediately reacted by triggering off a search and rescue operation and elaborate risk mitigation measures. In case of failure of the debunkering operation, a spillage might have polluted a marine environmental protected area of the Tuscan Archipelago National Park. Every day, starting from the 16th of January and until the fuel unloading operations finished, the MEDSLIK-II model was run to produce forecasts for a possible oil spill sourced from the *Costa Concordia*. Daily bulletins were provided to the Italian Coast Guard Operational Center. Those bulletins presented forecasts of ocean

Table 1 Main steps of MEDSLIK-II progress in research, development, and applications

##	Activity	Date	Mediterranean subbasin if applicable	Reference
1	Oil pollution hindcast during the Lebanon crisis, 2006	2011	Eastern Mediterranean	[5]
2	Publishing in the Internet as an open-source scientific tool	2012		medslikii.bo.ingv.it/
3	Publishing a full MEDSLIK-II description	2013		[12]
4	Parameter tuning and sensitivity analysis against SAR and optical satellite images of oil slicks, Algeria case experiment	2013	Western and eastern	[24]
5	Support of the *Costa Concordia* accidental debunkering and parbuckling	2012, 2013	Western Mediterranean	[40]
6	Testing the multi-model forcing on ocean currents	2014	Western Mediterranean	[40]
7	Improving the representation of beaching in the case of Lebanon crisis	2014	Eastern Mediterranean	[46]
8	Multi-model forcing on the combination of currents, waves, and winds, the MEDESS4MS Serious Game experiment	2014	Western Mediterranean	[38]
9	HPC MEDSLIK-II ensemble simulations for hazard assessment	2015, 2016	Eastern Mediterranean	[47, 48]
10	Algorithms of uncertainty penetration through MEDSLIK-II	2015, 2017		[48, 49]
11	User-oriented Web-based decision support system WITOIL	2016		[48]

currents and wind and oil concentration on an hourly basis. As an oil spill scenario could not be totally discarded, this information would have been crucial for planning the prevention measures of a hypothetical oil spill, thus optimizing the cleaning operations. Similar MEDSLIK-II calculations were carried out during the *Costa Concordia* parbuckling[10] in September 2013 (Fig. 17).

To compute the possible scenarios of fuel leaks, MEDSLIK-II was operationally linked [40] with a suite of ocean circulation models including (1) the basin-scale Mediterranean Forecasting System MFS [41]; two subregional models: (2) the Western Mediterranean WMED [42], (3) the Tyrrhenian Sea TYRR [43]; and (4) the high-resolution Interactive Relocatable Nested Ocean Model (IRENOM). The latter model can be deployed at any local area of the Mediterranean in a very short time as required by the management of emergencies caused by oil spills or contaminant release(s) at sea. The accuracy of the simulations was evaluated during a field experiment with the release of four i-SPHERE drifters in the area of the

[10] Is the righting of a sunken vessel using rotational leverage.

Fig. 16 *Costa Concordia* accident (Photo: Getty). http://www.mirror.co.uk/news/world-news/doomed-costa-concordia-was-carrying-5432140

accident. Being transported by ocean currents, the oil spill following-surface drifters (i-SPHERE) were designed to emulate oil drift at the sea surface [44]. Over the experiment, the highest skill score in the predictions of drifter trajectories was achieved by the IRENOM model with respect to both metrics of the trajectory separation distance and the skill score imposed by [45]. Thus, for the first time, a multi-model approach in oil spill modeling was implemented. Combining multiple oceanographic forcing, it was demonstrated [40] that such an approach could provide a higher degree of confidence than any single forcing alone.

Recently, De Dominicis et al. [38] enhanced the approach above by adding multi-model waves (Stokes drift) and winds. The MEDSLIK-II outputs were validated during a field exercise, called MEDESS4MS Serious Game, in the Elba Island area in May 2014. Satellite images covering the exercise area were acquired on an operational basis. Italian Coast Guard ship was sent to confirm the presence of oil slicks found remotely to the source area. Drifters with different water-following characteristics were deployed into the slick and then monitored over the following days. Oil slick observations (from satellite and ship) and drifter trajectories were then used to evaluate the quality of MEDSLIK-II forecasts (Fig. 18). The authors described the parametric tuning MEDSLIK-II in detail, focusing on uncertainties in underlying physics.

Oil-shoreline interaction, or the so called “beaching,” is an essential part of oil spill impact assessment, as it regards the definition of the location and extent of oiled shorelines, the amount of oil that reaches and stays at the shore, as well as the

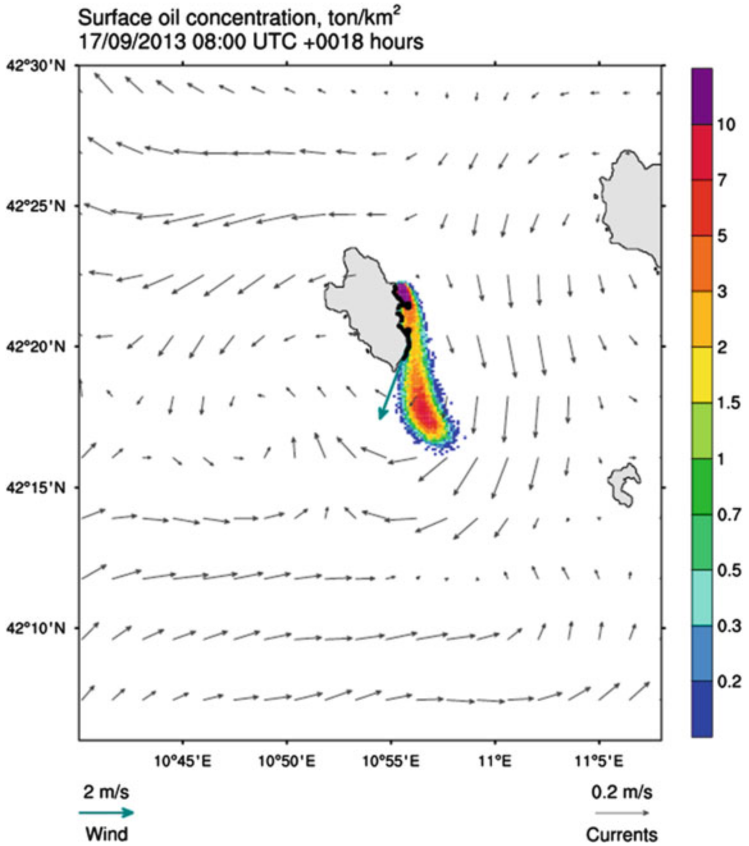

Fig. 17 Example of an oil spill forecast during the *Costa Concordia* parbuckling in September 2013

temporal characteristics of the processes in action. Representing these processes by MEDSLIK-II was efficiently studied for the Lebanon oil spill of 2006 [46].

High-performance computing (HPC) has stimulated ensembles of MEDSLIK-II calculations. An original methodology [47] of oil pollution hazard mapping was developed based on (1) the UNESCO definition of hazard, (2) actual ship traffic distributions provided by the Italian Coast Guard (ITCG), (3) ensemble runs of MEDSLIK-II, and (4) operational analyses from the Mediterranean Forecasting System (MFS) and the European Centre for Medium-Range Weather Forecasts (ECMWF). This methodology (Fig. 19) was applied to operational oil spill events in the southern Adriatic and northern Ionian Seas and relied on statistically confident simulations.

Overall, several hundred thousand MEDSLIK-II simulations were performed during the 2009–2013 time period. The hazard maps obtained (Fig. 20) were considered representative of future events under the assumption that the traffic

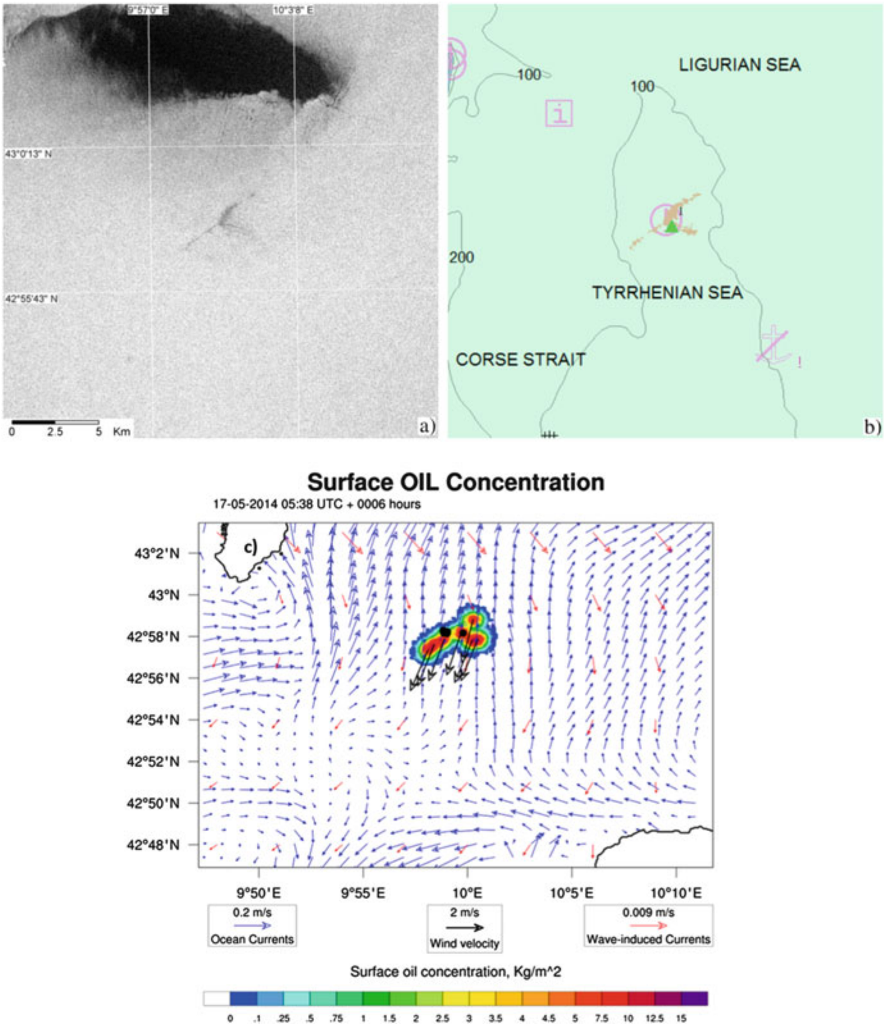

Fig. 18 (**a**) Oil slick remote detection, (**b**) geo-referencing, and (**c**) tracking by MEDSLIK-II during the MEDESS4MS Serious Game, May 2014. In (**c**), black dots depict the observed oil slick locations, while the color patterns indicate the model distribution (maps from De Dominicis et al. [38])

density distribution and the amount of oil operationally spilled were representative of the present state and will follow the estimated tendencies in the future, and the historical database of met-oceanographic conditions contained a realistic sample of possible weather and sea state conditions.

This methodology was also used to quantify the hazards that caused possible accidental oil spills from six (6) oil production platforms situated on the Adriatic shelf [48].

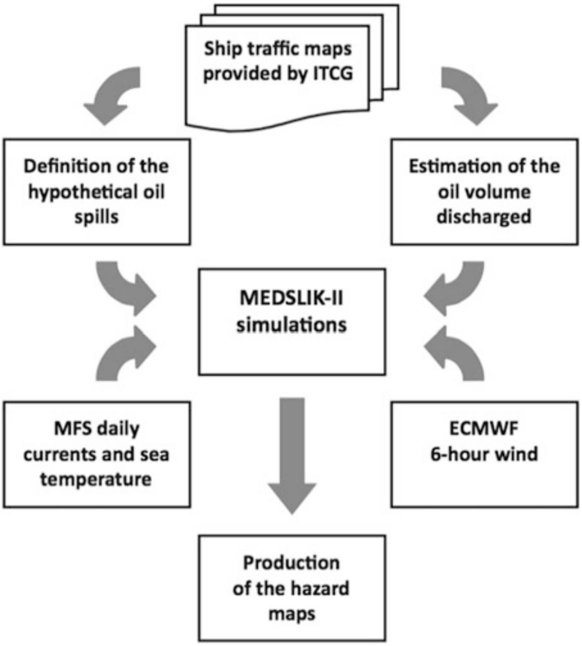

Fig. 19 Schematic diagram of the oil pollution hazard mapping methodology (diagram from Liubartseva et al. [47])

Finally, an innovative fully operational 24/7 Web-based decision support system, WITOIL[11] (Where Is The Oil), has been developed [48]. To compute the oil transport and transformation, WITOIL uses MEDSLIK-II forced by operational met-oceanographic datasets provided by the Copernicus Marine Environment Monitoring Service (CMEMS[12]). Results of the modeling are visualized through Google Maps. The system meets the real-time requirements in terms of performance and dynamic service delivery. Comprehensive computational resources and network bandwidth efficiently support the multiuser regime. The eight-language graphical user interface (Fig. 21) incorporates a great variety of user services, e.g., help and support, tooltips, and video tutorials. A special application for Android is designed to provide mobile access for competent authorities, technical and scientific institutions, and also to citizens.

[11]http://www.witoil.com.

[12]http://marine.copernicus.eu.

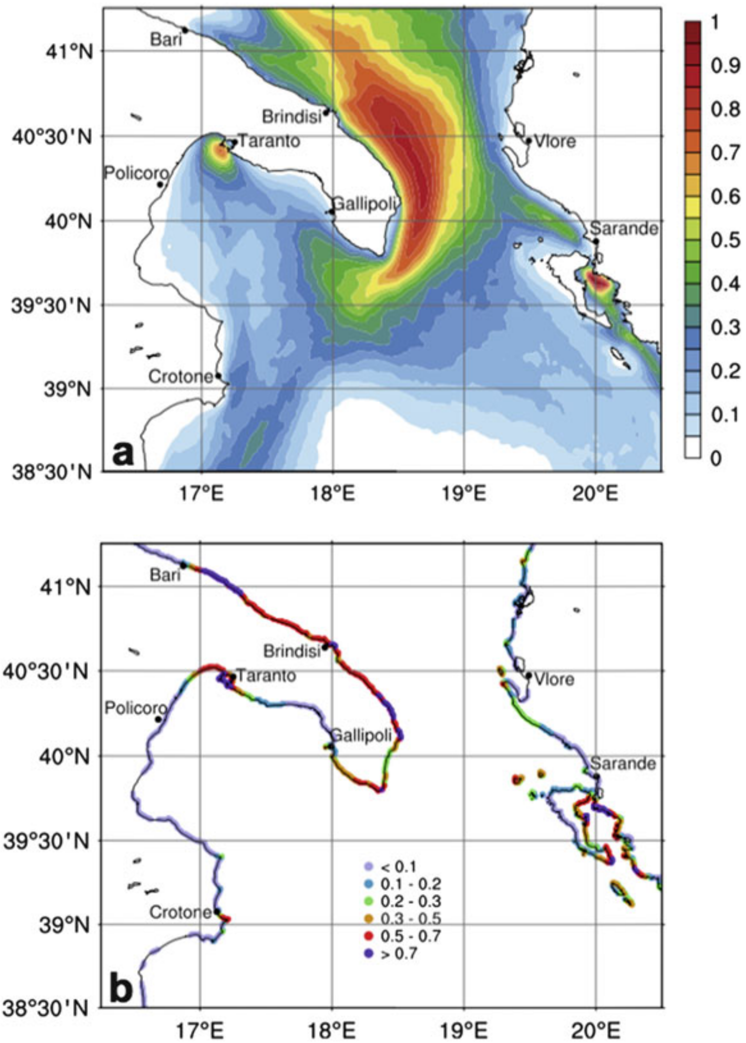

Fig. 20 Averaged 2009–2012 hazard maps in probability terms (**a**) at the sea surface and (**b**) on the coastline, in the Southern Adriatic and Northern Ionian Seas (maps from Liubartseva et al. [47])

7 Oil Spill Risk Mapping

In this chapter, we demonstrated that following the identification of a spill, operational oil spill modeling could support contingency field activities, forecasting the fate of the contaminant. Another way to support emergency management is to use oil spill risk mapping, offering an immediate response (order of few tens of minutes) to where is the likely oil spill movement and the potential impacts on the coasts. Oil spill risk mapping is a young science and it gives a complementary

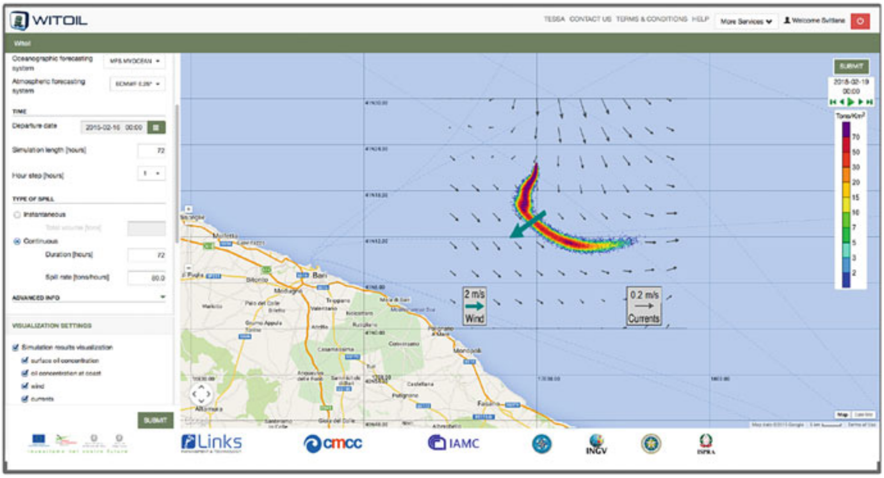

Fig. 21 A screenshot of the WITOIL user interface after the simulation of oil spill forecast (map from Liubartseva et al. [48])

input to operational oil spill forecasting for management of emergencies at sea. Oil spill risk mapping allows also estimating uncertainties and present the oil spill hazard in terms of probability distributions.

The literature on oil spill risk and hazard mapping is vast [47, 50] and suggests that there is no unique concept of risk, vocabulary, and hazard/risk quantification methods within the community. The lack of standards makes comparisons between hazard levels estimates by different studies unfeasible and, therefore, difficult to depict a global oil spill hazard scenario and the threat it might represent to our coast. An attempt to propose a theoretical framework for oil spill risk assessments based on the international standard ISO 31000:2009 and adapted to the specificities of the oil spill problem was presented by Sepp Neves et al. [51] using the IT-OSRA methodology. The core of the IT-OSRA methodology consisted on employing ensemble oil spill simulations to estimate not only the hazard but also its uncertainties.

Sepp Neves et al. [51] performed a case study employing IT-OSRA to the Lebanon summer 2006 oil spill case, in which were proposed nine ensemble members addressing uncertainties/inconsistencies identified in the available accident reports, namely the volume of oil spilled and its density, when the spill started and its donation. Based on the ensemble average of oil concentrations at the model coastal segments, an oil spill hazard map (Fig. 22a) and its uncertainties (Fig. 22b) were produced.

Comparisons between the hazard maps produced by IT-OSRA method (Fig. 22a) along the Lebanon coasts and in situ oil observations during summer 2006 [52] (Fig. 23a) demonstrate that areas with an assigned high hazard level are compatible with most of the areas actually impacted by the oil spill. The hazard estimates, combined with a coastal vulnerability map [53], were used to quantify the risk (Fig. 23b).

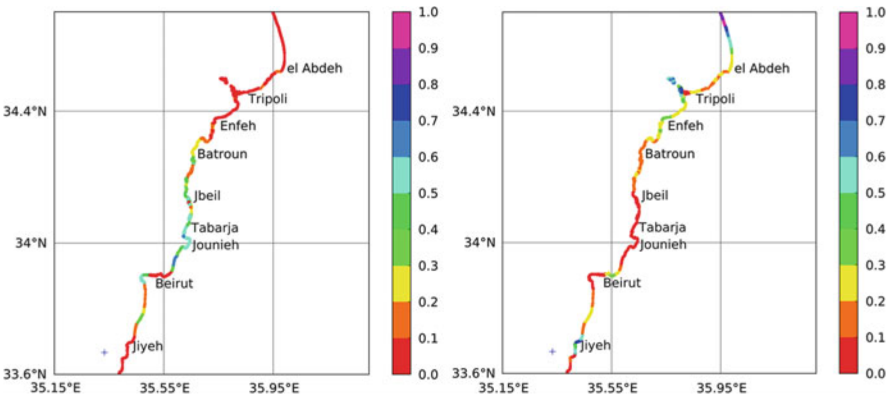

Fig. 22 Oil spill hazard levels (**a**) and its uncertainties (**b**) estimated for the Lebanese coast [51]. For the hazard maps, the values represent the ratio between the ensemble average concentration for a given segment and the maximum value observed in the study area. Similar strategy was used to compute the uncertainties, here the ratio between the local coefficient of variation and the maximum value observed in the study area. (Figures reproduced from Sepp Neves et al. [51])

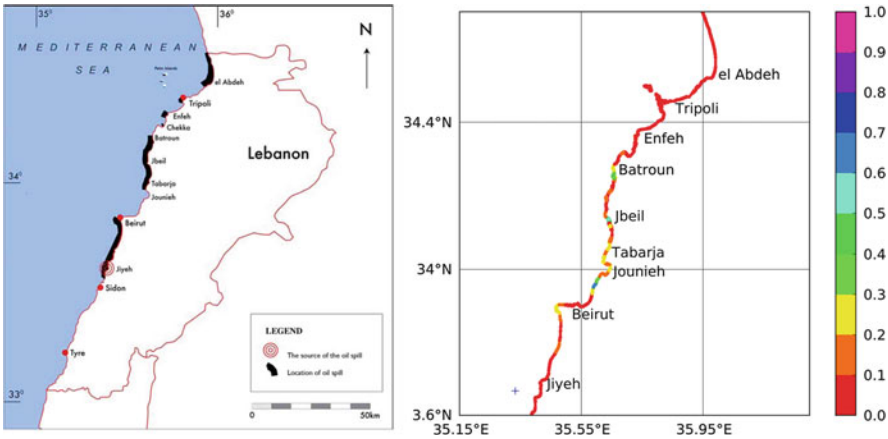

Fig. 23 In situ oil observations extracted from Green Line Association (2007) (**a**) and the final map of oil spill risk for the Lebanese coast (**b**) reproduced from Sepp Neves et al. [51]. Areas with a risk index closer to 1 are exposed to higher levels of risk than areas with risk values closer to 0

Moreover, the IT-OSRA method has been applied to a larger scale experiment in Southern Portugal [54] using again a multi-model, multi-physics approach. In this work, it is shown that computing averages of coastal concentrations supposing a Gaussian distribution of the oil at the coasts might not fit the numerical simulation data and work is underway to quantify the statistical nature of the coastal oil spill distributions.

8 Conclusions

Despite political, social, and economical differences and problems among the riparian countries of the Eastern Mediterranean Sea, all of them have ratified the protocols of the *Barcelona Convention* and are members of REMPEC. In parallel, EC member states in the region and those associated to the EC are members of EMSA-CSN. Within the frame of these organizations, the national response agencies in the Eastern Mediterranean – through the coordination actions of REMPEC and EMSA-CSN – cooperate to mitigate and fight major oil pollution incidents at the national, subregional, and regional scales.

Within the first trilateral cooperation between Cyprus, the Arab Republic of Egypt, and the State of Israel for preparedness and response to major oil spill accidents in the Eastern Mediterranean Sea, in the late 1990s, oil spill modeling was set at the forefront of any contingency plans. During the Lebanon oil pollution of summer 2006, the operational predictions of the advection of the spilled oil, completed by the MEDSLIK model, provided to neighboring nations a reliable daily picture of the extent of the oil slick and of the affected coastline, for the entire period of the pollution crisis.

Nowadays, the enlargement of the Suez Canal and the expansion of oil/gas exploration and production in the Levantine Basin render oil spill modeling prediction to be a pre-requirement to contingency plans and a necessary tool to the response agencies.

With the development and implementation of operational oceanography in the Mediterranean Sea, as one of the CMEMS regions, and the provision of satellite SAR images detecting possible oil slicks, it is now possible to obtain near-real-time operational oil spill modeling predictions. The successful implementation of EC projects addressing the oil spill modeling in the Mediterranean, particularly MEDESS-4MS, resulted in the harmonization of the input/output information for the needs of oil spill modeling, setting in this way the "basic standards" for oil spill models in the region.

In summary, the cooperation between the oceanographic community of MONGOOS and REMPEC as well as with EMSA-CSN in oil spill modeling issues offered the possibility to all the nations of the region to have access to oil spill predictions, even if at national level they have not yet been established. This is also the case for nations that cannot access a well-established oil spill model, such as MEDSLIK, POSEIDON-OSM, or MEDSLIK-II. Following this same path, the MONGOOS initiative to set the MEDSLIK II as a community oil spill model is aiming to attract young scientists to attain further improvements and developments in oil spill modeling.

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Numerical Modeling of Oil Pollution in the Western Mediterranean Sea

Andrea Cucco and Pierre Daniel

Abstract In this chapter we analyze the last 15 years of oil spill numerical modeling applications in the Western Mediterranean Sea. From the literature, around 17 different scientific papers were published between the years 2001–2016 with a focus on this same subject, but using different ocean and atmospheric forecasting systems as well as of weathering and particle tracking models. All the considered applications were classified in relation to the type of adopted numerical tools, the covered area, and the system accessibility. Besides this analysis, a summary of the major oil pollution events that occurred in the Western Mediterranean subbasins and a comparison between the number and the types of numerical applications carried out for each Mediterranean subregions (western, central, and eastern) were reported. Finally, two different operational systems characterized by different numerical tools, the one developed at Meteo-France, the MOTHY system, and the one developed at the Italian National Research Council, the BOOM system, were described in details along with their applications to two pollution events, the *Haven* accident that occurred in 1991 in the Ligurian Sea and the Porto Torres spill event in 2011 in the Strait of Bonifacio. With this chapter, the authors want also to provide an overview on the capability of the Western Mediterranean countries to respond in case of oil pollution events by adopting oil spill trajectory forecasting systems.

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Contents

1 Introduction

The Mediterranean Sea can be divided into two main regions: the Western Mediterranean (WM) and the Eastern Mediterranean (EM) separated by the Sicilian Channel generally identified as the Central Mediterranean (CM) (see Fig. 1). The Western Mediterranean region can be subdivided in turn into different basins: the Tyrrhenian Sea, the Ligurian Sea, the Algero-Provencal Basin, the Balearic Sea, and the Alboran Sea. The number of subdivisions is not univocal depending on the selected spatial scale and on the national context.

The WM is characterized by maximum water depths up to 3,700 m and is directly connected to the Atlantic Ocean through the Strait of Gibraltar (GS). The surface thermohaline circulation is anticlockwise with the Atlantic Waters (AW) entering through the GS, generating the Western Alboran Gyre and the

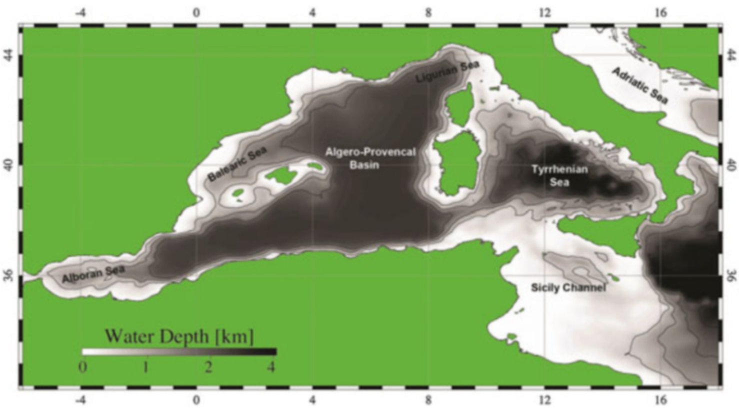

Fig. 1 Geometry, bathymetry, and subdivision of the Western Mediterranean Sea

Eastern Alboran Gyre in the Alboran Sea and the Algerian Current along the African coastline. The AW entering the WM give rise to the Modified Atlantic Waters (MAW) which flow partially into the eastern regions through the Sicilian Channel and partially into the Tyrrhenian Sea generating a coastally trapped current moving northward. The northward flow converges to the Ligurian Sea to generate the Ligurian-Provencal or Northern Current which carries the MAW along the northern WM up to the Balearic Sea [1]. The inner parts of the WM subbasins are characterized by periodic and temporary mesoscale features generated by the baroclinic instabilities of the main thermohaline coastal flows. The WM is characterized by weak tides, around few cm [2], and by the seasonal occurrence of intense atmospheric phenomena generated by the periodical passage of cyclonic structure which lead to the formation of the three main wind regimes in the area: the mistral from northwest, the libeccio from southwest, and the sirocco from southeast [3].

The WM subregions are characterized by the highest species diversities among the other basins [4]. Contemporary, these regions are the areas with most frequent overlapping between high biodiversity and high threats. In 2008, the Marine Protected Areas (MPA) with national or international designation in the Western and Central Mediterranean Sea were 40, accounting for 42.6% of the total number of MPA in the whole basin, which were 92, and covering a total surface of about 100,000 km^2 with 160 km^2 of them characterized by special restriction rules (e.g., no-take zones) [5]. In 2012, the total number of MPA increased to 170, with 87 located in the western regions and most of them in the Algero-Provencal Basin and in the Balearic Sea (see Fig. 2 [6]). Despite the many efforts for a regional scale conservation planning, the Mediterranean MPA cover only 4.24% of the total basin surface which increase to the 5.26% if including both the Natura 2000 sites and the regulated fishing zones [6].

The risk of oil pollution in the Mediterranean Sea is very high due to the number of oil extraction and refinement sites along the basin coasts [7]. In the Mediterranean region the major importers are Spain (net oil import 1.5 million bbl/d in 2003), Italy (net oil import 1.71 million bbl/d in 2003), and Greece (net oil import 400,838 bbl/d in 2002) [8]. According to the Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea (REMPEC), the Mediterranean Sea is Europe's main oil routes with about 350 million tons of oil and refined products annually transported, which cover about the 20% of the total world traffic [9].

Maritime activities in the western subbasins are intense if compared with the other subbasins. The highest vessel densities are found on the routes connecting the Strait of Gibraltar to the eastern regions and on the routes connecting the northern African ports to the European ports [4]. Along the coasts of the western subbasins, more than 17 major oil ports and 15 refineries are found especially along the Italian and Spanish coasts [10]. As an example, only for Italian ports facing the western subbasins, the total quantity of crude oil handled during the 2007 was estimated to be around 80 million tons [10].

While accidental pollution rarely occurs within the Mediterranean waters with three major accidents (large spills $>$ 700 tons) that occurred from 1967: the *Haven* case in the Ligurian Sea in 1991, the *Irenes Serenade* case in the Aegean Sea in

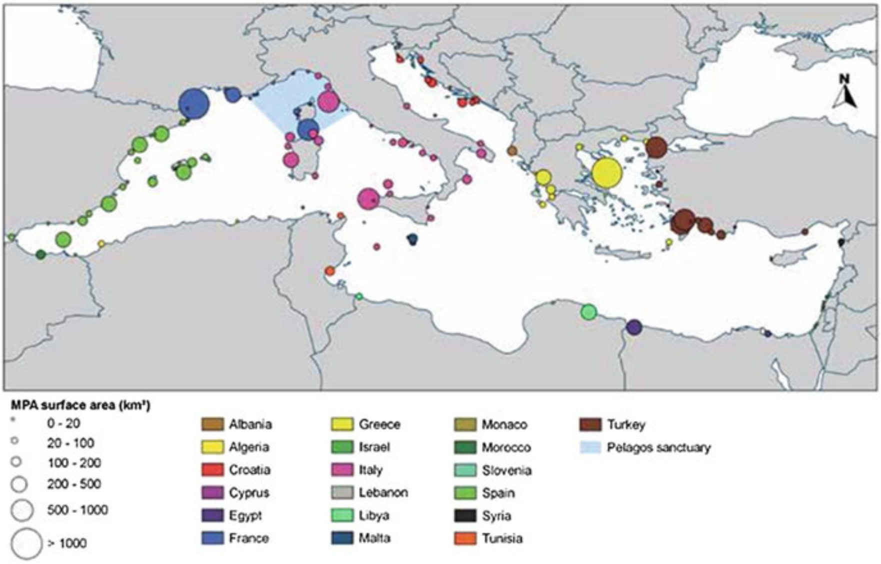

Fig. 2 Distribution of MPA in the Mediterranean Sea in 2012 (Figure extracted from Gabrié et al. [6])

1980, and the Lebanon spill in 2006 [11], operational pollution is a common practice, representing the main source of marine pollution from ships. Illicit sources due to ship routine operations, as degassing, deballasting, and other actions involving the voluntary discharge of oil residues, in violation of MARPOL 73/78 Annex I, have been estimated to cause as much as eight times the yearly amount of oil pollution as accidental spills [12].

The oil spilled into the WM waters during the decade 2000–2009 has been estimated to be around 4,200 tons. Considering the other regions, the Eastern Mediterranean accounts for two-thirds of the total quantity spilled during this decade, with about 20,000 tons. Nevertheless If the Lebanese spill of 2006 is taken out of this calculation, the Western Mediterranean, the Central Mediterranean (the Sicilian Channel), and the Eastern Mediterranean spilled roughly the same quantities (between 4,000 and 6,000 tons), while less than 100 tons was spilled in the Adriatic Sea, according to REMPEC.

From satellite Synthetic Aperture Radar (SAR) images collected during the period 1999–2004, the high densities of oil spill in the western regions were found in the Ligurian Sea and the northern Tyrrhenian Sea and along the main traffic routes off the African coastlines. A total of 9,299 possible oil spills were detected which interested a rough area of about 15,533 square degrees and with peaks in summer due to the intensification of maritime activities (see Fig. 3 [13]).

The satellite monitoring by SAR is, potentially, an effective tool to discourage the illegal practice of oil discharge [14]. Nevertheless, in Mediterranean regions, due to the high density of maritime traffic, its efficiency is not ensured

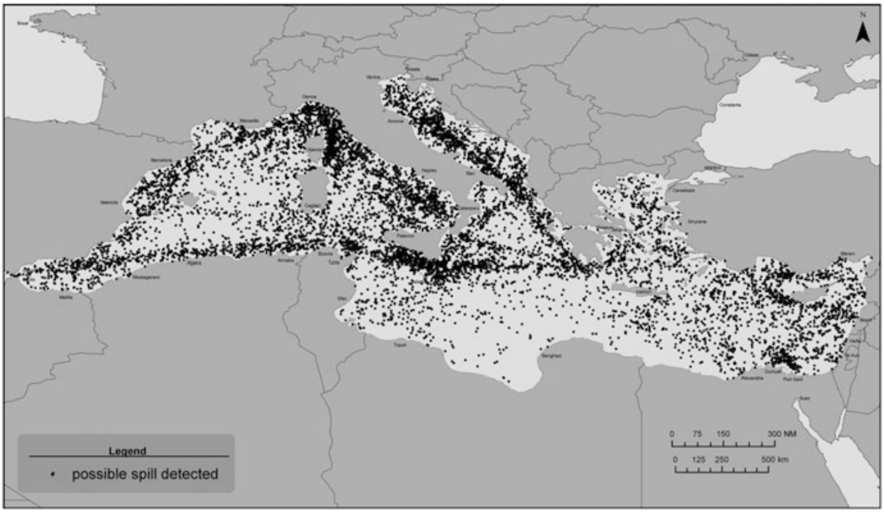

Fig. 3 Possible oil spills detected in the Mediterranean Sea during the period 1999–2004 (Figure extracted from Ferraro et al. [13])

[15]. Therefore, along with these surveillance systems, specific tools supporting the management of the pollution events once individuated are needed. In fact, as worldwide recommended, response plan must include, besides the continuously monitoring of the sea surface, specific systems based on operational ocean, and meteorological models to routinely provide information on surface ocean dynamics [16]. These operational tools, capable of predicting ocean and weather conditions as well as oil spill trajectories, allow decision-makers to promptly respond to environmental crises.

These systems are generally constituted by three different numerical components: an ocean and wave model (OM), an atmospheric model (AM), and a particle trajectory and oil weathering module (OSM). The three components are generally uncoupled, with OM and AM implemented for specific regions and daily providing the input data to the OSM which is constituted by a Particle Tracking Module (PTM) and a Oil Weathering Module (OWM) needed to simulate the advection and diffusion of the spilled oil as well as its biochemical transformation. The input data provided by the OM and AM to the OSM include surface currents, sea surface temperatures, main wave parameters, wind speeds and direction, and air temperatures. These operational systems guarantee a forecasting time lag varying between 3 and 5 days with a spatial coverage spanning from basin scale, whole Mediterranean Sea, to local scale, less than 1 km and often are equipped with a graphical user interface (GUI) to facilitate the usage for non-expert users.

This chapter is organized as follows: A list of the main oil pollution events that occurred in the WM is detailed in Sect. 2; an overview of the major research program focused on oil spill modeling in the WM and a review of the main numerical applications carried out within the last decades are reported in Sect. 2;

in Sects. 3 and 4 the description of two different prediction systems developed for the WM regions, the MOTHY [17] and the BOOM [18, 19], respectively, and their applications to real events are reported. Finally the concluding remarks are included in Sect. 5.

2 Main Oil Pollution Incidents in the Western Mediterranean Sea

During the last years, several oil spill events generated by maritime accidents occurred in the Western Mediterranean waters. A detailed description of the main pollution events that occurred during the last 50 years is reported in the following:

- On January 11 1978, the *Pavlos V* was traveling from Wilhelmshaven (Germany) to Milazzo (Italy) when a fire broke out in the machine room and spread throughout the entire vessel. The severely damaged tanker finally sank off the port of Trapani (Sicily). About 1.5 tons of fuel oil were spilled into the sea.
- The Cypriot tanker *Haven*, a 313 m long oil tanker, caught fire and suffered a series of explosions on April 11 1991 while at anchor seven miles off the coast of Genoa (Italy). The vessel was carrying approximately 144,000 tons of crude oil, and it is estimated that over 50,000 tons of fresh and partially burnt oil were spilled into the Ligurian Sea. Despite considerable pollution response operations at sea, oil slicks drifted westward, thus hitting various parts of the Ligurian coast and then reaching the French Riviera as far as Hyeres. This caused the worst oil pollution incident ever in the Mediterranean Sea.
- On October 21 1991, on its way from Ashdod (Israel) to Rouen (France), the bulk carrier *Erato* encountered very bad weather conditions and ran into difficulty. It sank off Algeria with a cargo of 25,894 tons of phosphate. During this accident, 500 tons of bunker fuel was discharged at sea.
- On January 20 1996, the cargo vessel *Kaptan Manolis I* suffered a leak while sailing off Cap Bon (Tunisia). The ship sank with its cargo of 5,000 tons of phosphates and 104 tons of bunker oil.
- On May 6 1999, during a loading operation onto the oil tanker *Enalios Thetis*, 55,650 liters of crude oil were spilt into the sea at Sarroch oil terminal (south of Sardinia, Italy). About 13 km of the shoreline were polluted due to the oil spill.
- On September 8 2000, the bulk carrier *Eurobulker IV* ploughed into rocks while attempting to enter the port of Portovesme (Sardinia, Italy). The vessel was carrying 17,000 tons of coal, 35 tons of diesel oil, and 170 tons of bunker fuel. The hull was considerably damaged by the rocks and 60 tons of bunker fuel leaked out. In spite of difficult conditions at sea, booms were deployed to protect the coastal zone. Several response vessels were also sent on-site.
- On August 12 2007, a collision occurred near the coast of Gibraltar between a double-hulled oil tanker and the bulk carrier *New Flame* which resulted in the sinking of the latter. As the accident happened in relatively shallow water, the

vessel subsequently settled on the bottom with bow submerged at a depth of 30 m and part of its decks above water. In the weeks following the collision, 780 m^3 of fuel were successfully removed from the vessel. No oil slick was detected on the sea surface during the operation.

- On January 10 2011 during the operation of oil transfer from a ship tanker at the offshore pipe station in front of the harbor of Porto Torres in the Strait of Bonifacio (Sardinia, Italy), about 50 m^3 of heavy crude oil were released into the sea. The oil drifted eastward beaching along a wide trait of the coast.

3 Oil Spill Modeling in the Western Mediterranean Sea: A Review

In recent years, several initiatives funded by both National and EU Research Programs were carried out to improve the effectiveness of decision-making processes in case of oil spill pollution in the Mediterranean Sea.

Two main projects were funded by the EU Commission throughout the MED Program: the TOSCA project, acronym for "Tracking Oil Spills and Coastal Awareness network" (http://www.tosca-med.eu/), and the MEDESS-4MS project, acronym for "Mediterranean Decision Support System for Marine Safety" (http://www.medess4ms.eu/). TOSCA and MEDESS-4MS were complementary to each other, with the first one mainly emphasizing the observational component, constituted by coastal high-frequency radars and on Lagrangian drifters, and the latter focused on the development and application of operational systems based on numerical modeling for predicting the fate of spilled oil. Both projects included partners from both western and eastern side of the Mediterranean with the ambition of supporting, with observational networks and operational forecasting systems, the management of oil spill pollution for the whole basin.

Similar programs were also funded by the National Research Programs of the main Mediterranean countries with the scope of improving the management of oil pollution in specific areas of the Mediterranean Sea (e.g., national waters, Mediterranean subbasins, or specific coastal areas).

As a result of all these initiatives, many European institutions, local agencies, and research centers currently host operational systems that provide short-term predictions of oil spill fate and dispersion as a support for managing oil pollution emergencies in the Western Mediterranean waters. All these operational systems have been developed within the last 15 years and constitute the final results, and the applicative aspects of decades of research activities carried out to develop specific numerical tools suitable for the Mediterranean environment.

Between 2001 and 2016 more than 40 different numerical tools and applications were reported and described in the scientific literature. The relative distribution of the oil spill modeling applications among the three main Mediterranean regions is analyzed. In terms of number of published papers, most of the efforts were focused on the numerical applications at basin scale or on study cases located in the eastern [20–31] and western subbasins [16, 18, 19, 32–45]. Only few and more recent applications involved case studies located in the central areas of the Mediterranean Basin, e.g., Sicilian Channel [15, 46, 47], and in the Adriatic Sea [48, 49].

At first sight, the discrepancies in the abundances of the numerical applications in the different areas could be related to the differences between the quantities of spilled oil in the considered regions. This could justify the higher number of applications for the WM and EM and the lower number for the Adriatic Sea. An exception is the Sicilian Channel, which, as reported by REMPEC [9], suffered similar amount of spilled oil of the WM and EM areas but with a lower number of reported numerical investigations.

An alternative explanation could be found considering the perception of the risk of oil pollution due to the past events. For both the WM and EM, in the last decades there have been disastrous accidents with important oil discharge events, as reported in previous section. This probably generated a higher sensibility to this type of risk for these areas. A confirmation of this assumption is the timing of the first applications, which for the WM and EM regions occurred after the major accidents.

The role of the risk perception in promoting the implementation of prevention tools is evident also for the Sicilian Channel and Adriatic Sea regions. For such areas, even if no major accidents occurred during the last decades, the perception of the risk from oil pollutions increased in the last years after the *Deepwater Horizon* disaster that occurred in 2010 in the Gulf of Mexico. This is particularly true for the Sicilian Channel where oil and gas drilling activities are frequent and the numerical applications have been carried out only in the last years and mainly focused on oil spill events from oil platforms.

In the Western Mediterranean region, during the last years, as reported from the literature, the applications of oil spill models and the implementation of operational forecasting systems have been homogeneous in time. In Table 1, a synthesis of the main applications carried out between 2001 and 2016 is reported. Along with the references, each system is described in terms of spatial scale and resolution of the adopted OM, type of OSM detailing if computing or not both the oil trajectories with a PTM, and the oil degradation processes by means of an OWM. Finally the presence of GUI allowing a non-expert user to interact with the system is evidenced.

Most of the applications were at subbasin scale with a focus on specific areas of the WM. The adopted OM, based on 3D hydrodynamic numerical models, were applied with a resolution ranging between 15 km and 1 km. Nesting procedures were used to provide open boundary conditions from already existing oceanographic forecasting systems based on state-of-the-art ocean and wave model applied to the whole Mediterranean (e.g., MFS, [50], Mercator Ocean [51]). Typical examples of applications (see [27, 32, 34, 42–45]) use a set of different OM and nesting procedures to simulate the current fields in selected areas of the WM with a spatial resolution up to 1 km.

Table 1 Oil spill modeling in the Western Mediterranean Sea, numerical features

NUM. APP. from literature	SYS. acronym	OM spatial scale	OM spatial res.	OSM type	GUI
Daniel et al. [32, 34]	MOTHY	Subbasin, WM CM EM	9–0.5 km	PTM + OWM	Yes
Jordi et al. [16]	–	Local area, Southern WM	15–0.01 km	PTM + OWM	Yes
Periáñez [33, 35, 36, 38, 39]	GISPART	Subbasin, Alboran Sea	3–1 km	PTM + OWM	Yes
Jorda et al. [37]	CAMCAT	Subbasin, Southern WM	1.5 km	PTM + OWM	Yes
Mestres et al. [40]	–	Local area, Southern WM	0.04 km	PTM	–
Cucco et al. [18, 19] and Olita et al. [41]	BOOM	Local area, Central WM	5–0.05 km	PTM + OWM	Yes
De Dominicis et al. [42]	MEDSLIK	Subbasin, Northern WM	6.5–2.2 km	PTM + OWM	Yes
Janeiro et al. [43]	–	Subbasin, Tyrrhenian Sea	1.5 km	PTM + OWM	–
Sayol et al. [44]	–	Subbasin, Southern WM	1.8 km	PTM + OWM	–
De Dominicis et al. [52]	MEDSLIK	Subbasin, Tyrrhenian Sea	10–1.2 km	PTM + OWM	Yes

In these cases the adopted OSM included both the PTM and the WM and were generally constituted by stand-alone numerical tools such as MEDSLIK-II [52], MOTHY [17], and GNOME [53]. Most of these applications were carried out to reproduce hypothetic scenarios of oil pollution or to reproduce the paths followed by released drifters in specific areas. Numerical experiments were carried out in the Tuscany Archipelagos in the Tyrrhenian Sea [43, 44], in the Gulf of Lion, in the Ligurian Sea [32, 34, 45], and in the Balearic Sea [37, 44].

Similar in terms of spatial scale and resolution but different for the simplification of the adopted OM are the set of applications carried out by [36, 38, 39] to simulate hypothetic oil pollution scenarios in the Strait of Gibraltar and the Alboran Sea.

In some specific applications, the OM were implemented and applied to local areas with spatial resolution of the order of 0.01 km with the aim of reproducing the wave and current field as an input to specific OSM tool. An example is the system developed and applied by [16] which used a hierarchy of OM and nesting procedures to reproduce hypothetic oil spill in the Bay of Palma. Other examples are the applications carried by [18, 19, 41] in the Strait of Bonifacio between Corsica (France) and Sardinia (Italy), which implemented a high-resolution OM and specific nesting procedures to simulate both synthetic pollution scenarios and real oil spill events that occurred in the area.

Finally, the application of [40] reproduced hypothetic oil spill scenarios in the Tarragona harbor in the Balearic Sea, by means of high-resolution hydrodynamic model coupled with particle tracking module and forced by synthetic open boundary conditions.

In the following section a detailed description of two different oil spill modeling applications and operational systems are reported: the MOTHY oil spill model and its application to the *Haven* accident that occurred in 1991 in the Ligurian Sea and the Bonifacio Oil Spill Model (BOOM) and its application to the Porto Torres discharge event that occurred in 2010 in the Strait of Bonifacio.

4 The MOTHY Operational System

MOTHY is a drift model implemented by Météo-France [17]. The system is operated since 1994 on demands of the French authorities for support of the oil spill fighting operations and on demands of the Maritime Rescue Co-ordination Centres for support of the search and rescue operations.

A meteorologist on duty in the marine forecast section at Météo-France is able to run the model around the clock. About 800 interventions each year are conducted with an averaged time response of 30 min. The system can be used worldwide. About a quarter of the requests concern the Mediterranean Sea.

MOTHY has been extensively used for the Erika and the Prestige incidents in the Atlantic Ocean. In the Mediterranean Sea, two major incidents (*Haven*, 1991, and *Lyria*, 1993; see Sect. 2) were revisited [31, 33]. No major accidents in French waters have taken place since the system is in place. About 50 oil drifts are performed each year in this area for small-scale pollution.

MOTHY oil spill model is one of the three versions of the drift system (the two others are for containers and search and rescue targets). Currently the mixed layer is computed using a combination of a shallow water model driven by the wind and the atmospheric pressure, coupled with an analytical turbulent viscosity model, so as to represent vertical current shear, and a background current provided by an oceanic model (MERCATOR or MFS). A continuous profile from surface to bottom describes the water column.

An extensive drifter experiment took place in 2007 in the Western Mediterranean Sea to assess the accuracy of drift models [54, 55]. The evaluation lasted for 2 months and included several drift, atmospheric, and ocean models. The main conclusions were that models perform relatively well along the coast, while the performance decreases in the open ocean, such as the Balearic Sea and in the open Mediterranean, where a number of mesoscale or sub-mesoscale eddies are not properly located in ocean models.

MOTHY system consists of four modules: a setup module to specify the model domain and parameters the atmospheric and oceanic forcings, and the pollutant description; a run module that performs the simulation; a visual interface for viewing the outputs; and a broadcast interface to send the results (several formats are available) to the end user (website, e-mail, fax).

4.1 The Haven Accident Test Case

The accident of the tanker *Haven* in April 1991 occurred 3 years before the MOTHY system was established. This accident was later used to verify the suitability of the MOTHY system to properly reproduce the drift of the oil slicks.

There is some uncertainty on the quantities of oil that drift on the sea surface. At the time of the accident, 144,000 tons of heavy Iranian crude oil and 1,223 tons of fuel oil and diesel were present on board. The total amount of hydrocarbons that burned during the 70 h following the first explosion was estimated at about 100,000 tons, while 3,000 tons were still trapped inside the wreck. The rest of the cargo was dispersed by the Liguro-Provencal Current and the winds mainly west-southwesterly. Once spilled at sea, the oil products were exposed to a series of physical and chemical processes that determined their fate at sea. Some of the spilled oil was collected directly from the sea surface, some was washed ashore, another part spread out from the intervention area, and the remaining part sunk.

In an oil drift model, environment data (wind and currents) are critical to accurately forecast the drift of the oil. At the time of the *Haven* accident, wind forecasts from atmospheric model were available. At Meteo-France, the limited area grid-point weather prediction model PERIDOT provided forecasts on a 35 km grid mesh (today the AROME model provides forecast on a 1.3 km grid mesh). In 1991, the operational oceanography systems did not exist yet. The surface current data came from scattered observations or inaccurate climatology. At the beginning of the 2000s, the combination of progress in Earth observation by satellites and drift buoys on the one hand and assimilation of the resulting data for 3D numerical modeling on the other led to the birth of a new scientific discipline: operational oceanography.

These new sources of data provide a more accurate picture of the surface currents and enable to revisit the *Haven* accident with regard of the oil drift. The MOTHY system was then used to reproduce the drift of the oil slicks of the *Haven* accident, using these new data. The drift of the slicks within the Liguro-Provencal Current and the coastal pollution of the French Riviera are more precisely reproduced as depicted in Fig. 4.

5 The Bonifacio Oil Spill Operational Mode

The Strait of Bonifacio is located between the islands of Sardinia and Corsica and separates two distinct Mediterranean subbasins, the Tyrrhenean Sea and the Sardinian Sea (see Fig. 5, upper panel). This area hosts two marine national parks, one Italian and one French, and is part of the International Sanctuary for the Protection of Marine Mammals. In contrast with this environmental relevance, maritime accidents have been occurring during the years with consequences on the marine life due to adverse impact of pollutants, such as hydrocarbons.

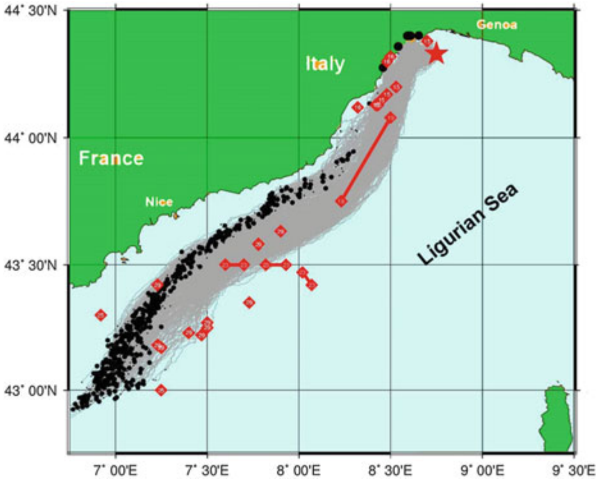

Fig. 4 Oil slick trajectories computed by MOTHY for a 2-week forecast run using MERCATOR currents. *Red star* represents the Haven accident location, *red diamonds* the observations, *black dots* the final position of the slick forecasted by MOTHY, and *gray lines* the computed trajectories (Figure extracted from Daniel et al. [32])

In order to facilitate the rapid planning and coordination of operations by the marine authorities to tackle pollution during oil spill emergencies in the Strait of Bonifacio, an operational forecasting system was developed under the framework of a project named "SOS – Bocche di Bonifacio" funded by the Italian Ministry for Environment.

The system, named BOOM, the acronym for Bonifacio Oil Spill Operational Model, is composed by a hierarchy of different numerical models and facilities to provide a prognostic tool for managing the oil spill emergencies in coastal waters.

The core of the BOOM is composed by a set of finite element numerical models, including a three-dimensional coupled hydrodynamic and wind wave model (SHYFEM, [56]), a PTM, and an OWM [18]. SHYFEM was adopted to reproduce the wind, tide, and thermohaline surface water circulation in the Strait of Bonifacio. The model domain was discretized by an unstructured mesh composed by 33,563 nodes and 64,292 triangular elements (see Fig. 5, lower panel) with a spatial resolution varying between a few km to 50 m. SHYFEM resolves the shallow water equations integrated over each layer in their formulations with water levels and transports.

The influence of the offshore water circulation was taken into account throughout a nesting procedure with a regional open ocean forecasting system, the WMED [57], which covers the Western Mediterranean area with a full three-dimensional implementation of the Princeton Ocean Model [58]. Surface boundary conditions were provided by the high-resolution meteorological forecasting system SKIRON [59]. The simulation of the oil trajectories and oil mass degradation was carried out using the PTM and an OWM coupled off-line with the hydrodynamic model. The system was validated through the comparison with experimental data consisting of surface current and transport data collected during several oceanographic campaigns carried out in the Strait area.

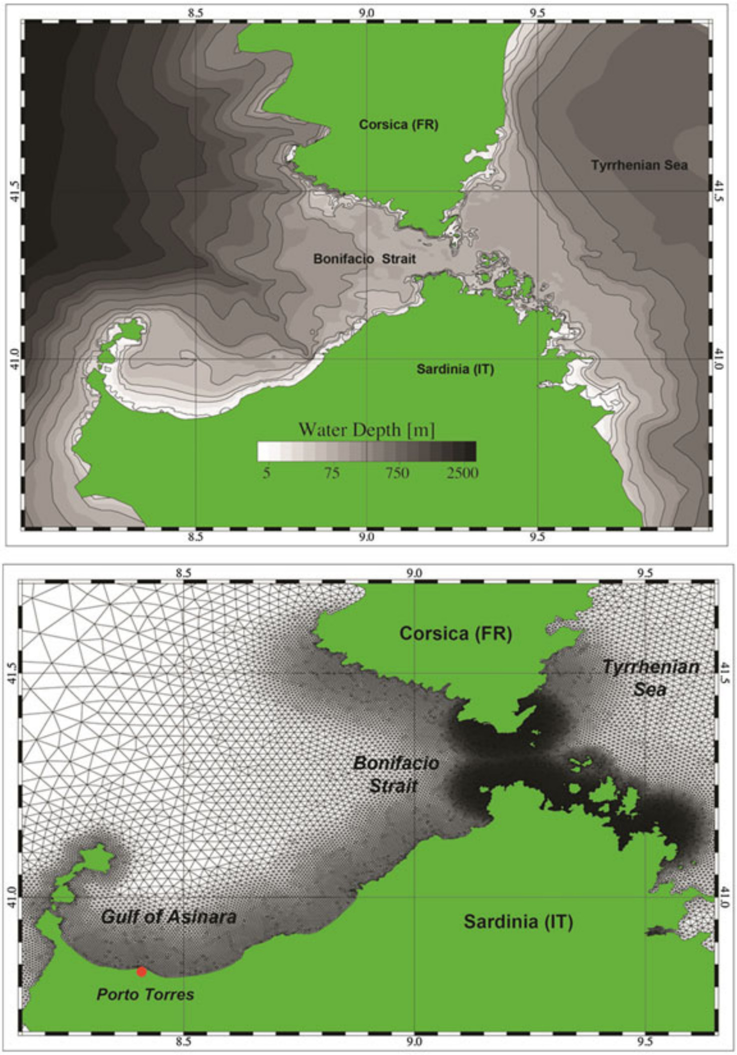

Fig. 5 Geometry and bathymetry of the Strait of Bonifacio area (*upper panel*) and zoom of the unstructured mesh used as BOOM numerical domain (*lower panel*)

BOOM is fully operational since the end of 2010 and provides daily and operational a 3-day forecast of surface water circulation and wave fields for the Strait of Bonifacio and Gulf of Asinara. A GUI allows a non-expert user to interact with the system by setting up scenarios, running simulations, and analyzing the produced consequences of an oil spill within a time lag of 72 h both in the past (backward simulations) and in the future (forward simulations) [60]. Besides the operational usage, the system has been also adopted to evaluate the risk induced by a hypothetical impact of hydrocarbons in the coastal areas of the Strait [41] and to provide a set of scenario analysis as a support to the pollution emergency operations plan of the coast guard [19].

5.1 The Porto Torres Oil Spill Test Case

The BOOM has been used operationally in early January 2011 during the accidental pollution event that occurred in the harbor of Porto Torres in the western side of the Strait of Bonifacio (see Sect. 2).

During the operation of oil transfer from a ship tanker at the offshore pipe station in front of Porto Torres, about 50 m^3 of heavy crude oil were released into the sea. The oil spilled out for about 18 h starting from January 10 2011 at 10:18 p.m. The slick drifted eastward for 5 days interesting the coast for more than 20 km from the accident location. On January 17, 7 days after the accident, an oil slick was individuated in the coastal waters at the entrance of the Strait of Bonifacio (see Fig. 6, upper panel).

The local authority run the BOOM system in backward mode to verify the connection between the oil slick and the Porto Torres accident in order to exclude any other sources of spills in the area (e.g., tanks cleaning bilge waters). The simulation results revealed that the source of the oil slick was the accident site. Samples of floating oil were then collected and analyzed certifying its origin from the Porto Torres event confirming therefore the BOOM results.

Subsequently, a set of hindcast simulations were carried out to verify the system capability in reproducing the fate of the oil spill in forward mode. A 10-day simulation run was performed using atmospheric field and open boundary data produced by SKIRON and by WMED. The model reproduced with accuracy the most probable trajectories followed by the spilled oil during the whole period. This was confirmed by the predicted position of the oil particles beached on the coast, which mainly corresponded to the areas impacted by the pollutants during the event (Fig. 6, lower panel). Furthermore, the system simulated the presence of oil particles on water at the entrance of the Strait after 7 days from the released time at accident location, in agreement with both the experimental evidence and with the results obtained from the operational backward run (Fig. 6, lower panel).

6 Concluding Remarks

Eight countries facing at the Western Mediterranean Sea characterized by different political, social, and economic condition: Spain, Gibraltar (UK), France, Monaco, Italy, Tunisia, Algeria, and Morocco. All are parties to the Barcelona Convention and most of them are EU nations; nevertheless, the cooperation and the coordination actions necessary to prevent and to manage oil pollution emergencies at regional scale need to be improved. Following the example of the RAMOGEPOL

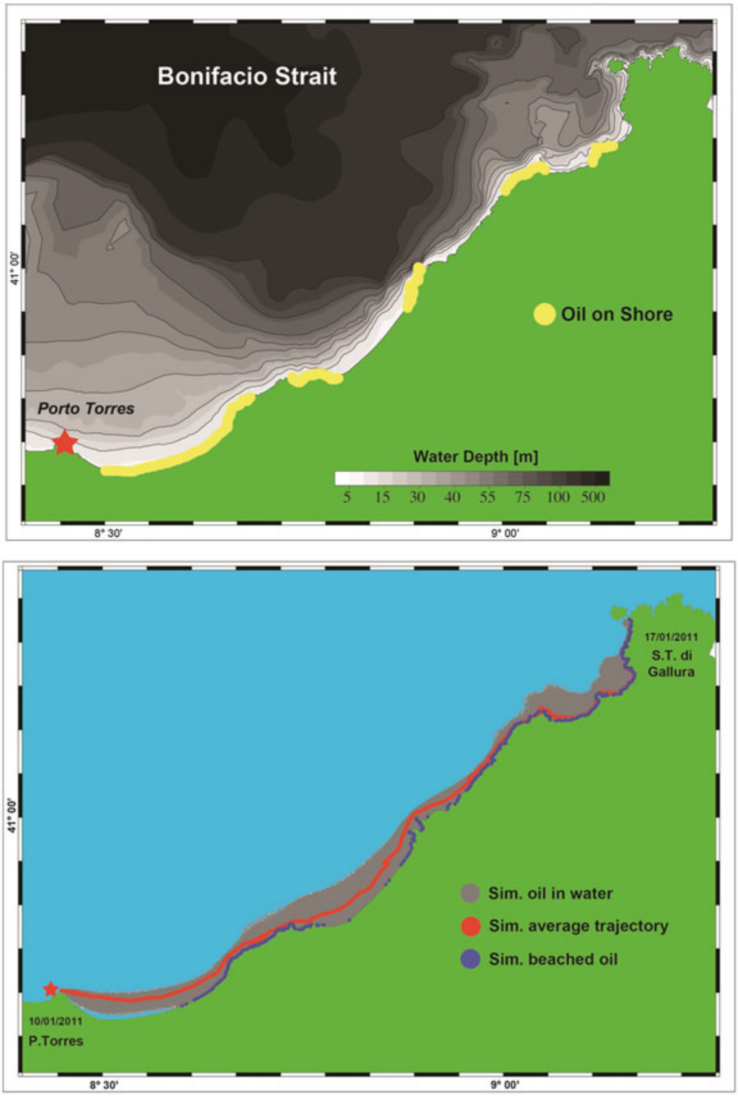

Fig. 6 Map of the area interested by the accident of Porto Torres that occurred in January 2011 (*upper panel*) and the hindcast simulation results (*lower panel*). *Upper panel*: *red star* indicates the accident location; in *yellow*, the coastal areas hit by the oil spill after the release. *Lower panel*: *red lines* indicate the average trajectory followed by the simulated particles; *gray points* indicate the position of particles during the whole simulated period; in *blue*, the coastal areas hit by the oil spill after the release as predicted by the model results (Data extracted from Cucco et al. [19])

Plan between Italy, France, and Monaco, promoted by REMPEC [9], which organize yearly anti-pollution exercises including oil drift forecast, further active bi- or trilateral cooperation agreements among borderers of WM countries should be promoted in the WM region to guarantee an effective response action in case of transnational pollution events.

While operational oceanography and numerical modeling techniques are widely considered as essential tools to face at oil pollution emergencies at sea, their usage is not homogeneously widespread among the WM countries. Most of the numerical applications that have been analyzed in this chapter were carried out and implemented by Research Institutions and Agencies within EU countries and often with a focus on their national waters. As a consequence, from the literature, most of the coastal sea areas of the southern WM, facing at sea traits with a high density of maritime traffic, have not been specifically considered as study site for numerical modeling applications. Of course, many of the oceanographic and oil spill operational systems currently active at Mediterranean basin and subbasin scales (e.g., MOTHY and MEDSLIK) are capable to provide a support in case oil spill events occurring in such areas. Nevertheless, the lack of specific applications and the consequent absence of direct experiences on the forecasting assessments for the local ocean dynamics can be an obstacle to the improvement of the pollution response capability for such areas.

A further effort should be made to both assess cooperation statements between WM borderer countries in order to successfully respond in case of oil spill pollution events at subregional scale and to improve the already existing state-of-the-art operational systems based on off-line oil spill models (e.g., MOTHY and MEDSLIK) by coupling them with forecasting systems able to provide reliable predictions of the main atmospheric and ocean dynamics at different spatial scales (e.g., ocean model based on unstructured mesh as SHYFEM) in order to properly respond in case of pollution events involving both the open sea and the coastal waters.

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Projects on Oil Spill Response in the Mediterranean Sea

George Zodiatis and George Kirkos

Abstract The Mediterranean Sea is an almost landlocked sea which constitutes just 0.7% of the global water surface. The intense shipping traffic and the recent boom of Oil and Gas exploration activities constitutes the Mediterranean amongst the seas facing the highest risk from oil spills in the world. The Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea (REMPEC) and the oil spill response activities of the European Maritime Safety Agency (EMSA) spearhead a variety of initiatives to protect the Mediterranean against oil related pollution. The European Union has also funded a significant number of projects to support the oil spill response capacity and capabilities in the Mediterranean region focusing mainly on three pillars: monitoring of marine operations and detecting oil spills, developing oil spill dispersion models, strengthening the capacity of oil spill response authorities and developing innovative oil spill combating technologies. The successful implementation of such projects has significantly contributed to the protection of a valuable and sensitive ecosystem such as the Mediterranean Sea.

Keywords Eastern Mediterranean, Environmental impact, Legislation, oil spill, Oil spill response, Pollution, Satellite monitoring, oil spill modelling

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Contents

1 Introduction

The Mediterranean Sea is currently amongst the seas facing the highest risk from oil spills in the world. This risk comes largely due to the large number of shipping operations taking place within its waters and coasts; it is worth mentioning that more than 30% of all international sea-borne trade by volume originates from or directed to Mediterranean ports or passing through its waters, and nearly 25% of the world's sea-transported oil transits the Mediterranean Sea. Moreover, it is estimated that 2,000 merchant vessels of over 100 tons are at sea at any moment, with a total of 200,000 crossing the Mediterranean annually. This over activity of marine/ shipping related operations has a seriously consequence to the Mediterranean Sea. The Mediterranean Sea constitutes 0.7% of the global water surface and it receives 17% of global marine oil pollution [1]. More specifically, it is estimated that every year between 100,000 and 150,000 tons of crude oil are deliberately released into the sea from shipping activities.

Nowadays, the risk of a big scale oil spill incident is greater than ever due to the deployment of a series of offshore installations across the Mediterranean Sea. According to a study made by the Mediterranean Oil Industry Group (MOIG), there are approximately 100 facilities handling oil in the Mediterranean Sea. Amongst them the 40% are refineries, 24% are ports, 26% are oil terminals and 10% are offshore platforms [2]. Accurate figures regarding the number of existing oil rigs are not easy to come by and reported numbers vary widely. More recent analyses of the Clarksons Database Data regarding the Mediterranean indicate the number of fixed offshore structures related to the oil and gas industry, in the Mediterranean to 367 and additional nine FPSOs located in the region [3]. These offshore facilities/installations pose a great risk to the sea and coastal environment and the consequences of a big scale incident can be devastating not only at local but at regional level as well, affecting the economies of many countries at Mediterranean Basin level.

2 The Roles of Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea and European Maritime Safety Agency in Oil Spill Response

In order to organize an efficient and coordinated oil spill response in the Mediterranean Sea, a number of instruments have been put in place, the most significant of which are administered by the Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea (REMPEC) and the oil spill response activities of the European Maritime Safety Agency (EMSA) [4].

2.1 The Role of Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea

One of the key bodies in dealing with oil spill response is the REMPEC which is administered by the International Maritime Organization (IMO) in cooperation with United Nations Environment Programme/Mediterranean Action Plan (UNEP/MAP). The objective of REMPEC is to contribute to preventing and reducing pollution from ships and combating pollution in case of emergency [5]. REMPEC assists countries in the prevention of pollution of the marine environment from ships and the development of preparedness for and response to accidental marine pollution and cooperation in case of emergency consisted by:

1. Strengthening the capacities of the coastal States in the region in oil spill response.
2. Developing regional cooperation in the field of the prevention of pollution of the marine environment from ships.
3. Assisting coastal States of the Mediterranean region which so request in the development of their own national capabilities for response to pollution incidents.
4. Providing a framework for the exchange of information on operational, technical, scientific, legal and financial matters between member countries.
5. Assisting coastal States of the region, which in cases of emergency so request, either directly or by obtaining assistance from the other Parties, or when possibilities for assistance do not exist within the region, in obtaining international assistance from outside the region.

Further details of the role of REMPEC are provided in a separate chapter in this volume [6].

2.2 The Role of European Maritime Safety Agency

Another important instrument for oil spill response is the EMSA. The Agency provides technical assistance and support to the European Commission and Member States in the development and implementation of EU legislation on maritime safety, pollution by ships and maritime security. It has also been given operational tasks in the field of oil pollution response, vessel monitoring and in long range identification and tracking of vessels.[1] Within EMSA, a marine pollution preparedness, detection and response capability has been established, including a European network of standby oil spill response vessels as well as a European satellite oil spill monitoring and vessel detection service (CleanSeaNet), both with the aim of contributing to an effective system for protecting EU coasts and waters from pollution by ships. Currently, seven EMSA contracted oil spill response vessels are stationed in the Mediterranean Sea.

Further details of the role of EMSA and its operational tasks are provided in a separate chapter in this volume [7].

3 Funding for Oil Spill Response

3.1 Funded Projects Overview

In order to support the oil spill response capacity and capabilities in the Mediterranean Region, a number of EU and national or international funded projects have been implemented over the years.

EU funded projects identified in this report can be broadly classified into three general categories:

1. Oil spill risk assessment, modelling and monitoring.
2. Oil spill response capacity building and training.
3. Oil spill response technological development.

Significant effort was put towards developing tools to monitor ship traffic and marine operations in areas with intense ship traffic as well as the detection of oil spills using moorings, drifters, ferry box and gliders networks (ARGOMARINE and PREMARPOL projects). Other projects developed oil spill dispersion models and platforms where different models could be integrated (MEDESS4MS, MOST, METANE, HAZARD, PRIMI and MEDSLIK-II projects) and others tried to strengthen the capacity of civil protection authorities through exercises and training tools (NEREIDS, TOSCA, RAOP-MED and Mediterranean Pollution Control projects). Then there are projects that develop innovative technological solutions to

[1]EMSA website [12].

assist oil spill response operations (KILLSPILL, EU-MOP, HOVERSPILL and URready4OS).

3.1.1 Kill Spill Project

General Information

- *Title:* Integrated Biotechnological Solutions for Combating Marine Oil Spills (Kill Spill)
- *Project Period:* 2013–2016
- *Geographical Scope:* Even though the main testing of the project results will be carried out in the Mediterranean, North and Norwegian Seas, the project will develop knowledge and tools that are applicable worldwide
- *Funding Program:* 7th Framework Programme for Research and Technological Development under the Grant Agreement no. 312139 within the theme Food, Agriculture and Fisheries and Biotechnology
- *Website:* http://www.killspill.eu/

Background

Oil spills can result in significant releases of oil in the marine environment. Oil spill response is a resource intensive, timely and costly process which on average results in only 10% of the oil released in a marine oil spill to be captured. Weathering processes and biodegradation further reduce this amount, but the project considers that a lot more could be achieved by enhancing these processes.

Main Objectives

The project's main objective was to develop highly efficient, economically and environmentally viable biotechnological solutions for the cleanup of oil spills caused by maritime transport or offshore oil exploration and related processes.[2]

These new developments include biosensors to monitor hydrocarbon degradation, novel environmentally friendly dispersants and adsorbents, combined microbial and additives formulations, multifunctional bioremediation agents and tools for sediments decontamination. The impact and toxicity of these newly developed products will be evaluated; and they will be validated in mesocosms and on real oil spills.

Additional objectives include the development of appropriate tools for:

[2]KILLSPILL project website [13].

- First response,
- Follow-up and
- Longer-term actions, specifically tailored to a broad range of different kinds of oil spills.

Main Results

The Kill Spill project has not been concluded by the time of the writing of this report but significant work has been carried out in the following activities:

- Development of biodegrading booms for small oil spills.
- Development of novel oil spill dispersants such as specialized biological surface-active compounds (biosurfactants, biodispersants and bioemulsifiers) and other suitable mineral dispersants and sorbent materials to accelerate oil dispersion, emulsification, sorption and ultimately hydrocarbon bioavailability to microbial degradation leading to complete mineralization.
- Development of (bio)monitoring methods such as biosensors, transcriptomics, stable isotope ratios and diagnostic isomer ratios to verify biodegradation processes in spill events and to better characterize the microbes involved.
- Development of novel or improved technologies, which accelerate the biodegradation of hydrocarbons in contaminated sediments.
- Development of multifunctional remediation agents for oil spills.

3.1.2 EU-MOP Project

General Information

- *Title:* Elimination Units for Marine Oil Pollution (EU-MOP)
- *Project Period:* 2005–2008
- *Geographical Scope:* The project targets the European Waters and specifically the Baltic and the Mediterranean Seas
- *Funding Program:* The project is funded by the EU Commission under the 6th Frame Work Programme (DG-RTD)
- *Website:* http://www.transport-research.info/project/elimination-units-marine-oil-pollution

Background

Oil pollution either from marine accidents or from routine ship operations is one of the major problems that threatens the marine environment. Efforts in protecting the environment after an oil spill could cost billions of euros in cleanup and subsequent damage costs, often producing questionable results. The key factor for efficient cleanup operations is to develop an adequate structure focusing on the confrontation of oil when is into the sea and diminish the impact on nearby coasts.

Main Objectives

The EU-MOP project proposes the design and proof of concept of autonomous EU-MOPs, capable of mitigating and eliminating the threat arising from oil spill incidents. The EU-MOPs were expected to be low-cost, possibly recyclable, autonomous vessels/drones that would be released in the oil spill area and would use sensors to identify the spill and combat it locally. The concept was to release a swarm of these units to confront the whole profile of the spill.[3]

Additional objectives were to establish:

- Innovative concepts in oil spill management;
- Novel devices for oil spill confrontation;
- An integrated framework for oil spill management and
- An advanced structure for the dissemination of oil pollution response policies.

Main Results

During the EU-MOP project, a new concept for oil spill response featuring autonomous unmanned robot vessels that operate as a swarm in order to efficiently collect the spilled oil was developed.

An EU-wide anti-pollution equipment inventory identified existing gaps in the anti-pollution arsenal, in order to target the recorded weaknesses. The project resulted in the development of two EU-MOP designs in the form of a Catamaran and a Monocat, designs that featured distinctive advantages.

The project carried out tank tests for these designs to estimate their resistance.

A simulation framework was developed to assess the preferred sensor configurations and control systems of the EU-MOPs which simulated both the robots and the oil slick. Furthermore, several swarm strategies were developed, in the process of identifying the most efficient ones. In the validation of the swarm behaviour, the main objective was to demonstrate physically the swarm behaviour via studying mobile land-based robots to collect "oil" which was projected onto the floor with the help of a video projector. Three separate simulation modules were developed and integrated: the oil fate, robot and visualization programs. A model was developed addressing the strategic planning of stockpiling EU-MOP units in candidate (port) facilities, so as to optimally respond to potential oil spill incidents in a nearby risk area.

[3]EU-MOP: Transport research and innovation portal [14].

3.1.3 HoverSpill Project

General Information

- *Title:* Development of a small hovercraft vehicle for fast response at difficult access or ecologically sensitive oiled sites (HOVERSPILL)
- *Project Period:* 2009–2013
- *Geographical Scope:* Even though the main testing of the project results was carried out in the Mediterranean, the project will develop knowledge and tools that are applicable worldwide
- *Funding Program:* 7th Framework Programme for Research and Technological Development
- *Website:* http://www.cedre.fr/en/Our-resources/Research/Response-equipment-and-products/HOVERSPILL-2009-2013

Background

On the market, there is a lack of amphibious vehicles dedicated to fast oil spill response operations in difficult-to-access areas such as estuarine or river in shallow waters. The lack of such tools renders the response to oil spills in the above mentioned environments difficult resulting in increased response times and poor effectiveness.

Main Objectives

The main objective of the HoverSpill project was to develop an autonomous system capable of working at difficult access and ecologically sensitive sites using air cushion vehicle (or hovercraft) technology. The hovercraft was to be designed to comply with certain operational and environment requirements[4]:

- To consist of an autonomous and multipurpose platform capable of providing enough room to operate safely and supplying the required power for implementing oil spill response devices;
- To be light and small in size, suitable for road transport and for easy and fast implementation and launch in various ways;
- To be easy to use and handle in restricted areas;
- To be easy to maintain and to repair in the field and
- To be environmentally friendly (minimum impact on ground).

[4]HOVERSPILL: CEDRE website [15].

Main Results

During the duration of the project, an oil spill literature and experience assessment was carried out that identified possible difficult-to-access areas where an oil spill could occur and the necessary capabilities that an oil spill response vehicle should possess. Based on this assessment, the project conceptualized, designed and developed the HoverSpill, an innovative System based on a hovercraft specialized for high speed Oil Spill emergency response and remediation. Its independent power generator and oil separation device cleans up coasts, beaches and shoals where vessels/land devices cannot operate. Its amphibian performances and compactness makes it easy on road or vessel transportation and beach based operation.

The HoverSpill is a hovercraft with unsinkable and shock proof soft hull, lateral skirt protection, oil resistant skirts and a Flapton System that allows for maximum manoeuvrability. HoverSpill's simple construction from parts commonly available in industrial market makes for ultra-simplified maintenance and low cost. The vehicle can also be used in other situations such as in flooding, firefighting or police operations. It could also serve in conservation activities. The project also resulted in the development of a diphasic oil–water separator, deployed during skimming operations on floating slicks, and assembled together with the recovery system (skimmer + pump).

3.1.4 METANE Project

General Information

- *Title:* Development of a modelling tool to study oil behaviour in the event of a deep sea leak (METANE)
- *Project Period:* 2011–2014
- *Geographical Scope:* French Mediterranean waters
- *Funding Program:* Single Inter-ministerial Fund of the Regional Council of Brittany
- *Website:* http://wwz.cedre.fr/en/Our-resources/Research/Response-equipment-and-products/METANE-2011-2014

Background

For many years, Oil and Gas industry stakeholders have clearly expressed their need for tools to predict and model oil and gas leaks. The accident involving the Deepwater Horizon platform in the Gulf of Mexico in April 2010 confirmed the importance of fully understanding these underwater phenomena and their consequences at the sea surface [8].

Main Objectives

The METANE project's (Modelling underwater gas/oil blowout and LNG leak) long-term aim is to obtain a comprehensive IT system to describe the behaviour of gas or oil in the marine environment in the event of accidental discharge. The aim of this project is to improve both the safety of personnel on-board offshore Oil & Gas installations and the pollution response to limit the impact on the marine environment [8].

The first objective of the METANE project is to develop a decision support tool for the implementation of contingency plans for industrial risks related to oil and gas leaks at sea.

The second objective of the project involves conducting pilot-scale trials to test the observations made on a smaller scale and to provide input for scientific research and debates on the mathematical equations describing these phenomena.

Main Results

The work of the project led to development of a tool featuring scientific modelling of the dynamics of a gas and/or oil plume when rising in the water column, taking account of the specific characteristics of the deep ocean. Calibrating and validating the chosen numerical models were carried out using Cedre and EMA technical resources (5-m column, pressurized column, high-frequency camera, etc.).

The METANE tool is made up of a computing code which is reachable through a graphical user interface (GUI) providing access to the initialization of the computation process and to the post-treatment and visualization of the results. Results from the simulation are directly exploitable in the quantitative view: displaying plume slices or a cut view, picking points in the plume to obtain information about oil/natural gas concentration and velocity, and 2D plot outputs are also available, giving extra information on surface pollutant concentration, or fountain elevation with radius [8].

The METANE tool provided answers to operational questions: where and at what rate does the plume surface and how concentrated is it? Adopting a "serious game" approach, the results of the tool are presented in a 3D scenario and thus offer a realistic view of the accident for intervention team training.

3.1.5 MOST Project

General Information

- *Title:* Development of a tool to analyse and predict the evolution of drifting oil slicks (MOST)
- *Project Period:* 2012–2013

- *Geographical Scope:* The project is related to the French waters of the Mediterranean Sea
- *Funding Program:* Collaborative & Innovative Technology Program in Exploration and Production of Hydrocarbons (CITEPH)
- *Website:* http://wwz.cedre.fr/en/Our-resources/Research/Response-equipment-and-products/MOST-2012-2013/

Background

Oil spill response efficiency is currently held at low levels which means that only a small portion of released oil is actually collected and removed by oil spill combating units and equipment. In order to implement oil spill response equipment in a more efficient way, the following parameters are necessary:

– Prediction of the slick formation;
– Prediction of the spill drift;
– Prediction of the evolution of oil at the surface, i.e. whether it will fragment or not; and
– Estimation of the quantities of drifting oil in order to determine the resources required for response operations at sea and/or on the shoreline.

Main Objectives

The aim of the MOST project (Mapping Oil Spill Drift) is to improve decision support for the definition of the response strategy to be implemented, by significantly improving the processing technique for images obtained by remote sensing in the field.[5] The idea is to develop an IT tool to analyse these images based on a new protocol designed to:

- Accurately outline drifting slicks and provide more accurate information on their shape and therefore their surface area;
- Geolocate oil spills on a map environment and
- Estimate the oil spill thickness to the greatest extent possible.

The information collected through the developed tool will be sent to Météo France for use as input data for the MOTHY drift model.

[5]CEDRE 2016 [16].

Main Results

The MOST project resulted in the development of a software tool, which can be used to accurately describe the shape and geometry of a drifting slick from a remote-sensing image.

3.1.6 MEDESS-4MS Project

General Information

- *Title:* Mediterranean decision support system for marine safety (MEDESS-4MS)
- *Project Period:* 2012–2015
- *Geographical Scope:* The project is relevant to the whole Mediterranean Sea region
- *Funding Program:* Financed by the European Regional Development Fund within the Med Programme for Strategic Projects
- *Website:* http://www.medess4ms.eu/

Background

One of the permanent risks from an incident in the Mediterranean is associated with the heavy traffic of maritime transport and with the coastal and offshore installations related to oil industry. Such a dense activity imposes on the coastal countries the need for preparing an operational response in cases of major incident. The use of oil spill models is a significant part of oil spill response activities and Member States agencies have been using a number of well-established oil spill models during real oil spill incidents within the Mediterranean for years. On the other hand during the last decade, the GMES marine core service (nowadays the Copernicus marine service) and the associated national ocean forecasting systems developed. However, there was a distinct lack of coupling these forecasts with oil models and more importantly there was a lack of common services which would harmonize and integrate the existing systems in order to improve the efficiency of oil spill response.

Main Objectives

The MEDESS-4MS project is an ambitious project aiming at improving capacities in preventing and mitigating maritime risks deriving from oil spills through the use of forecasting and support decision tools. The project would deliver an integrated operational multi-model oil spill drift prediction service connected to existing monitoring platforms (EMSA-CSN, REMPEC and AIS), using the well-established oil spill modelling systems, the data from the Copernicus MED-MFC marine service and the associated national ocean forecasting systems [9].

The project's overall objectives are:

- To implement an integrated real-time multi-model oil spill forecasting system;
- To implement an interconnected network of data repositories that will archive and provide in operational way the access to all available environmental and oil spill data;
- To test the service functionalities with key end users: REMPEC, EMSA and national agencies responsible for combating oil spills and
- To develop the integrated system with a unique access web portal with different services and user profiles, multi-model data access and interactive capabilities.

The reasoning of the project is to set up an integrated real-time operational oil spill forecasting service for the Mediterranean for national response agencies, REMPEC and EMSA, that will give these response agencies the capability to use real-time information about position of the oil slick, and interface it with oil spill models capable to forecast the movement of the pollution providing tailored products to oil spill crisis management users, contributing substantially to maritime risks prevention and maritime safety. This capability will allow for significant decrease in response times to oil spill incidences and since oil spills are like fires, where fighting them when still small makes all the difference, MEDESS-4MS developed the most effective tool for initiating the appropriate response when disaster occurs at sea.

Main Results

The MEDESS-4MS project has resulted in a large number of deliverables and activities relevant to oil spill response. A large number of studies and reports were produced regarding oil spills modelling and oil spill response in the Mediterranean sea[6]:

- Development of Socio-economic Vulnerability Maps from Oil Spills for the Mediterranean;
- Analysis of ship traffic and ship density in the Mediterranean;
- Analysis of oil transport and
- Analysis of historical accident data in the Mediterranean region.

Furthermore, a large number of research papers were produced as part of the project and the project was represented in various relevant conferences.

One of the most important outcomes of the project is the MEDESS-4MS Web Portal that provides comprehensive information and data regarding oil spills and oil spill response in the Mediterranean Sea. The web portal also serves as a data

[6]Medess-4MS project website [17].

repository backed by database that is linked to data contained in ENI database developed in the MEDSTAR project as well as other databases.

The main service delivered by MEDESS-4MS is an integrated real-time operational oil spill forecasting service for the Mediterranean for national response agencies, REMPEC and EMSA.

The multi-model oil spill forecasting system is composed of environmental information from the Copernicus MED-MFC marine service and the national ocean forecasting systems interfaced with oil slick data from existing monitoring platforms from EMSA-CSN, as well with AIS data. It uses the real-time information about position of the oil slick, and interfaces it with oil spill models capable to forecast the movement of the pollution providing tailored products to oil spill crisis management users, contributing substantially to maritime risks prevention and maritime safety.

The service is accessible through a User Interface that is basically the web portal on which the MEDESS-4MS services are made available. The system is accessed by different users' categories and thus implements authentication services, profiling, management of customized contents and centralized administration. Users have the possibility to choose the MEDESS-4MS oil spill model that best satisfies their local or subregional needs, and select the necessary forcing data from the output of local, subregional and regional ocean and meteo-forecasting systems.

The MEDESS-4MS services are delivered through three service scenarios (SS), in order to assist operational response agencies:

SS1 – Real-time interactive oil spill predictions by the end-user request. It is an automatic system that runs after an oil spill alert from satellite data. It is a scenario used by selected authorized users (i.e. official agencies of Member States).

SS2 – Delayed mode simulations by end-user request. In this solution, intended for the use of REMPEC and generic users, the UI provides the means to access monitoring component, environmental data and model outputs and receive integrated remote/in situ data. The User queries the NDR Service to consult historical data, for study or statistical purposes and possibly query the NDR to back trace data with the aim of identifying possible polluting ships.

SS3 – Decision support system (DSS) to manage emergency operations. These services consist of a DSS operational tool proposing to the users a set of possible scenarios, developed according to the foreseeable meteo-marine conditions and to the possible on-site interventions. The DSS is then used for oil spill crisis management and built upon a set of simulation functionalities, launched by the UI to support the work of operational decision makers.

3.1.7 TOSCA Project

General Information

- *Title:* Tracking Oil Spills & Coastal Awareness network (TOSCA)
- *Project Period:* 2010–2013
- *Geographical Scope:* The project is relevant to the whole Mediterranean Sea region
- *Funding Program:* Financed by the European Regional Development Fund within the framework of the Med Programme
- *Website:* http://www.tosca-med.eu/

Background

The increasing importance of Eastern Mediterranean ports and the traffic density concentrated around Western and Central Mediterranean ports are constantly raising the risk of an important marine incident. For these reasons, Med partners need to work together on a stronger current monitoring system and on effective action plans in case of maritime accidents in order to reduce the risks and the impacts caused by a maritime accident.

Main Objectives

The TOSCA project aims to improve the quality, speed and effectiveness of decision-making process in case of marine accidents in the Mediterranean concerning oil spill pollution and search and rescue (SAR) operations.

More specific objectives include[7]:

- Provision of real-time observations and forecasts of the marine environmental conditions in the Western and Eastern part of the Mediterranean Sea through the construction of an observational network, based on state-of-the-art technology (HF radars and drifters);
- Development of a decision support tool for authorities in charge of marine emergency response and
- Set up a sustainable network of local authorities, policy makers and scientists in the Mediterranean.

The network will be used to implement action plans in collaboration with local authorities, as well as to set a common scientific strategy in cooperation with policy makers to provide immediate response, mitigation and long-term management of oil spill pollution and SAR operations in case of marine accidents.

[7]TOSCA project website [18].

Main Results

The main result of the TOSCA project was its contribution in the development of new and updated knowledge on surface currents and noticeable progress in the monitoring of oil slick drift. The added precisions and data collection from this project could now help authorities choose the right strategy for the deployment of drifters to track oil spills.

The TOSCA project has developed an innovative approach using HF radars and drifter measurements to provide crucial and complementary information to predict oil spill dispersion and trajectory more accurately. To provide real-time observations and forecasts, an observational network, based on state-of-the-art technology (HF radars, drifters and ocean modelling systems), was installed and assessed in five sites of the Mediterranean sea, on the coastal areas near the outlets of major existing or planned oil pipelines and on high traffic areas.

The major results of the analysis of the data set obtained during the experimental campaigns prove:

- The benefit of HF radars as a powerful tool to provide satisfactory estimation of transport and to improve our response to oil spill and SAR emergencies;
- The benefit of an optimal drifter deployment strategy to be used to correct radar intrinsic errors or enhance models and to get direct information on oil spill transport and dispersion and
- The benefit of the TOSCA strategy to enhance numerical models and provide more accurate forecasts of the trajectory of oil spill, a wreckage or a lost person.

3.1.8 NEREIDS Project

General Information

- *Title:* NEREIDS
- *Project Period:* 2013–2015
- *Geographical Scope:* The project is relevant to the Eastern Mediterranean Sea region
- *Funding Program:* Financed by the Humanitarian Aid & Civil Protection, in the area of preparedness in Civil Protection and Marine Pollution
- *Website:* http://www.nereids.eu/

Background

Oil spills in a cross-border environment increases the operational challenges of civil protection and other authority's in combating the spill. There is a need for development of a high level of communication, cooperation and training capacity between cross-border oil spill response authorities to improve the effectiveness of the response.

Main Objectives

The NEREIDs project aims to increase preparedness and collaboration in civil protection and marine pollution amongst Greece and Cyprus, building on international standards, best practices and innovative Information and Communication Technologies.[8]

Additional objectives of the NEREIDs project include:

- The advancement of cross-border civil protection and marine pollution cooperation for direct response to disasters;
- Increasing the preparedness for the mitigation of oil spill impacts on the coastal environment;
- Increasing the coordination between various oil spill response authorities in Greece and Cyprus as well as the capacity to receive foreign assistance;
- Development and implementation of e-learning tools based on innovative concepts of online games, mobile technologies (m-learning), crowd sourcing and web applications to train civil protection and marine pollution professionals, volunteers and other related stakeholders as well as for increasing awareness, knowledge and skills and
- Limiting the consequences of emergencies through sharing experiences and best practices on developing and making use of situational reports.

Main Results

- The project succeeded in improving the collaboration of Greece's and Cyprus's oil spill response stakeholders through common trainings, working meetings and two full-scale tabletop exercises for oil spill response where realistic scenarios that included the request of assistance from the EU host nation support mechanism.
- Additionally, the project developed tools to allow for the availability of crucial information to the response authorities specifically, an online Incident Report Database was developed to collect, evaluate and verify information on incidents in a standardized user friendly format (see http://www.nereids.eu/site/incidents_view/admin/debr-list.php). Statistical analysis and evaluation of the incidents report database containing historical accidents and oils spills for the last 50 years was carried out to identify accident and response patterns.

[8]NEREIDs project website [19].

- Based on seafloor and near-coast morphology data, oil spills coastline susceptibility maps were developed to assist authorities to better develop response plans.
- A variety of training and informative tools have been developed such as a web-based learning game, educational material to train civil protection and marine pollution professionals, volunteers and other related stakeholders and E-training courses based on ICT Technologies to deliver high-quality learning experience to remote professionals, volunteers and other related stakeholders.
- An e-learning portal in the field of civil protection and marine pollution for spreading knowledge with the appropriate content to reach a broader audience has been developed as well as a mobile learning (m-learning) application to be used as a tool for educating the appropriate personnel.

3.1.9 PREMARPOL Project

General Information

- *Title:* Prevention and Combating of Marine Pollution in Ports and Marinas (PREMARPOL)
- *Project Period:* 2011–2014
- *Geographical Scope:* The project is relevant to the Eastern Mediterranean Sea region
- *Funding Program:* Financed by Greece–Cyprus 2007–2013 Interreg Cross-border program
- *Website:* http://www.oceanography.ucy.ac.cy/pages/premarpol/

Background

Pollution phenomena such as oil pollution, increased concentrations of suspended particles in water, foul smells and other contaminants are common within and in adjacent port facilities. However, such pollution is incurring negative impacts both on the physical environment as well as the further growth of close-to-port areas. There is a distinct necessity for the prevention of any port related pollution but also for the development of the necessary mechanisms to timely detect and mitigate any pollution caused. The necessity for the implementation of such a system is now becoming imperative, since most international organizations and the EU institutions impose strict penalties on environmental unreliable port operators.

Main Objectives

The PREMARPOL project aims to assist the competent authorities to prevent and fight marine pollution in ports, in order to protect the health of neighbouring populations, i.e. port workers, port clients and local residences. Additionally, the project aims at the protection of the physical environment within and adjacent ports from any kind of port related pollution.[9]

Project objectives include the installation of modern pollutants detection sensors in the ports of Cyprus, Rhodes and Samos, as well as the adjacent water bodies and the development of an integrated information system which would collect and process the acquired data in order to assist competent bodies to implement timely pollution prevention and mitigation measures.

Main Results

The project has developed and implemented a series of multisensor instruments within ports for real-time data on water quality status of the port basin water as well as water bodies adjacent to the port area. The sensor readings were presented on an online web portal that is open to the public.

3.1.10 Mediterranean Pollution Control Project

General Information

- *Title:* Oil Pollution Management Project for the Southwest Mediterranean Sea
- *Project Period:* 1992–2000
- *Geographical Scope:* The project is relevant to the Eastern Mediterranean Sea region
- *Funding Program:* Financed by the World Bank global environment trust fund
- *Website:* http://projects.inweh.unu.edu/inweh/index.php

Main Objectives

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 MARPOL7 3/78 Convention requirements [26].

The project also achieved the 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 amongst the countries in the region (Algeria, Morocco and Tunisia) for preventing and combating oil pollution and improving the quality of the marine environment.

Additional objectives include:

[9]PREMARPOL project website [20].

- Utilization of national data sets to assess long-term regional trends in marine pollution, both for national coastal waters and for adjacent international waters;
- Enhancement of the national monitoring capability of the three countries and
- Development of a coastal environmental management framework.

Main Results

A major institutional outcome of the project has been the development of a framework for a comprehensive national and regional management of oil pollution, the drafting of a regional contingency plan (RCP) and the purchase of standardized equipment to combat pollution. Furthermore, the project also initiated cost recovery system at the port level through an adequate tariff structure, and at the national level through creation of an environmental fund, enactment of a law regarding fees and penalties and enactment of polluter-pay rules [26].

3.1.11 ARGOMARINE Project

General Information

- *Title:* Automatic Oil spill Recognition and Geo-positioning integrated in a Marine Monitoring Network (ARGOMARINE)
- *Project Period:* 2009–2012
- *Geographical Scope:* The project is relevant to the whole Mediterranean Sea region
- *Funding Program:* Financed by the European Commission under the Transport Theme of the 7th Framework Programme for Research and Technological Development
- *Website:* http://www.argomarine.eu/

Background

The Mediterranean Sea is amongst the world's busiest waterways accounting for 15% of global shipping activity by vessel deadweight (DWT). Ship traffic through Mediterranean basin daily consists of 2,000 ferries, 1,500 freight ships and 2,000 commercial crafts, and 300 of them are tankers (20% of the world amount of oil sea traffic), carrying more than 350M oil tons per year (8M barrel per day). The high ship traffic combined with the difficult, in many places, navigation routes constitutes the Mediterranean Sea as one amongst those facing the highest risk of oil pollution. Additionally, the recent developments in Eastern Mediterranean for exploration and exploitation of offshore Petroleum Hydrocarbons increase the threat to Eastern Mediterranean States.

Thus, decision makers in this region have a strong need for an efficient pollution monitoring and forecasting system, to support them in planning and conducting preventive and emergency interventions.

Main Objectives

The scope of the proposed ARGOMARINE project is to develop and test an integrated system for monitoring of the marine traffic and pollution events due to carriers/commercial ships as well as recreational boats through environmental-sensitive sea areas.

Main Results

A methodology and tool was developed to identify and analyse oil spills from SAR images coming from satellite-hosted platforms. This monitoring is implemented by means of electronic, geo-positioning and tools for transmitting ship navigation data through a high speed communication network. Environmental data from different sensors (SAR, hyperspectral sensor and thermal sensors) on satellites, aircraft, vessels, in situ anchored buoys and AUVs are collected and sent by telemetric links to a central server for map processing. Therefore, to monitor marine pollution, data from both satellite and airborne remote sensors and in situ sensors on vessels and buoys are integrated to derive information about water quality and spread of hydrocarbons/oil slicks over large areas.

External data such as weather station data, weather operational models and large-scale hydrodynamic and wave models are gathered and placed in a 3D hydrodynamic model a wave model and an oil spill model.[10]

All the data and the information obtained are merged and elaborated in a Marine Information System (MIS), i.e. an information system where all collected data are stored and tools for data retrieval, data manipulation and analysis, as well as for presentation, are available through a common interface. The ARGOMARINE platform guarantees a better management of sea and coastal areas and a reduction in the burden of continuous visits all over the territory in the traditional surveillance modalities. These factors will reduce the cost of the environmental conservation system and simultaneously improve the quality and efficiency of agencies that are in charge of control services.

[10] ARGOMARINE project website [21].

3.1.12 HAZADR Project

General Information

- *Title:* Strengthening common reaction capacity to fight sea pollution of oil, toxic and hazardous substances in the Adriatic Sea (HAZADR)
- *Project Period:* 2012–2015
- *Geographical Scope:* The project is relevant to the Adriatic Sea region
- *Funding Program:* Financed by the IPA Adriatic Cross-Border Cooperation Operational Programme
- *Website:* http://www.hazadr.eu/

Background

The Mediterranean is one of the most crowded seas in the world in terms of traffic. Even if it covers only 0.7% of the total seawater surface in the world, it hosts 30% of the overall international maritime traffic. Sea pollution by oil, hazardous and noxious substances can happen at any time and in any place, especially along the main maritime routes due to technological and natural hazards and during the loading and unloading vessels' operation in the sea terminals, where the likelihood of marine environment pollution is the highest. The Adriatic Sea is no exception, especially since it represents a narrow and shallow basin across which petroleum transport is directed towards transit ports mainly situated in the northern part of the Adriatic.

Main Objectives

The main objective of the project is the establishment of a cross-border network for the prevention of risks and the management of emergencies, in order to reduce the risk of pollution and contamination of the Adriatic Sea and strengthen a common reaction capacity of the communities belonging to the Adriatic region against environmental and technological hazards due to collisions, shipwrecking and spillage of oil and toxic material into the sea.[11]

Main Results

The project's results include:

[11]HAZARD project website [22].

- An assessment of the legal and administrative framework on oil spill response of the countries of the Adriatic region has been carried out.
- A statistical analysis of maritime incidents, from 1970 to 2014, considering all the events recorded in the main international databases was completed.
- Coastal vulnerability maps were developed in order to provide the decision maker with the most accurate knowledge of the area that might be impacted by the spill.
- Oil spill risk assessment for the Adriatic region has been carried out.
- The AdriaCOAST forecasting system was developed to run autonomously every day and produce a 72-h forecast to predict the oil dynamics (direction, speed and impact) on the sea surface and its possible stranding is GNOME (General NOAA Operational Modelling Environment).
- A common database on the state of readiness and spatial distribution of pollution preventing equipment along the Adriatic coasts as well as the improvement of the operational instruments to cope with the environmental and technological hazards was developed.
- A joint radar monitoring program based on a set of radar systems and VHF devices was developed.

3.1.13 RAOP-MED Project

General Information

- *Title:* Risk Assessment Analysis on Offshore Platforms in South East Mediterranean (RAOP-MED)
- *Project Period:* 2013–2015
- *Geographical Scope:* The project is relevant to the South East Mediterranean region
- *Funding Program:* Financed by the Cross-Border Cooperation within the European Neighbourhood and Partnership Instrument (ENPI) Mediterranean Sea Basin Joint Operational Programme
- *Website:* http://www.raop.eu/

Background

In recent few years, the Mediterranean Sea is increasingly becoming a field of oil and gas exploration and production due to a series of deep sea deposits found especially in the Eastern Mediterranean region. According to a recent study made by the MOIG, there are approximately 100 facilities handling oil in the Mediterranean Sea with increasing trend.

Main Objectives

RAOP-MED project aims to offer a holistic study on the risks associated with the exploitation and exploration of the continental shelf and seabed that includes prevention, early detection and control of the oil spill, reorganization and redistribution of the resources available for efficient and accurate combat of the oil spill at the early stages and, furthermore, to raise awareness of the possible consequences of such an incident in financial, environmental and social level.

Therefore, RAOP-MED specific objective is the development of a comprehensive Risk Management Plan that evaluates the risk of an oil spill incident caused by offshore platform in the Mediterranean Sea and propose all the necessary structural and institutional changes and suggest possible response mechanisms that need to be taken into account in order to minimize the response time and improve the overall performance of competent authorities and relevant stakeholders to an oil spill combat.

Main Results

The project has resulted in a number of significant results to improve the oil spill response capabilities of the South-Eastern Mediterranean countries[12]:

- An analysis of maritime traffic through the Automated Identification System (AIS) in conjunction with the oil transport data was carried out that resulted in vessel traffic and density maps and the identification of High Risk areas for Oil Spill incidents/releases.
- The probability of occurrence of an oil spill due to a ship–oil platform collision was carried out by assessing the traffic density in relation to the location of the offshore structure. Additionally, an oil spill evaluation was carried out to assess the probable size and type of oil spill release.
- Development of integrated sensitivity maps for the Southern Eastern Mediterranean area that can provide a very valuable tool for the risk assessment of any area in the Southern Eastern Mediterranean sea was carried out.
- A comprehensive Impact Damage Assessment was developed based on the predictions of the well established MEDSLIK oil spill model, to assess the consequences of any possible Oil Spill release in the South East Mediterranean.
- An assessment of the technical capacity of each country (Cyprus, Egypt, Israel, Lebanon, Syria, Turkey and Greece) to respond effectively to oil spill incidences within it territorial waters was carried out. Additionally, the status of enforcement of the various International and Regional Conventions and Protocols for Prevention Control and Combating Oil Pollution by the South-Eastern Mediterranean countries was carried out showing that the East Med region is

[12]RAOP-MED project website [23].

characterized by heterogeneous level of preparedness and response due to the partial fulfilment of the relevant country's obligations derived as signatory Parties to the existing treaties or even more because they have not ratified yet a number of them.

The strategic impact of the project is that it developed knowledge and tools that can allow the participating countries to: (a) redraft their Emergency Contingency Planning on Oil Spills to include risks from Offshore Structures; (b) increase awareness to Institutional and Operational Stakeholders and (c) to improve distribution of oil response equipment.

3.1.14 PRIMI Project

General Information

- *Title:* Pilot marine pollution by hydrocarbons (PRIMI)
- *Project Period:* 2007–2010
- *Geographical Scope:* The project is relevant to the Mediterranean region
- *Funding Program:* Funded by ASI (Italian Space Agency)
- *Website:* http://spatial.telespazio.it/plone3.0/Primi/

Background

Marine pollution by oil is a threat that increasingly threatens the ecosystem complex sea/coastal areas. Earth observation systems are an effective way to monitor and combat oil spills and have an increasing application by authorities. However, observation systems had some obvious gaps between requirements and performances such as: the necessity for high revisit times, wide spatial coverage, indication of the spills fate, composition, age, quantities and system reliability.

Main Objectives

PRIMI was a Research and Development project aiming to address the identified gaps in the oil spill earth observation systems and increase the use of satellite data in support to environmental protection. The main goals were to [10]:

- Increase the frequency of monitoring through the use of SAR and Optical data and the use of multiple sensor bands and polarizations.
- Provide slick forecasts for the 72 h after detection in support to remediation actions.
- Supply estimates of parameters such as spill volume, wind and wave conditions, etc., extremely useful during intervention planning.
- Provide data to end users via WEB–GIS technologies.

Main Results

The PRIMI project has developed a modular system able to detect polluted areas both in SAR and in optical imagery, ensuring a wide coverage and a frequent revisit time, to provide a forecast of the observed slicks, using numerical models, meteorological and marine data products and to present all the relevant information to the system end users via a user friendly WEB–GIS portal.

3.1.15 URready4OS Project

General Information

- *Title:* Underwater Robotics Ready For Oil Spills (URready4OS)
- *Project Period:* 2014–2016
- *Geographical Scope:* The project is relevant to the Mediterranean region
- *Funding Program:* The project is financed by the Directorate-General Humanitarian Aid and Civil Protection of the European Commission
- *Website:* http://www.upct.es/urready4os/

Background

Surface oil is not the only effect of oil spills. Underwater oil plumes can come from bottom leaks and from surface patches forming subsurface plumes as recently been brought into the public eye during the 2010 Deepwater Horizon incident. The existing capacity in combating underwater oil plumes is not as developed as surface oil plumes.

Main Objectives

The project's aim is to develop a fleet of autonomous underwater vehicles (AUVs), unmanned aerial vehicles (UAVs) and unmanned surface vehicles (USVs) with operational capability to intervene against oil spills in European Seas using new cooperative multivehicle robotic technologies [11, 25].

Main Results

The project has successfully developed a fleet of unmanned vehicles that are equipped with relatively low-cost standard sonar and oil-in-water sensors to detect and monitor underwater oil plumes. Three different kinds of vehicles are involved: (a) AUVs, (b) USVs and (c) UAVs. The URready4OS is completed by two separate pieces of software: (a) NEPTUS – a command and control console and data visualization tool and (b) MEDSLIK – an oil spill tracking and fate forecasting model.

While the AUVs measure the oil in water, the USVs and UAVs increase the AUVs operational range acting as gateways for communication between the vehicles and the base station, either on land or ship, where near real-time data are received. Using the data from the vehicles, the system is able to build up a highly accurate and dynamic image of the spill. Ultimately, this cooperating multivehicle robotic technology allows a cheap, flexible, expandable, precise and rapid DSS for Civil Protection decision makers by optimizing the response time before the oil reach the coast [25].

3.1.16 MEDSLIK-II Project

General Information

- *Title:* Oil spill model code MEDSLIK-II
- *Project Period:* 2011–2016
- *Geographical Scope:* The project is relevant to the Mediterranean region
- *Funding Program:* The development of the MEDSLIK-II model is supported by a formal agreement signed by the following institutions: Istituto Nazionale di Geofisica e Vulcanologia, Centro Euro-Mediterraneo sui Cambiamenti Climatici, Consiglio Nazionaledelle Ricerche – Istituto per lo Studio dell' Ambiente Marino Costiero, Alma Mater Studiorum – University of Bologna and the developers of the MEDSLIK oil spill model
- *Website:* http://medslikii.bo.ingv.it/

Background

Oil particles are dispersed by turbulent fluctuation components that are parameterized with a random walk scheme. In addition to advective and diffusive displacements, the oil spill particles change due to various physical and chemical processes that transform the oil (evaporation, emulsification, dispersion in water column and adhesion to coast).[13] Understanding of the behaviour of oil particles in the water column is essential for effective oil spill response.

Main Objectives

The aim of the model is to act as a tool to allow for improved oil spill response planning as well as oil spill combating.

[13] MEDSLIK-II model [24].

Main Results

MEDSLIK-II is a model based on MEDSLIK, that simulates the transport of surface slicks by the sea currents and by the wind. MEDSLIK-II includes high-frequency currents and wind fields in the advective components of the lagrangian trajectory model, the introduction of the Stokes drift velocity and the coupling with the remote-sensing data.

MEDSLIK-II requires as input the oil spill data, the wind field, the sea surface temperature and the three-dimensional sea currents collected from several different sources. The oil spill data required to define a numerical oil spill initial condition are: location, time and area of the spill, as well as the age of the oil spill from initial arrival in the sea. This information can be easily provided to MEDSLIK-II by satellite monitoring systems.

Using the required input parameters, the model produces as output the oil properties evolution and the position, every hour and for the next days, of the surface, dispersed oil and of the oil arrived on the coasts.

4 Conclusions

In this report, 16 European projects relevant to oil spill prevention and mitigation in the Mediterranean Sea have been presented, the majority of which have been completed within the last 10 years. This shows that the EU is actively pursuing and investing in the protection of the Mediterranean from Oil Spills. The implementation of these projects has yielded valuable information that allowed for the improvement of the capacity of the Mediterranean countries to protect the Mediterranean against oil pollution. The main benefits arising from these projects include:

1. Bringing together the academic and operational aspects of oil spill response to identify better solutions.
2. Strengthening the relations between oil spill response authorities in the various Mediterranean countries and facilitating the exchange of expertise.
3. Developing better understanding of the behaviour of oil spills.
4. Assessing the risk of oil spills and their impacts and identifying hot spots or sensitive areas to protect. This allows for better allocation of resources to achieve more effective oil spill response.
5. Developing and implementing powerful and sophisticated models and tools to predict oil spill dispersion and behaviour.
6. Developing new, more efficient, cost effective and environmentally friendly solutions for the cleanup of oil spills.

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Oil Spill Beaching Probability for the Mediterranean Sea

J. A. Jiménez Madrid, E. García-Ladona, and B. Blanco-Meruelo

Abstract In this chapter, different kinds of oil spill beaching maps are proposed for the Mediterranean. These beaching maps can be useful as a complementary tool to vulnerability analysis and risk assessment in the Mediterranean. Firstly, it is defined an oil beaching map for a single point, which is the situation, for example, in the analysis of an oil platform. Next, the oil beaching map is defined for a line, analysing the main route of oil tankers in the Mediterranean. The final oil beaching maps defined show the percentage of particles which reach the coast in an interval of time: one week, two weeks, one month and two months. The information depicted in the maps is based on Lagrangian simulations using particles as a proxy of oil spills evolving according the environmental conditions provided by a hindcast model of the Mediterranean circulation.

Keywords Mediterranean Sea, Oil spill, Beaching map, Lagrangian simulation

Contents

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1 Introduction

The Mediterranean Sea is currently the shortest route from Asia to Europe. About 1/6 of the global maritime traffic and 1/3 of the global seaborne oil (almost 8 million oil barrels per day) is carried through the Mediterranean Sea, which only represents the 0.8% of the ocean surface. In a report by the Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea, there has been estimated a total oil spillage of around 310,000 t since 1977 and at least 120,000 t of other noxious substances since 1988 [1]. There have been a total of 659 accidents related with pollutant release with 545 involving oil. However, the updated data available since 1977 exhibit a decreasing trend since the 1990s, in both the quantity of oil and other hazardous and noxious substances as well. This tendency is only disrupted by the major accidents of *MT Haven* in 1991 and Lebanon spills in 2006. The *MT Haven* accident has been by far the largest in the Mediterranean, not only because the spilled quantity was quite huge (about 145,000 t, among the top ten biggest spills from tankers) but also due to the environmental damage. The accident caused a serious pollution of sea waters, seabed and along the Ligurian coast, from Genoa to Savona, producing a shipwreck that still today constitutes a potential source of pollution. Even though the estimated amount released in the *MT Haven* incident was comparable and even greater than other devastating accidents over the world ocean (e.g. *Deep Water Horizon, Prestige, Erika* or *Exxon Valdez*), the environmental impact, while being severe, was of relative lesser extent compared to such other incidents. Particular circumstances as the closeness to the coast, the rapid response and the environmental conditions were elements limiting the damage in comparison, for example, with the *Prestige,* the *Erika* or the *Exxon Valdez,* in which more than 1,000 km, 400 km and 800 km of coast were, respectively, affected. Thus, when one of such incidents takes place the consequences associated with economic impact, cleaning operations and environmental pollution depend on the characteristics around the event.

According to [2], the main factors impacting the cost of spills are the persistence of the oil in the environment, sea and weather conditions, the rate and the amount of the spill, the effectiveness of clean-up and also geographical, biological and economic characteristics of the affected area. In case of an oil spill accident, the most pressing issue is to know whether the oil slick will go onto a coastal area in the following days. The short term response can be assessed through combined meteorological–oceanographic and oil spill forecast systems [e.g. 3, and the references therein]. Nevertheless, even for state of the art of oil spills forecasting models, the prediction horizon is limited to 5–7 days considering that this is in fact imposed by the forecast horizon of a meteorological prediction. If a 7-day forecast predicts that slicks still will have not reached any shoreline, the most exposed coastal segments to the long term slick drift remain uncertain. Under such circumstance, taking into account statistical information of coastal segments affected by spills (at the scale of months) may provide some insight to figure out which is the most exposed coastline. Such information may come from past pollution events on a given region, or from statistical information on beaching obtained from simulations using hindcasts of past environmental conditions. This procedure was adopted by the US Department of Interior to evaluate environmental consequences prior to lease sales or approval of industry's plans [4–7] and was proposed for oil spill risk assessment after the *Prestige* incident for the Cantabrian coast, in the northern coast of Spain in the Bay of Biscay [8, 9]. In [10] it was reanalysed the risk assessment procedures that could have been taken in the *Prestige* incident showing the costs/benefits of different policy alternatives based on prior knowledge about the statistics of beaching.

Recently, similar approaches have been carried out in several areas of the Mediterranean Basin: the Bonifacio Strait [11], the Strait of Otranto [12], the Strait of Sicily [13], the southeastern Levantine Basin and in the Lebanon coast [12, 14]. All these studies have been focused to carry high resolution analysis for limited regions but a global picture of the whole Mediterranean Basin is lacking. In this chapter we present different kind of basin scale oil beaching probability maps for oil spills through a statistical approach of spills trajectories from available hindcast of the Mediterranean circulation. In Sect. 2 we describe the methodology, the data and the model to compute the beaching probability maps. In Sect. 3 we show results for three kind of oil beaching maps: a basic one representing the affected coastline by oil spills produced by point sources, a second map compiling the affectation by spills coming from an ensemble of point sources along a route (tankers paths) and the last shows the percentage of particles reaching the coast from a regular source of points covering the whole Mediterranean Basin and during a finite period of time. We finally summarise the main conclusions and discuss the limitations of the approach here presented.

2 Methodology and Simulation Setup

Forecasting the long term behaviour of oil spills is not an easy task given the turbulent nature of the ocean and atmosphere. Spill dispersion is very influenced by the evolution and complex dynamics of these two geophysical flows. For this reason, a statistical perspective is necessary to get some insight in the understanding of the long term behaviour of an oil spill and its evolution within such flows. In the definition of different oil probability beaching maps we will analyse Lagrangian simulations performed from a hindcast of atmospheric and oceanic flow fields observed in past years for the Mediterranean Sea. This basically means that the ocean system is forced by historic atmospheric reanalysis where observed data and

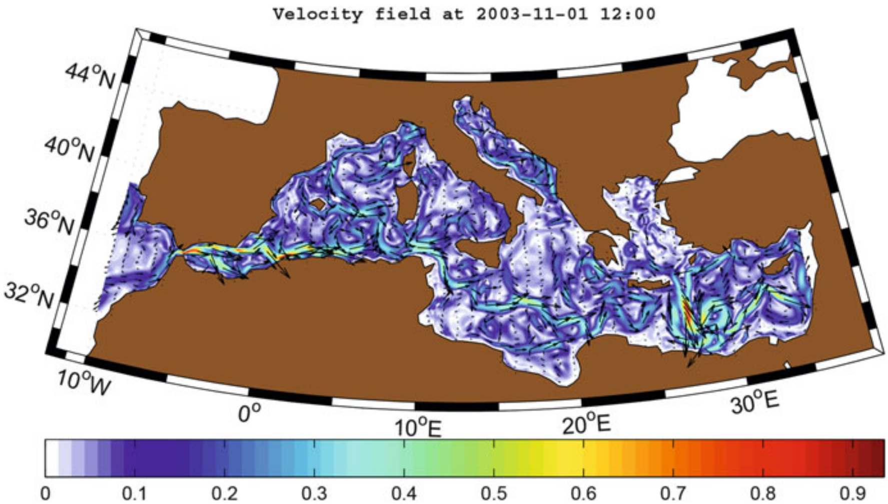

Fig. 1 Snapshot of the module of the surface velocity field (in m/s) produced by NEMO-MED12 hindcasts

model analysis have been combined to provide continuous spatiotemporal forcing fields over several years.

For modelling purposes we consider the spill as formed by discrete parcels mainly dragged by winds and advected by ocean currents. Thereby the temporal evolution of spills can be simulated in a first approach essentially using long term time series of winds and current fields provided by a hindcast simulation. In this chapter, we use the NEMO-MED12 model for the ocean currents [15], which is a Mediterranean configuration of the NEMO model [16] with a stretched grid in latitude of 1/12° of resolution corresponding to a cell range of about 6–8 km. It has a variable vertical resolution with 50 z-levels being of about 1 m at the surface, 20 m at 100 m depth and 460 m at the bottom. The ocean model has been forced with winds obtained from the ARPERA atmospheric model [17], a dynamical downscaling of the European Center for Medium Weather and Forecasting products. Time series of atmospheric fluxes and wind stress at 50 km resolution have been used during the period 1998 to 2007. As an example, Fig. 1 depicts a snapshot of the oceanic surface velocity field obtained from this hindcast. It can be seen that the major well-known features of the Mediterranean surface circulation, as the Algerian Current, the Mid-Ionian Jet or the Liguro-Provençal Current, are reproduced and agree with classical surface circulation schemes [e.g. 18, 19].

Producing an exhaustive set of basin scale beaching probability maps is a huge computational task, if not unsolvable giving the great amount of degrees of freedom. For this reason, in this chapter we show partial results defining different strategies to get oil beaching probability maps. To illustrate it, we will keep a simplified version of the Lagrangian model of spills retaining the processes that mainly influence the predictability at long scales: the current advection and the wind drag. In fact the intrinsic unpredictability of both the atmosphere and ocean dynamics and the uncertainties of the initial conditions are crucial aspects for forecasting the long term evolution. In the simplified Lagrangian model, each particle evolves according to the following differential equation:

$$\frac{d\mathbf{x}}{dt} = \mathbf{u_C} + \alpha \cdot \mathbf{u_W}, \tag{1}$$

where $\mathbf{x}$ is the vector position of an oil particle. The particle is advected by the water current $\mathbf{u_C}$, and the wind action $\alpha \cdot \mathbf{u_W}$, where α is related with the wind drag being $\mathbf{u_W}$ the wind velocity at standard level of 10 m. In the hindcast product we are using, the wind forcing is provided in terms of wind stress at the surface, τ_s. Thus, to obtain $\mathbf{u_W}$ at the 10 m level, we consider the boundary layer logarithmic law near the air–water surface [20],

$$u_W(z) = \left(\frac{u_*}{k}\right) \ln\left(\frac{z}{z_0}\right), \tag{2}$$

$u_w(z)$ is the mean wind at any level z, k is the von Kármán constant ($k \simeq 0.4$), u_* is the characteristic velocity associated with the intensity of turbulent fluctuations and z_0 is the roughness length. Taking into account that

$$\tau_s = \rho_a \ u_*^2, \tag{3}$$

where ρ_a is the air density and the scaling law proposed by [21], one gets

$$z_0 = \frac{\beta u_*^2}{g} = \frac{\beta \tau_s}{\rho_a g}, \tag{4}$$

where $\beta = 0.016$ for the sea [see p. 381 in 22]. At this point, the wind drag term in Eq. (1) can be expressed as a function of the surface stress by replacing the roughness length in Eq. (2) and establishing $z = 10$ m. The same procedure is applied to both, meridional and zonal, components of velocity to obtain

$$\frac{d\mathbf{x}}{dt} = \mathbf{u_C} + \frac{\alpha}{\sqrt{\rho_a} k} \left(\sqrt{\tau_{s_U}} \ln\left(\frac{10 \rho_a g}{\beta \ \tau_{s_U}}\right), \sqrt{\tau_{s_V}} \ln\left(\frac{10 \ \rho_a g}{\beta \ \tau_{s_V}}\right)\right), \tag{5}$$

where τ_{s_U}, τ_{s_V} are, respectively, the zonal and meridional wind stresses at the surface and $\alpha \simeq 0.03$ according to [23].

Compared with short term forecasts, long time computations can be more affected by round-off errors of the numerical approximation. So here a fifth-order Runge–Kutta method is used to perform the numerical integration of equation 5. There are several choices for spatial-time interpolation of the velocity field but the most appropriate combination, in terms of having enough good mathematical properties and accuracy, is to use bicubic spatial interpolation in space and third order Lagrange polynomials in time. Although there exist interpolating methods with higher accuracy this choice provides accurate results at a moderate computational cost (see [24] for a detailed discussion on different interpolating methods).

A final aspect to be considered in the production of the beaching probability maps is to establish a beaching criteria for oil particles. In the simulation a particle runs aground when it is close to the coast (i.e. the particle is inside a grid cell where at least one of its vertexes is land) and the particle drifts less than roughly 500 m during the last 24 h. The beaching probability is then computed as the fraction of particles which have reached a coastline segment. For the results here presented we have decided to divide the Mediterranean coastline into segments of 50 km length to produce beaching probability maps. This is a reasonable compromise according to the model resolution of the ocean hindcast. A rectilinear coastline segment will be roughly characterised by 5 model grid cells which is a length long enough to compensate for the poor representation of the coastline by the model grid.

3 Beaching Probability Maps

According to the ISO-based risk management framework adopted for oil spills risk assessment the first step is to identify the sources of risk [14, 25]. The sources of oil spills are mostly the result of point sources leaks but the sources of risk can be associated either to fixed points and areas (oil and gas platforms, coastal downloading facilities, bunkering areas, refineries, harbours, etc.) or to entire continuous lines as can be pipelines or main oil tanker paths. In Fig. 2 we show the accumulated detection of sea surface pollution over the period 2011–2014 over Spanish territorial waters made by aircrafts surveys and from satellite imagery. Although not all the detected slicks can be attributed to oil pollution, we can clearly distinguish the patterns aggregated around the trade lines connecting the Strait of Gibraltar with the Spanish, French and Italian harbours in the northwestern region of the western Mediterranean Basin. Although less evident some concentrations of slicks appear associated with those harbours disposing of refining and downloading infrastructures.

Consequently, we can think either in terms of beaching probability maps collecting the partial statistics associated with fixed point sources or maps associated with the risk of oil spills coming from intense traffic lines. This conceptual separation is somehow artificial but distinguishing between these kind of sources is directly linked to the computational resources needed to elaborate beaching probability maps. In fact a global picture that includes these specific cases can be in principle generated by dealing with a uniformly dense distribution of point sources across the whole basin. Nevertheless, in the following we show results going from some cases considering long time effects from single point sources to those coming from a uniform distribution of point sources covering the whole basin but limited to relative short times.

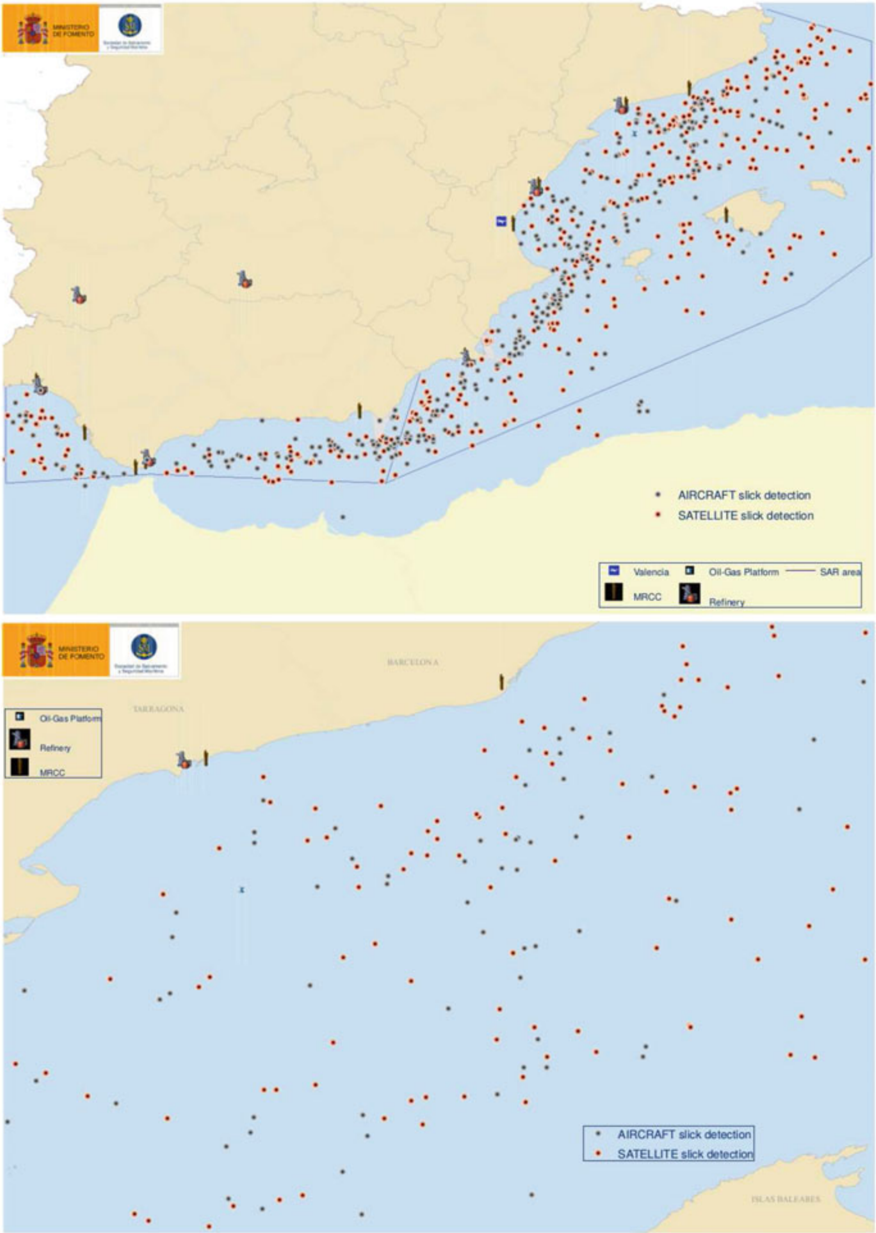

Fig. 2 Maps of slicks detected with aircraft and satellite in the period 2011–2014. The *top figure* shows the slicks detected in the Spanish Mediterranean waters and the *bottom* shows slicks detected around the area of the *Casablanca* oil platform and *Woodford* position. *Dots* in *red* correspond to satellite detection through the CleanSeaNet program combining information from RADARSAT, COSMO-SKYMED and ENVISAT radar images. *Dots* in *black* are detection by specialised CASA 235 aircraft units operated by the Search and Rescue Spanish Agency (SASEMAR)

3.1 Beaching Maps from One Single Point

Among the isolated point sources, oil and gas platforms are a clear example of a single source of risk. However, there are also many other sources that are candidates to produce continuous slicks with the circumstance that its origin can be unnoticed by surveillance and early warning systems. These are ship wrecks that may leak fuel or crude because marine corrosion may damage their hulls structures [26]. It may arise not only from relatively recent and well-monitored situations, as the *Prestige* wreck or the *MT Haven* wreck in the Gulf of Genoa [27] but also from older cases. Of particular relevance are sunken vessels during the World War II [28] that presently are aged enough to be seriously damaged by the action of marine corrosion and which may release diverse pollution substances [29]. These cases can be unnoticed during routine surveillance because the leak may be detected away from its origin and somehow hidden among the marine traffic activity; in fact this was the reported case of the *SS Jacob Luckenback* incident [30]. In the Western Mediterranean there is a significant concentration of World War II sunken vessels along the Algerian coast and in the Levantine Basin (see [27] from the compilation made by [28]). A real recent case was the *Woodford* incident (see Fig. 3), a British tanker sunk during the Spanish Civil war in 1937. A leak of light fuel in year 2008 from its tanks was initially reported as of "unknown origin" by fishing vessels operating in the region around the wreck. In this case the spills almost disappeared after several days because were mainly composed of highly volatile light fuel. The adopted solution was to adequately empty the leaking tanks and re-seal the rest of the hull.

Beaching probability maps associated with such situations can be analysed in advance to assess those cases that may be of serious concern. To illustrate a case like this one, we have chosen the point source located at the *Woodford* sunken position (0°45.65′, 40°08.94′) on the western shelf of the Spanish Mediterranean coast (Fig. 4). A continuous and regular release of virtual particles has been considered to perform the analysis of oil beaching. Different sizes and shapes can be considered to release particles at the point source in order to better model the shape and size of the configuration representing the spill, but for the case here presented, we have selected a 3×3 square centred at the point source with 200 m of separation between particles roughly corresponding to a characteristic ship wreck size. We have repeated this procedure every 0.1 h for the whole period of the available hindcast data (9 years period) which represents a total amount of roughly 300,000 tracking trajectories emanating from the point source.

In Fig. 4 one can see that the coast around Valencia City (from Jávea to Castellón de la Plana, red and yellow colours in Fig. 4) would be affected by an oil spill coming from the vessel. Quantitatively speaking if an oil spill of 100 t occurred at that point, then over 5 t of oil would reach the coast around the Valencia City. But as it can be noticed there are other places with non-negligible probabilities (green, yellow and orange colours scale) which are also affected. Notably the northwestern coast of Majorca Island. By order of importance, segments along the coastline of

Fig. 3 *Left*: The *Woodford* tanker proceeding from Kontanz to Valencia was sunk by the Italian submarine *Diaspro* in 1937. *Right*: Spill from *Woodford* tanks as observed from aerial surveillance (courtesy of SASEMAR)

Fig. 4 Beaching probability map for a spill produced at *Woodford* sunk position (the vessel icon in the image). The *vertical line* in Gibraltar Strait indicates the percentage of particles which reach the Atlantic Ocean

Gulf of Valencia and other areas as the northern coast of the Balearic Islands or the region around Ebro's Delta would also be affected. Specially relevant is the area around the Ebro's Delta, of high ecological and economical interest, where the simulation shows that approximately 3 t of oil could reach the delta. This value is relatively low compared with the other segments, but given its higher vulnerability, a great ecological and economic impact should be expected in this area. It is worth to notice that some segments far away from the point source as some segments in the northern Tunisian coast, may also receive a relatively medium quantity of oil. In Fig. 5, one can see the histogram of the time needed for particles to reach the northern Tunisian coast. The first particle arrives after the first 25 days and the last one needs about 450 days. However, the mean time of beaching at the Tunisian

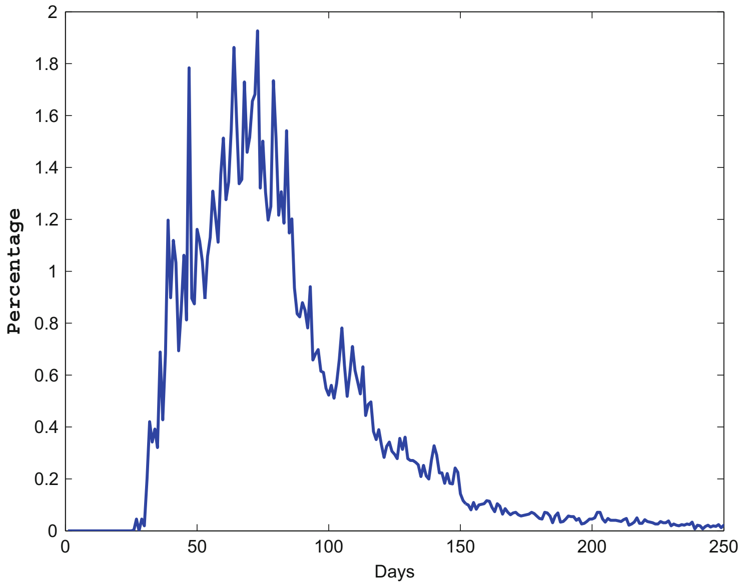

Fig. 5 Histogram of the time required for particles to reach the northern Tunisian coast. In the plot is depicted the percentage of particles reaching the Tunisian coast each day

coast from the *Woodford* is around 60–80 days and 50% of released particles reached the Tunisian coast in the first 70 days.

We consider now another case representing a point source related to an active oil drilling platform, the *Casablanca* oil platform operated by REPSOL S.A., located on the northeast shelf of the Western Mediterranean Sea, also close to the Ebro's Delta (Fig. 6). One can see that the coast slightly north and around Barcelona would be affected by an oil spill coming from the platform. Quantitatively speaking if an oil spill of 100 t occurs at the platform, then over 15 t of oil will reach the coast around Barcelona area. Similarly to the *Woodford* case other places with non-negligible probability are also affected. Notably the northwestern coast of Majorca with similar pollution levels as in the Barcelona area. The rest of affected segments by order of importance are qualitatively the same as those found for the Woodford source. However it is remarkable that the area around the Ebro's Delta would receive a bigger quantity of oil compared with the Woodford case. The simulation shows that approximately 5 t of oil could reach the Ebro's Delta.

According to the release procedure, these maps represent the total beaching probability associated with a point source but beaching probability maps may depend in general on the time of the year at which the spill is produced — see [31] for a discussion about this issue. Probably the observed differences in distinct periods are produced by different seasonal wind and currents regimes.

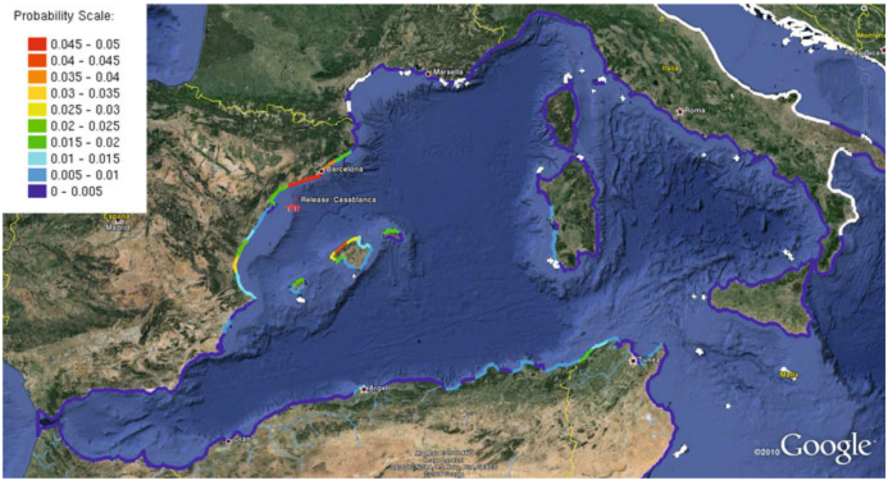

Fig. 6 Beaching probability map for a spill produced at the *Casablanca* oil platform (the *red platform icon* in the image). The *vertical line* in Gibraltar Strait indicates the percentage of particles which reach the Atlantic Ocean

3.2 Beaching Maps for a Traffic Line

Now, we focus our attention in the generation of beaching oil maps considering major traffic lines of tankers traversing the Mediterranean Basin. The main routes of tankers have been compiled in the geographical information system on marine trade elaborated during the SAFEMED project (Maritime traffic flows and risk analysis in the Mediterranean sea, see http://safemedgis.rempec.org/). Figure 7 depicts the main paths of oil tankers through the Mediterranean Sea. The red lines are the main routes for crude oil tankers for the year 2005. In Fig. 7, the major traffic activity can be seen concentrated along the route from Strait of Gibraltar to Suez Canal being the natural path towards the harbours in the north of Europe. Besides, additional secondary routes in terms of oil trade activity linked to several Mediterranean harbours with downloading facilities, as Genoa, Marseille, Tarragona, Arzew, together with the trade line linking the Black Sea, should also be considered as potential sources for incidents involving spills. Here is opportune to note that even if data correspond to 2005, around teen years ago from now, tankers routes remain similar and associated with major downloading infrastructures which remain actives more than this period. The line thickness represents the intensity of the traffic in 2005 which may differ from the present situation but shape and location can be reasonably assumed to be located at the same place.

We have produced an oil beaching map for the main tanker line going from Strait of Gibraltar to Suez Canal. Probably, the most accurate way of producing a beaching map would be to release particles in a randomly way along the traffic route, taking into account the probability density function associated with the oil

Fig. 7 Main paths of oil tankers through the Mediterranean Sea. *Black* and *grey dots* are main ports were crude oil tankers have been calling in year 2005. *Red lines* are main routes for crude oil tankers for year 2005 and *lines* in *orange* are the main traffic routes for the same year. (*Source*: Med GIS on Maritime Traffic from EU funded Safemed Project, see http://www.safemedgis.rempec.org/)

traffic intensity along the route. Unfortunately, we did not have access to such information so here we have proceeded to compute the map in a different way. We have equally distributed a set of points along the route and we have released our test particles in each selected point in the same way as for a point source (Sect. 3.1). Then, we have computed the percentage of particles reaching each coastline segment coming from all the points in the line and distributed every 70–100 km along the route (Fig. 8). This implies 43 point sources along this tanker route where 12.8 millions of particles have been released producing the beaching map depicted in Fig. 9. Somehow expected, the main result is that the northern coastline of the Mediterranean would be much less affected than the southern coastline. In fact, in the northern coastline, there are several places that will not receive oil at all (white segments). In the southern coastline, the most affected regions correspond to segments in the northern Tunisian coast and the coastline close to Alexandria, from the Nile's Delta to Gulf of Kanais (orange, yellow and green segments in Fig. 9), that spanning a coastline length of about 250 km. Alexandria is an important tourist destination that may suffer a strongly economic impact as a result of an incident along the tanker traffic line. Also notice that Alexandria is the Egypt's largest seaport, serving approximately 80 % of Egypt's imports and exports and being an important industrial node for oil and natural gas pipelines from Suez.

3.3 Beaching Maps for the Whole Mediterranean Basin

In this last section we introduce a beaching map where the information showed is not the most affected coastline but the probability of reaching the coast for a spill

Fig. 8 Selected point sources associated with the oil tanker route joining the Suez Canal with the Gibraltar Strait

Fig. 9 Oil beaching probability map associated with the main oil tanker route joining the Suez Canal with the Gibraltar Strait. The *vertical line* in Gibraltar Strait indicates the percentage of particles which reach the Atlantic Ocean

coming from any point located in the Mediterranean during a fixed amount of time. We follow the similar idea as the "coastal approach" map defined by [32], where a map point in the basin is associated with a quantity representing the percentage of particles released in that point entering into a band of 2 grid cells thickness adjacent to the coastline in a fixed number of days. Thus, we release particles simultaneously in a set of points uniformly distributed across the whole Mediterranean Basin and then, we allow the particles to evolve during a determined number of days checking

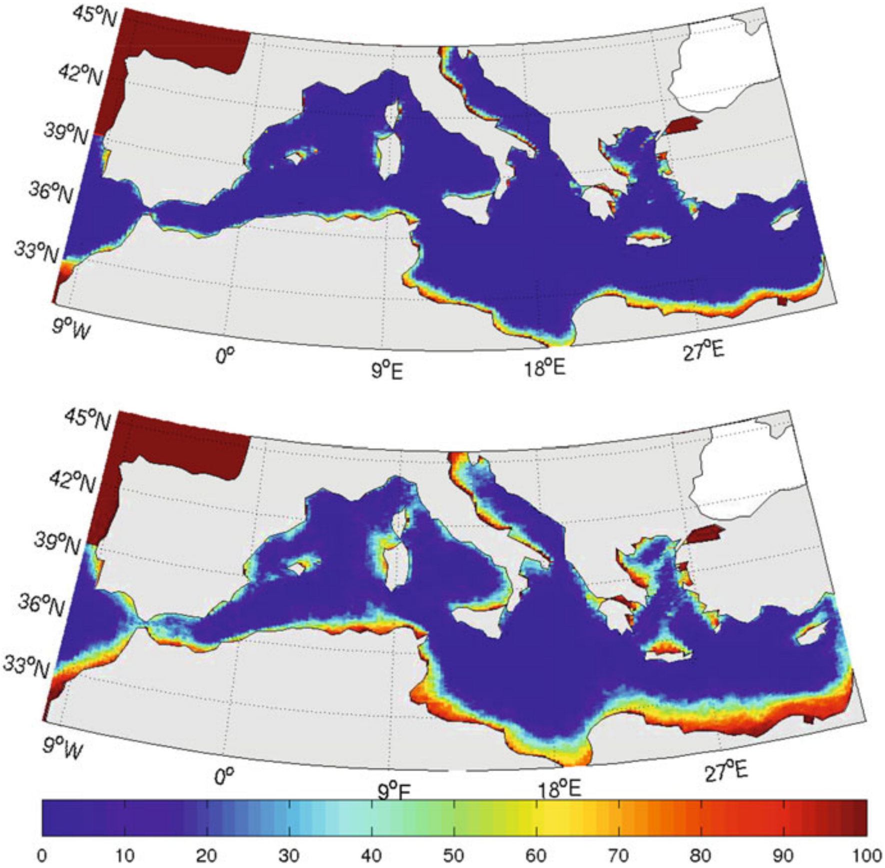

Fig. 10 Beaching maps for the Mediterranean Sea. At each point, the colour represents the percentage of particles beached in a fixed interval of time. The evolution time is one week (*top*) and two weeks (*bottom*), respectively

whether they have beached according to the criteria presented in Sect. 2. Then new particles are released again Δt days later and we repeat the process for all the available time series in the hindcast.

In Figs. 10 and 11 some maps following the former procedure are depicted. A 200×200 grid of point sources is defined covering all the Mediterranean region. At each grid point a particle every $\Delta t = 100$ days has been released, which means that over 30 particles have been discharged in every grid point over the whole period. Then four temporal intervals have been considered, one and two weeks, and one and two months, respectively, to get the percentage of particles which have beached from every grid point in that temporal interval. The dark red colour in the Marmara Sea and North and South of the Western Iberian boundary correspond to model limits, so the results close to these boundaries are not very reliable. In these plots,

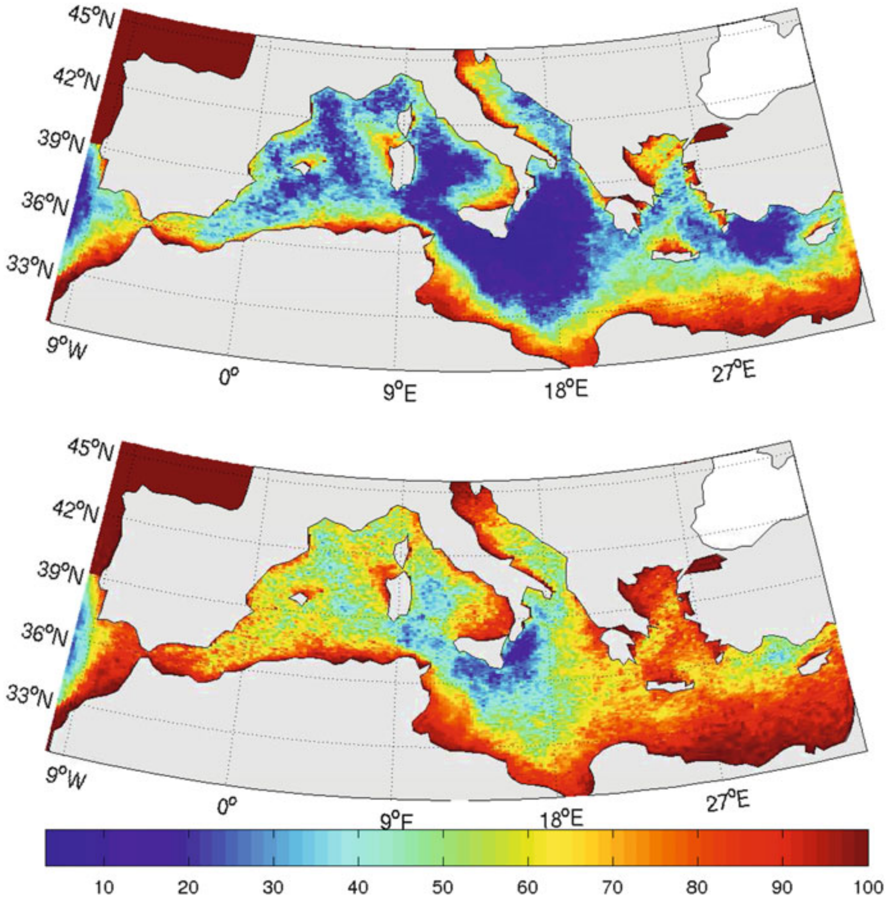

Fig. 11 Beaching maps for the Mediterranean Sea. At each point, the colour represents the percentage of particles beached in a fixed interval of time. The evolution time is one month (*top*) and two months (*bottom*), respectively

one can see how the percentage of beached particles increases progressively as they are advected for a longer time period in the whole domain. As it is expected point sources relatively close to the coast are able to run aground for short times, in less than 2 weeks (Fig. 10). After two weeks of evolution these regions expand notably encompassing bigger offshore source regions in the western Thyrrenian sea, along the Tunisia–Libyan coast but mainly along the southern part of the Levantine Basin. In particular in this region almost all the particles would beach at any of the scales considered and the region with all the particles beached (red colour) grows faster in time than in other areas. Additional smaller regions as the Alboran Sea, the western coast of Sardinia and the Aegean Sea also contribute.

Big areas of the central Algerian Basin, the Ionian Sea, part of the southern Turkish coast in front of the Antalya coast or the Gulf of Lyon almost do not contribute (bluish colour, less than 30 % of particles have beached). In some cases, this can be due to the presence of relatively strong along-coastal currents or the influence of strong westerly winds preventing particles to reach the coast. In other cases, eddies and characteristic closed circulation patterns retain particles offshore at the scale of one or two months. Moreover, after two months of evolution, there still exist regions where only a few number of particles would reach the coast (bluish colour).

The maps depicted in Figs. 10 and 11 highlight the importance to take into account the long time evolution of an oil spill. In the case that a spill is not rapidly or easily controlled in less than a week, actual forecasting systems will not be able to manage in a proper manner the long term evolution of the spill. The results presented in this section qualitatively agree with the dispersion analysis made by [32] (see their Fig. 10) using a different ocean circulation model. The differences found here are probably due to the differences in the forcing winds or the beaching criteria as we have considered a better definition of the coastline, but also to the different hindcast period used to carry the simulations.

4 Summary

The Mediterranean Basin is a very sensible environmental area submitted to a great anthropic pressure from dense human settlements in its margins, a great amount of tourist activities and because is the most important route for marine trade between Asia and Europe. All these activities are related to several pathways by which the oil pollution enters into the marine environment. As indicated in the introduction, although cumulative statistics show a decreasing trend in number of oil spills, large spills still constitute a major fraction of the total amount of oil spilt in marine water. Their environmental and socio-economic impact is a complex combination of several individual factors and circumstances that renders difficult to totally prevent it. In many past incidents around the world, large spills response cannot be totally afforded even with transnational efforts and spills may still remain for a long time when the environmental circumstances lead the spill to remain at sea for scales of weeks and months. In this chapter, we have undertaken a statistical approach in the Mediterranean Basin to face the uncertainties and limitations inherent of any short time meteo-oceanic oil spill forecasting system.

A set of different beaching probability maps have been computed simulating the oil spills trajectories as virtual particles released from some sources of risk in the Mediterranean Sea. A selection of maps have been produced to avoid the complexity and difficulty, that would have represented carrying an exhaustive and complete analysis due to the required extremely demanding computational costs. The statistical analysis is based on available hindcasts of 9 years of the Mediterranean circulation forced with realistic atmospheric forcing conditions coming from standard meteorological products. Some characteristic sources of danger have been considered: point sources typically associated with fixed infrastructures (drilling oil–gas platforms) but also potential spills coming from sunken vessels and lines sources associated with tankers paths. Thus, the proposed maps constitute a first guess of the percentage of spills that will beach at a certain coastline segment according to their sources. As expected from the two examples of point sources considered, the most exposed areas are in general associated with nearby segments but not in a trivial way. For these two point sources, located relatively close, the affected segments are in general qualitatively similar but the most exposed segments for each one are located in opposite directions. The *Casablanca* oil platform source affects majorly the northward coastline while the *Woodford* source affects the southwards part. The maps also reveal that far away coastline segments, as those located around the Majorca Island and certain segments of the Tunisian coast also appear affected. It is interesting to remark this result because, this non-local affectation seen in the maps highlights the long range connectivity between regions and therefore stresses the need of carrying basin scale approaches. The third example, associated with the most relevant tanker route crossing the whole Mediterranean Basin, just confirms that a great portion of the north African coast is the most exposed in case of an accident and particularly around the Nile's Delta.

A third type of map is proposed to quantify the percentage of particles that reach the coast in a fixed period of time from any source located in the whole basin. The results show that, for short times, the points around the coasts provide the major fraction of beaching particles with special relevance for points along the African coast, the western part of Adriatic coast and around the Aegean Sea. This remains qualitatively similar up to two weeks while for longer times a general contribution from the whole Mediterranean surface is evident. However the major part of offshore sources are located in the eastern part of the Levantine Basin, the Aegean, the north Adriatic, the western Thyrrenian and in the Alboran Sea close to the Strait of Gibraltar. Once again this clearly demonstrates that regional approaches are adequate for short time events because most of the contributions arise from points relatively close to the coast, while for longer times greater regions should be taken into account to have a more representative view of the long range connectivity.

Nevertheless, due to the high computational cost of carrying these simulations and the high number of degrees of freedom in terms of processes, parameters and points sources considered the results are obviously of limited extent. The beaching probability maps computed here have several limitations. First they rely on the use of hindcast simulations which may no capture all the variability of the Mediterranean circulation and the results depend strongly on the representation of such circulation. In particular, several aspects like the spatial resolution and the model ability to deal with the dynamical processes in coastal areas, upon which ultimately depend the beaching of particles, are probably the most relevant. As soon as forecasting systems are improved and new hindcats are delivered the results can be recomputed. Precisely, at the time of preparing this manuscript a new recent hindcast of the Mediterranean circulation has been released by Copernicus CMEMS service. However, the long term statistics contribute in fact to diminish the influence of this lack of representation. A second important limitation is the simplified oil transport model used here lacking other transport processes as Stokes drift, stochastic dispersion but also the fate processes as evaporation, weathering, emulsification, etc. [e.g. 3, 33, 34]. In this work the oil is considered to have a long persistence time characteristic of heavy oils. Most of spills regularly surveyed are composed by light oils and other hydrocarbon substances having generally shorter persistence times due to those fate processes. Then the results here presented are quite conservative in the sense that beaching probabilities could be overestimated, in particular for those segments far away from the source. Thus, the computed beaching maps are useful as a proxy for the heaviest oils or even for other kind of pollutants with long persistence times in water like plastics. Note, for example, the non-negligible beaching in the Tunisian segments obtained from the *Woodford* and *Casablanca* point source. The results show that the characteristic time scales where a significant quantity of oil reaches this area is of the order of 2–2.5 months which fits within the range of persistence of heavy crude oils. Finally, other aspect that can be improved in dealing with beaching maps associated with line sources is to reflect better the traffic intensity, for example, by weighting the segments according to the traffic probability density function.

In summary the production of oil beaching maps through Lagrangian simulations are a highly valuable piece of information in the management of an oil spill emergency and can be elaborated routinely even in the absence of incidents. Limitations are not insurmountable and depend basically on computationally resources and can be easily generalised and extended to additional sources of danger or applied to other kind of pollutants. The statistical approach based on beaching probability maps, as the one shown here, does not have to be considered as a substitute of short time forecasts essential for the immediate days after an incident but may be used as a good complementary information to assess decision makers since the first days of a spill event. These maps combined with vulnerability analysis lead to provide valuable information for a better preparedness and contingency plans.

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Conclusions for Part I: The International Context

Angela Carpenter and Andrey G. Kostianoy

Abstract This book (Part 1 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 chapters presented at the international level. Those chapters consider the history, sources and volumes of oil pollution entering the Mediterranean Sea, including data presented in Part II of the volume in national case studies. It also examines oil inputs from specific sources including shipping and oil transportation and oil and gas production. Chapters in Part I also examine the role of international and regional bodies including the International Maritime Organization and European Maritime Safety Agency, together with activities undertaken for oil spill prevention and intervention under the Convention for the Protection of the Mediterranean Sea Against Pollution (Barcelona Convention, 1976) and its Protocols, for example. The role of the Regional Marine Pollution Emergency Response Centre for the Mediterranean Region (REMPEC) is considered through its work on a regional strategy for oil pollution prevention and response. Numerical modelling of oil pollution in the eastern and western Mediterranean and oil spill forecasting and beaching probability are also discussed at an international level, complementing the national case studies presented in Part II. 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 chapters present a picture of oil pollution from a range of sources (shipping – accidental, operational and illegal), offshore oil and gas exploration and exploitation, and coastal refineries, and the roles of the various agencies in

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preparedness and prevention activities, 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, Numerical modelling, Offshore oil and gas exploration and production, Offshore oil and gas installations, Oil pollution, Oil pollution preparedness and response, REMPEC, Satellite monitoring, Shipping

Contents

The Mediterranean Sea lies between the coasts of Europe to the north, Africa to the south, Asia to the east at the entrance to the Dardanelles Strait and the Strait of Gibraltar in the west [1]. It is divided into two deep basins in the west and east and further subdivided into a number of seas, the Balearic (Iberian), Ligurian, Tyrrhenian, Ionian, Adriatic and Aegean Seas [1]. The Mediterranean Sea is one of the most highly valued in the world, with a range of ecosystems including coastal habitats, estuaries, coastal plains, wetlands and rocky shores, for example [2]. It was estimated that around 472 million people lived in Mediterranean countries in 2010, mainly concentrated in coastal areas, and the population of the region is forecast to grow to 572 million by 2030, increasing environmental pressures such as demand for water and energy, waste generation and impacts on coastal areas around the region [3].

The Mediterranean Sea is one of the busiest in the world with around 15% of global shipping activity by number of calls [4] and around 200 million passenger movements annually [3]. The major shipping routes in the region (see Fig. 1) are dominated by crude oil shipments coming from the eastern Black Sea, Northern Egypt and the Persian Gulf (via the Suez Canal) [5], and around two-thirds of all merchant vessel voyages in the Mediterranean, some 325,000 voyages in 2007 and 2013, are internal to the region [4].

In addition to shipping activities which contribute to environmental concerns in the region as a result of CO_2 emissions, oil pollution and marine litter [3], a range of oil and gas exploration and production activities around the Mediterranean also generate waste and release to the water and air [6]. Offshore oil and gas reserves are located in the waters of Algeria, Croatia, Cyprus, Egypt, Greece, Israel, Italy, Lebanon, Libya, Montenegro, Palestine, Syria and Tunisia, and offshore exploration and exploitation activities are taking place in the eastern Mediterranean basin, for example [6].

Marine environmental protection of the Mediterranean Sea, including marine pollution control, falls at a regional level under the scope of the United Nations Environment Programme (UNEP) Regional Seas Programme and the 1975 Mediterranean Action Plan [7]. That Action Plan was approved and adopted by 16 Mediterranean countries and the European Community (now the European Union). EU member states are mainly located on the northern Mediterranean Sea (Spain, France, Italy, Slovenia, Croatia and Greece, together with the Island States of Cyprus and Malta). The non-EU countries bordering the Mediterranean are the Principality of

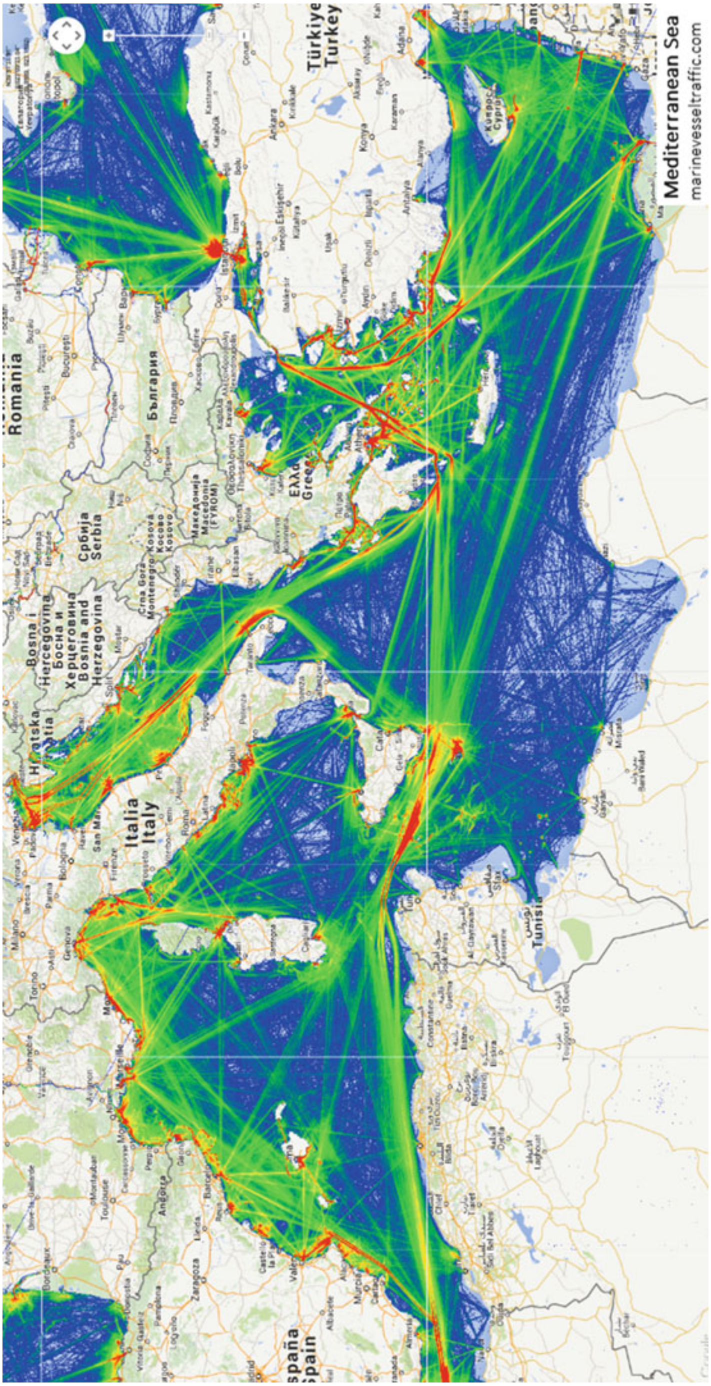

Fig. 1 Density map of ship traffic in the Mediterranean Sea (http://www.marinevesseltraffic.com/MEDITERRANEAN-SEA/ship-traffic-tracker, accessed on 27 August 2018)

Monaco, a sovereign city state on the French Riviera; Bosnia and Herzegovina, Montenegro and Albania (on the eastern Adriatic coast); Turkey, Syria, Lebanon and Israel (on the eastern Mediterranean coast); and Egypt, Libya, Tunisia, Algeria and Morocco (on the North African coast).

The Convention for the Protection of the Mediterranean Sea Against Pollution (Barcelona Convention) was subsequently adopted in 1976 in order to protect the marine environment across the whole region [8]. Contracting Parties (CPs) to that Convention includes all 21 Mediterranean coastal states plus the EU. Protocols to the Barcelona Convention cover activities such as dumping of pollutants from ships and aircraft, inputs of pollution from land-based sources and pollution from offshore exploration and exploitation, for example.[1] Also in 1976, the Regional Oil Combating Centre (ROCC; subsequently renamed the Regional Marine Pollution Emergency Response Centre in the Mediterranean Region (REMPEC) in 1989) was established to help Mediterranean coastal states cooperate in combatting oil pollution and deal with marine pollution emergencies [9]. Over more than four decades, REMPEC has undertaken activities such as assisting CPs to draft and adopt national marine pollution contingency plans, develop subregional agreements and strengthen national legislation in areas such as pollution prevention and response and pollution from ships, for example. The roles of the various bodies at different levels (regional, international, EU) as they relate to oil pollution in the Mediterranean Sea are examined in specific chapters in this book [4, 14–16].

This book (Part I of the volume) also provides an international context to oil pollution in the Mediterranean Sea [10–13] and examines aspects of numerical modelling, oil spill response and beaching probability in the region [17–20]. The focus of Part II of the volume, published separately, is on “national activities”, with chapters written by experts and practitioners covering Spain, France, Italy, the Adriatic coastal waters of Italy, Slovenia, Croatia, Turkey, Israel, Cyprus and Algeria [21–30].

The history, sources and volumes of oil pollution in the Mediterranean Sea are set out, and highlight that while oil inputs come from a range of sources including shipping activities, oil and gas platforms, ports and oil terminals, land-based sources, natural seeps and atmospheric inputs [10], large quantities of oil are transported around the region (18% of global crude shipments), and, of the top 180 oil spills over 6,000 tonnes globally since the early 1960s, a number have occurred in the Mediterranean Sea [10]. The first of these was the *Fina Norvege* spill close to Sardinia in May 1966, and 6,000 tonne plus spills have continued to occur ever since [10]. Of the top 20 major oil spills since 1967, only 2 have occurred in Mediterranean waters (see Table 1). In addition, operational oil spills of between 1 and 10 tonnes occur almost daily in the region, from a range of different ship types, so that oil pollution continues to be an ongoing problem [10].

[1]For the latest status of signatures and ratifications of the Barcelona Convention and its Protocols (last notification received: 20 September 2018), see http://web.unep.org/unepmap/ and select the link from that page.

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	*Uriquiola*	1976	La Coruna, Spain	100,000
11	*Hawaiian Patriot*	1977	300 nautical miles off Honolulu	95,000
12	*Independenta*	1979	Bosphorus, Turkey	94,000
13	*Jacob Maersk*	1975	Oporto, Portugal	88,000
14	*Braer*	1993	Shetland Islands, UK	85,000
15	*Aegean Sea*	1992	La Coruna, Spain	74,000
16	*Sea Empress*	1996	Milford Haven, UK	72,000
17	*Khark 5*	1989	120 nautical miles off the Atlantic coast of Morocco	70,000
18	*Nova*	1985	Off Kharg Island, Gulf of Iran	70,000
19	*Katina P*	1992	Off Maputo, Mozambique	67,000
20	*Prestige*	2002	Off Galicia, Spain	63,000

Note: Quantities rounded to the nearest thousand tonnes. Spills highlighted in grey occurred in the Mediterranean Sea
Source: ITOPF [31]

The most recent spill to occur in the Mediterranean was the result of a collision between the Tunisian vessel *Ulysse* and the Cypriot container ship *CSL Virginia* on 7 October 2018, in open sea 28 km from land north of Cap Corse (Corsica). As a result, the hull of the *Ulysse* became lodged in the starboard side of the *CSL Virginia,* breaching tanks and leading to the leakage of bunker fuel which formed 7 distinct slicks over around 25 km [32]. The emergency tow vessel *Abeille Flandre* was on site on the afternoon of 7 October and the oil spill response vessel *Jason*, carrying oil spill response equipment, arrived that evening. The RAMOGEPOL agreement, an emergency response plan set up between France, Italy and Monaco in 1993, to combat accidental marine pollution incidents, was activated that same day [32]. Over the period to 1 November 2018, and in the face of increasingly bad weather, it was necessary to clean up beaches in many areas as oil was washed ashore (49 beaches had been impacted by 25 October and that number continued to grow). By 3 November, oil residues were still being detected on new beaches, and public access was banned. It was estimated that around 530 m^3 of fuel escaped from the

CSL Virginia, although the majority of bunker fuel in the hold and double hull was pumped out by 24 October [32]. Clean-up activities involved more than 500 people, 34 French and Italian vessels and 11 French and Italian aircraft, plus a range of organisations, state experts and private organisations [32]. This accident serves to illustrate the significant impact that oil spills can have, particularly when oil is washed ashore. The spill did not, however, constitute a major spill as it was less than 6,000 tonnes in size. In respect of oil spills from shipping activities, it should be noted that with the introduction of double-hulled tankers and segregated tanks, the US National Research Council (NRC) in 2003 estimated that transport spills represent less than 13% of total petroleum releases worldwide, while spills from platforms represent 3% of the worldwide total [33]. By comparison, natural seeps of oil from reservoirs represent around 46% of worldwide total petroleum releases to the sea according to the NRC Report [33]. Figures identify very different percentage values for these releases, however vary very widely, with, for example, the percentage for natural seeps being 11% according to a 1993 report [34] and 7% according to an undated report by another report [35]. A 2003 report by UNESCO, however, indicates that of the 400,000 to 1,000,000 tonnes of oil pollution entering the Mediterranean Sea each year, 50% comes from routine ship operations and 50% from land-based sources via surface runoff [36].

It is therefore clear that there is little consensus on sources and volumes of oil entering the marine environment of the Mediterranean Sea. Kostianoy and Carpenter [10], by taking into account a range of information sources, including chapters in this volume (see e.g. [4, 18, 22]) to suggest that the volume lies somewhere in the middle of the range of between 1,600 and 1,000,000 million tonnes per year, i.e. and estimated value of 50,000 to 100,000 tonnes per year. Dividing the upper 100,000 tonnes figure by 365 days gives an input of 2,740 tonnes per day from shipping sources alone. They conclude that it is therefore not possible to know the real value of oil pollution in the Mediterranean Sea or the contribution made by the various sources.

Shipping and oil transportation is the subject of the next chapter in Part I [11] which reviews the different ways of transporting crude oil and refined oil in large quantities around the Mediterranean region. The chapter also examines the current state of knowledge relating to ship accidents and operational spills in the region and, more broadly, also examines how satellite imagery may help in providing proof of oil pollution and identifying the polluter [11]. The Mediterranean Sea is used by a diverse range of shipping fleets including fishing vessels (coastal and high seas fishing), cruise ships, leisure craft, military vessels (including the US Navy), passenger vessels (passenger only and cargo plus passenger), cargo vessels, container carriers, tankers, plus offshore oil exploration and exploration vessels. All such vessels will produce oil which has the potential of being released into the marine environment, for example, through generation of oily waste in bilge water or used lubricating oil. If oil is released at sea, perhaps due to a lack of adequate facilities on land in which to discharge waste or due to financial considerations, this is called an "operational spill". The quantity of such a spill may be small (from a few litres to a few cubic metres), and sailors may not consider that they are polluting the ocean in this event since the volumes are so small [11]. It is generally the much larger accidental spills of thousands of tonnes that are the most visible: spills coming as a result of the grounding of a vessel or a collision, as in the most recent example off Corsica [32], or from human error, a technical failure or sinking in a storm [11]. Spills can also come from oil pipelines, but, while pipelines do exist in the Mediterranean, a map of the network around the region was not available and so it was not possible to identify specific incidents [11]. As illustrated in Fig. 1, the Mediterranean is crossed by many shipping routes, including those which cross the region along its east-west axis and those which serve the regions ports. In the case of oil transportation, ships from the Black Sea and Middle East countries travel through the Turkish Straits and Red Sea and the Suez Canal, accordingly, to enter the Mediterranean Sea and then travel either on to countries around the region or further into Western Europe via the Strait of Gibraltar [11].

Fourteen large accidental oil spills occurred between 1970 and 2015, attributable to specific vessels. By far the largest of these accidents was the sinking of the *MV Haven* on 11 April 1991, off the Port of Genoa, Italy [36]. The tanker, with 144,000 tonnes of Iranian heavy crude oil on board, caught fire at anchor, exploded and sank in three parts. Over 10,000 tonnes were spilt before the sinking, and oil continued to be released for more than a year, with contamination on the coastlines of Italy, France and Monaco [36]. While aerial surveillance to monitor for oil pollution has been taking place over many years (see also [16]), more recently satellite technology has become available to obtain close to real-time radar satellite imagery (see also [23] in Part II of this volume), with satellite images being accepted as additional (but not sole) proof in the prosecution of polluters [11]. However, small operational spills are more frequent and less visible and quantifiable, since ship owners and ship masters are aware that they are unlikely to be seen pollution, particularly outside the waters of France, Spain and Italy where aerial surveillance takes place. This again emphasises the uncertainty of volumes of oil entering the Mediterranean Sea, particularly in the eastern basin, and along the coast of North Africa [11].

The eastern Mediterranean basin, including the east coast of Italy in the Adriatic Sea, is also the location of the majority of oil and gas exploration and production activities in the Mediterranean, together with the offshore waters of Algeria [12]. A 2002 estimate of oil reserves in the region indicates that there was a reserve of around 50 billion barrels of oil and 8 trillion m^3 of gas in the region, while there were over 350 wells drilled for offshore production in the waters of the eastern basin in 2005 [12]. During the last decade, offshore exploration has taken place off the coast of Cyprus, and in the oil fields offshore of northern Greece, offshore oil and gas fields have been developed off the coast of Egypt, gas has been discovered in the Leviathan field off Israel, and oil and gas exploration and production are also taking place off the coasts of Algeria, Spain, Libya, Tunisia, Malta and Turkey [12]. All of these activities pose a serious threat to the marine and coastal zone environment (see, e.g. [25]), to the seabed and to sea-bottom habitats, with oil spills able to persist in the marine environment for many years [37–39]. Kostianoy and Carpenter [12] present an overview of oil and gas production in the Mediterranean Sea by country, identifying existing fields and ongoing exploration activities [12]. They highlight that while the Mediterranean was not known as an important region for oil and gas, offshore exploration and exploitation activities pose a serious threat to the environment, with the potential for accidental spills from offshore platforms and from the ships that service them, particularly since those activities are taking place in areas that are less easily accessible than the older oil and gas fields and in deeper waters, for example [12]. At the same time, the older fields are maturing and ageing, also potentially adding to the risk of accidental discharges [12]. For EU member states, however, measures are in place to reduce the likelihood of major accidents and to improve response mechanisms in the event of an accident taking place [40].

A range of international measures covering all the states around the Mediterranean Sea are in place for oil spill intervention [13]. Oil spill intervention is described as being “planned actions and measures taken during a casualty to limit damage or avoid a spill or contain the amount spilled altogether”, while “intervention” specifically “concerns first responders and instantaneous decisions during an incident to correct ‘imminent’ situations” [13]. Global regulations relating to oil pollution control stem from the 1982 UN Convention on the Law of the Sea (UNCLOS) or regulations and standards adopted by the International Maritime Organization (IMO) [41]. The first of these measures is the 1990 International Convention on Oil Pollution Preparedness, Response and Cooperation (OPRC; [42]) which requires states to cooperate in the event of a pollution incident occurring, 19 out of 23 Mediterranean countries being parties to this convention[2] [13]. The second international measure is the 1969 Intervention Convention, which relates to oil pollution on the high seas [43] under which parties to the Convention are required to take measures to “prevent, mitigate or eliminate grave and imminent danger to their coastline or related interests from pollution or threat of pollution of the sea by oil, following upon a maritime casualty or acts related to such a casualty, which may reasonably be expected to result in major harmful consequences” [43]. Thirteen Mediterranean coastal states are parties to this Convention[3] [13]. At a regional level, the Convention for the Protection of the Mediterranean Sea Against Pollution (Barcelona Convention [8]), discussed in more detail at [14], has 22 CPs, while its 7 protocols, covering aspects ranging from the dumping from ships and aircraft to the most recent protocol on integrated coastal zone management, have been ratified by varying numbers of CPs (see [14] for full details of ratifications at November 2016).

A further international measure relating specifically to ships and including a requirement for ships over 400 gross tonnage (GT) to have on board an approved Ship Oil Pollution Emergency Plan (SOPEP) is the International Convention for the Prevention of Pollution from Ships 1973, as modified by the Protocol of 1978

[2]The 19 Mediterranean Sea countries that are parties to the OPRC are Gibraltar, Spain, France, Monaco, Italy, Malta, Slovenia, Egypt, Croatia, Albania, Greece, Turkey, Syria, Lebanon, Israel, Libya, Tunisia, Algeria and Morocco.

[3]The 13 Mediterranean Sea countries that are parties to the Intervention Convention are Spain, France, Monaco, Italy, Slovenia, Egypt, Croatia, Montenegro, Syria, Lebanon, Tunisia, Algeria and Morocco.

(MARPOL 73/78) [44]. All countries bounding the Mediterranean (apart from Bosnia and Herzegovina) are parties to Annex I (oil pollution) and Annex II (noxious liquid substances) of MARPOL 73/78 [13]. The role of the IMO as it relates to maritime transportation, oil pollution, oil tankers, illicit vessel discharges and the Mediterranean Sea as a special area under MARPOL 73/78 Annex I is examined in detail in a separate chapter [4].

The issue of maritime zones, i.e. internal waters, territorial sea, contiguous zones and exclusive economic zones (EEZs), in the Mediterranean region remains unresolved in some cases [13]. Some coastal states have claimed territorial waters out to 12 nautical miles (nm), while others have claimed contiguous zones to 24 nm [13]. Other countries have claimed zones under national legislation, while in other cases, boundary delimitations are as a result of bilateral or international agreements between various nations [13]. This can pose issues in determining responsibility for intervention and in national contingency planning to deal with pollution incidents as, for example, concerned authorities must be aware of what constitutes coastal waters and geographical coordinates outside areas under national jurisdiction, while the smoothness of oil spill intervention activities will depend on how national response or national contingency plans have been developed [13]. It is therefore concluded here that Mediterranean coastal states must define a solid action plan that will deal with accidental vessel source pollution before a major accident occurs and that prevention through "intervention" is better than having to clean up the effects of such pollution [13].

As noted previously, the IMO has a specific role to play in terms of oil pollution from shipping, particularly since both operational and accidental spills can have a significant impact on the environment [4]. The Mediterranean Sea is recognized as being an area where there are marine environments with special oceanographic and ecological features, and, as the "ubiquity, abundance, and broadness of detected operational spills in the Mediterranean" have long been recognized, this resulted in the IMO granting "special area" status to the region in November 1973 [4]. As a "special area", operational discharges are strictly limited, and special mandatory methods for preventing sea pollution are required [45]. The definitions of the different types of operational oil pollution is examined, with legal operational discharges (where oil is discharged in waste at levels under 15 parts per million (ppm)) is allowed, but illegal discharges exceeding 15 ppm are not. As legal discharges can be visible in the wake of a ship for several hours, even at levels less than 15 ppm, it can be difficult to differentiate between what is legal and what is not [4]. "Special area" status requires that operational discharges can only occur in specific circumstances, including that the tanker is not within a special area and is more than 50 nautical miles from the nearest land, and that it has in operation an oil discharge monitoring, control system and a slop tank arrangement [46].

Crude oil shipments dominate the shipping lanes of the Mediterranean, with an estimated 220 million tonnes of crude oil loaded in Mediterranean ports in 2006; the vast majority of crude oil is either loaded or unloaded through a very small number of ports [4]. Within the Mediterranean region, these vessels may be inspected under one of two port state control (PSC) regimes, either the Mediterranean MOU, parties to which are Algeria, Cyprus, Egypt, Israel, Jordan, Lebanon, Malta, Morocco, Syria, Tunisia, Turkey and the Palestine Authority in its membership [47], or the Paris MOU which includes Croatia, Cyprus, France, Greece, Italy, Malta, Slovenia and Spain as parties from the Mediterranean Sea region [48]. Bosnia and Herzegovina, Libya, Monaco and Montenegro are not part of the MOU regimes [4]. Under these regimes, a proportion of foreign flag vessels[4] calling into a port are inspected against a series of measures to ensure compliance with them, including MARPOL 73/78 and its Annexes. While MARPOL 73/78 Annex I places very strict limits on discharges from oil tankers, which may be selected for inspection under the MOU regimes, it is important to note that smaller vessels under 400 GT are not regulated or inspected in the same way [4]. Operational discharges from smaller vessels therefore continue to pose a threat as a source of oil entering the marine environment [4]. At the same time, Mediterranean coastal states must work with the IMO and the MOU regimes to develop stronger regional cooperation to deal with oil pollution [4].

The Barcelona Convention and its Protocols [8] provide a legislative "soft law" tool for Mediterranean state CPs to individually, and collaboratively, tackle oil pollution entering the marine environment from all potential sources [14]. The Barcelona Convention was adopted in 1976, following the establishment of the UNEP Regional Seas Programme in 1974 and the Mediterranean Action Plan (MAP) in 1975. The MAP provided a framework for countries in the region to address common challenges in protecting the Mediterranean marine environment [49]. For example, under the MAP, a number of Regional Activity Centres were established, including two with direct relevance to oil pollution, the Mediterranean Pollution Assessment and Control Programme (MED POL) and the Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea (REMPEC). The latter is discussed in more detail in Part I of this volume [15]. The main objective of MED POL is prevention and elimination of land-based pollution, and it provides assistance to CPs in facilitation National Action Plans addressing such pollution. REMPEC has at its main objective preventing and reducing pollution from ships and combatting pollution in case of an emergency, and its activities include strengthening the capacity of CPs to develop preparedness for and response to accidental marine pollution. For example, REMPEC provides assistance to CPs in the event of an emergency under the Offshore Protocol of the Barcelona Convention which relates to exploration and exploitation activities on the continental shelf and seabed [50]. A key component of the Barcelona Convention is that CPs are required to take measures to prevent, abate, combat and, to the fullest extent possible, eliminate pollution of the Mediterranean Sea. There are seven protocols of the Barcelona Convention, and these have continued to develop and be amended over time, with the latest protocol being adopted as recently as 2008. Four protocols have relevance to oil pollution:

[4]The standard inspection target for the nine regional MOUs is 15% of foreign flagged vessels, although the Paris MOU has an annual ship inspection target of 25%.

- The *Protocol for the Prevention of Pollution in the Mediterranean Sea by Dumping from Ships and Aircraft* (Dumping Protocol), adopted in 1976 and renamed the *Protocol for the Prevention and Elimination of Pollution of the Mediterranean Sea by Dumping from Ships and Aircraft or Incineration at Sea* following amendments adopted in 1995. The amended Dumping Protocol [51] has not yet entered into force.
- The *Protocol Concerning Cooperation in Combatting Pollution of the Mediterranean Sea by Oil and Other Harmful Substances in the Case of Emergency* (Emergency Protocol), adopted in 1976 and subsequently amended to be the *Protocol Concerning Cooperation in Preventing Pollution from Ships and, in Cases of Emergency, Combating Pollution of the Mediterranean Sea* (Prevention and Emergency Protocol), with the revised Protocol being adopted in 2002 [52].
- The *Protocol for the Protection of the Mediterranean Sea against Pollution from Land-Based Sources and Activities* (LBS Protocol), adopted in 1980 and subsequently amended in 1996 [53].
- 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), adopted in 1994 [50].

Key requirements of these protocols, together with status of signatures and ratifications, are set out in detail by Carpenter and Johansson [14], who note that these protocols have gained a greater level of acceptance from CPs than the remaining protocols which cover Specially Protected Areas and Biological Diversity (adopted originally in 1985), Transboundary Movements of Hazardous Wastes and their Disposal (adopted in 1996) and Integrated Coastal Zone Management in the Mediterranean (adopted in 2008) [14]. This illustrates the fact that CPs have made commitments to combat oil pollution in the region. These commitments are, as noted above, supported by the work of REMPEC which, over its 40 plus year history, has made a number of contributions to the Mediterranean region [54]. Those contributions include providing 15 CPs with assistance in drafting, reviewing and adopting national marine pollution contingency plans, assisting groups of countries to draft and adopt subregional agreements on preparedness and response to spills, assisting countries in emergency situations through its 24/7 centre which deals with such emergencies and compiling an inventory of port reception facilities in non-EU CPs to help ship captains identify where wastes under MARPOL 73/78 can be discharged; and in the area of illicit discharges of oil from ships, REMPEC has assisted CPs to the Barcelona Convention in strengthening national legislation on the enforcement of MARPOL, while a Mediterranean Network of Law Enforcement Officials relating to MARPOL (MENELAS) was established in 2013 [54]. REMPEC plays a major role in pollution prevention by promoting ratification of international conventions such as MARPOL, assisting national Maritime Administrations to deal with implementation and enforcement of those conventions and providing training courses and assessments of technical and legal expertise in CPs [15]. It has also been involved in setting up marine pollution monitoring and surveillance systems in response to continuing illicit discharges in the region, in addition to services provided under the European Maritime Safety Agency's *CleanSeaNet* service (EMSA CSN; see [16]), and assisted CPs in establishing legal frameworks to transpose MARPOL Annex I into national legislation [14]. REMPEC therefore plays a role in marine pollution preparedness, for example, through contingency planning at national and subregional levels, and also in the area of marine pollution response [15]. For example, any CP can request assistance from REMPEC in the event of a pollution incident, with REMPEC able to request information from the Mediterranean Operational Network for the global Ocean Observing System (MONGOOS) virtual Emergency Response Office (ERO) on meteo-oceanographic data and oil spill simulations to predict the movement of oil at sea [55]. REMPEC can also provide in site assistance in the event of an accident, as occurred following the sinking of the oil tanker *Agia Zoni II* off Piraeus, Greece, in September 2017 [56]. Greece requested assistance from REMPEC to deal with this incident, and two representatives of the Mediterranean Assistance Unit (established in 1993 to offer expert advice) were mobilised to the accident to provide technical support in areas such as sunken oil assessment, removal techniques and how to remove oil from sandy beaches [15]. REMPEC has also been involved in areas such as facilitating the exchange of technical and scientific information through the establishment of a Mediterranean Technical Working Group (MTWG) in 2000, commissioning of a study on maritime traffic flows in the Mediterranean sea, participating in projects to develop oil spill forecasting models and coordinating a project on oil-polluted shoreline clean up, for example [15]. Finally, REMPEC also plays a role in promoting government and industry cooperation, including the Mediterranean oil industry, to provide national and regional overviews covering areas such as oil pollution preparedness, prevention and contingency planning [15]. REMPEC therefore provides a common forum for sharing and transferring information between countries, is a vehicle to harmonise existing legal and administrative frameworks and helps to continuously build capacity in the Mediterranean Sea region [15].

EMSA also plays a significant role in the Mediterranean Sea region, and in EU waters more broadly (see, e.g. [57]), through monitoring and protecting those regions from pollution and ensuring the safety and security of ships operating within them [16]. EMSA was established in 2000 as a specialist agency of the EU to provide EU member states and the Commission with technical and scientific support in the area of maritime safety and to monitor implementation of EU legislation in that area [16]. EMSA was, in part, created as a result of growing concern about maritime transport and oil pollution following the sinking of the single-hull tanker *Erika*, 400 km off the tip of Brittany in December 1999. About 20,000 tonnes of heavy fuel oil was spilled following the break-up of the vessel into two parts, with strong winds and currents eventually causing the oil to wash ashore initially on Christmas Day 1999, and the oil eventually polluted 400 km of French shoreline between Finistère and Charente-Maritime [58]. As a result of this spill, the EU adopted a range of measures including the accelerated phasing in of double-hulled oil tankers and measures on safety of maritime traffic and more effective pollution prevention from ships [16]. An EU directive on the provision of port reception facilities was also developed [59] so that EU facilities would be required to provide adequate facilities into which ships could discharge wastes (including oily wastes), and EMSA had responsibility to establish information and monitoring systems to identify ships that failed to do so [16].

EMSA now has a range of tasks including facilitating cooperation between EU MS on development of a common methodology for maritime accident investigation and implementation tasks in areas such as sustainable shipping, ballast water, greenhouse gases and ship recycling, for example [60]. Operational tasks of EMSA include traffic monitoring, search and rescue, fisheries monitoring and pollution monitoring, for example [61]. EMSA also provides a Pollution Response Service as one of its operational tasks, with a fleet of oil spill response vessels (OSRVs) accessible to EU member states and also available to third-party states if deemed necessary [16]. Requests for vessels and equipment are dealt with by an Emergency Response Coordination Centre (ERCC) [16]. In January 2015, there were 18 OSRVs, 8 of which were based in the Mediterranean region, with a wide variety of equipment on board to deal with oil spills [62].

In relation to pollution monitoring, EMSA uses data collected from satellite monitoring under *CleanSeaNet* (CSN), a European satellite-based oil spill and vessel detection service [63] which uses a range of satellites such as RADARSAT-1, RADARSAT-2, COSMO-SkyMed (see [23]) and the European Space Agency's SAR satellites (Sentinel-1 satellites) [64]. A review of available data from EMSA CSN for the period 2008–2011 for EU member states identifies that the average number of detections per satellite image by country is highest in the waters of Cyprus (2.38 detections per image), Greece (1.51) and Italy (1.03). France (0.25) and Spain (0.52) have lower values, but EMSA CSN data includes both the Mediterranean and Atlantic waters of those countries. Croatia (0.45) and Malta (0.41) have low values for detections per image. It can be concluded that, while satellite imagery can be an important tool for identifying oil pollution, which then should be confirmed as oil by aerial surveillance, for example, the low levels of satellite images received across the region and lack of aircraft verification of images in the eastern Mediterranean, means that it is difficult to determine the number of spills that occur in the region [16]. The actual number of spills is likely to be much higher than the available data suggests, and there is a need for increased satellite monitoring, making it more likely that ships will be caught illegally discharging in the region. In this respect, Italy has invested in COSMO-SkyMed satellite mission which, with its frequent revisiting time, day and night and all weather acquisition capability, provides an essential part of its national plan to deal with marine oil pollution, in conjunction with aerial and naval monitoring activities [23].

Numerical oil spill modelling is another area with major applications in helping to deal with marine oil pollution. Two chapters in Part I [17–18] outline how oil spill models have been used to contribute to preparedness and response activities and used during real oil pollution accidents, in the eastern and western Mediterranean Sea. In the eastern Mediterranean, the probability of a major oil spill is high when considering the increasing level of exploration and exploitation activities, particularly in the Levantine Basin [17]. There is also an increased risk of spills from the enlargement of the Suez Canal in Egypt to accommodate larger tankers, the upgrading of refineries and ports in the region to accommodate anticipated increases in ship tonnage and volumes of hydrocarbons produced from new fields and the lack of mitigation plans and real-time surveying technology to help agencies respond to a major spill [17]. As a result, a number of initiatives have been developed in recent years to improve preparedness and response measures, including the EU-funded *Mediterranean Decision Support System for Marine Safety* (MEDESS-4MS) project, together with making marine data accessible via the *European Marine Observation and Data Network* (EMODnet); for example, satellite data from the *Copernicus Marine Environment Monitoring Service* (CMEMS) is available via EMODnet [17]. A wide range of activities are taking place in the eastern Mediterranean including the use of geo-information systems, use of satellite synthetic aperture radar (SAR) and an automatic identification system (AIS) to track vessels, and these contribute to the detection of oil slicks, together with their sources [17]. The majority of SAR-detected oil slicks are along the main shipping routes in the Levantine Basin and arise from operational activities such as degassing and deballasting, together with illegal discharges [17]. Using four well-established oil spill models in the Mediterranean Sea, data from CMEMS, national ocean-forecasting systems and a range of other data sources, MEDESS-4MS uses information on the position of an oil slick to predict its movement for oil spill crisis management actors, for example [17]. The oil spill models used by MEDESS-4MS – MEDSLIK, MEDSLIK-II, POSEIDON and OMS – are examined in detail in by Zodiatis et al. [17], including their use in real-life oil spills from a range of sources, to show that operational oil spill modelling can, for example, identify likely oil movements and potential impacts on coastal areas [17]. Research is ongoing in the area of oil spill risk mapping, but it can be concluded that the availability of near real-time satellite SAR images of potential slicks and operational oil spill predictions under projects such as MEDESS-4MS have resulted in the development of harmonized basic standards for oil spill modelling in the region. At the same time, cooperation across the oceanographic community, REMPEC and EMSA CSN opens up access to oil spill predictions to all nations across the region [17].

MEDESS-4MS, together with the EU-funded *Tracking Oil Spills and Coastal Awareness Network* (TOSCA) project, also contributes to oil spill modelling in the western Mediterranean Sea, an area where the highest vessel densities are found along routes connecting the Strait of Gibraltar to the eastern Mediterranean and connecting northern African ports with European ports [18]. The work of TOSCA, which also has partners in the eastern Mediterranean, mainly deals with the use of coastal high-frequency radars and on Lagrangian drifters to observe oil slicks [18]. Many numerical tools and applications have been developed over the last 15 years, and their use in the western and eastern basins, together with the central area of the Mediterranean, is briefly outlined by Cucco and Daniel [18], who then examine the use of such models in the western Mediterranean basin in more detail. These include the MOTHY drift model, developed and implemented by Meteo-France and operational since 1994 [65], and the *Bonifacio Oil Spill Operational Model* (BOOM) system developed at the Italian National Research Council and operational since 2010 [66]. The MOTHY and BOOM models have been tested using real-life oil pollution incidents to reproduce the drift of oil slicks and provide a more accurate picture of surface currents in the western Mediterranean [18]. MOTHY has been used to reproduce the drift of the slick from the *MV Haven* accident, while BOOM has been used to evaluate the risk from hydrocarbons in the Bonifacio Strait between Corsica and Sardinia, using an accidental spill occurring in January 2011, for example [18]. It is concluded, however, that more work is needed to improve oil spill modelling in the western Mediterranean by coupling existing state-of-the-art operational systems in the region with forecasting systems that predict the main atmospheric and ocean dynamics at different spatial scales, in order to properly respond to both open sea and coastal water pollution events [18].

In addition to MEDESS-4MS and TOSCA, a number of other oil spill response projects have been funded by the EU [19]. These projects provide support for oil spill response capacity and capability across the Mediterranean region and include projects relating to monitoring marine operations and detecting spills and development of oil spill dispersion models and projects to strengthen the capacity of oil spill response authorities including by developing innovating oil spill combating technologies [19]. Zodiatis and Kirkos [19] provide details of a number of such projects, including their scope, funding source, website details, main objectives and main results. Examples of such projects include providing biotechnological solutions to clean up oil spills (the *Kill Spill Project*), providing technological solutions such as autonomous *Elimination Units for Marine Oil Pollution* (EU-MOP project) and developing a modelling tool to study behaviour of oil in the event of a deep sea leak (*METANE Project*) [19]. In total 16 such projects are presented, the majority of which have been completed in the last 10 years. These projects illustrate how the EU is actively seeking to protect the Mediterranean sea from oil spills, by bringing together academic and operational aspects of oil spill response, strengthening relations between oil spill response authorities in different Mediterranean countries, developing a better understanding of oil spill behaviour and developing new solutions for cleaning up oil spills, for example [19].

Complementary to many of the vulnerability analysis and risk assessment tools used in the Mediterranean would be a number of different types of oil spill beaching maps [20]. Such maps include oil beaching maps for a single point, for example oil platform, oil beaching maps for a traffic line to analyse the main oil tanker routes in the region, and maps showing the percentage of particles which reach the coast at given points in time (1 week, 2 weeks, 1 month, e.g.) [20]. In defining these different map types, a statistical perspective is used to gain insight into the long-term behaviour of oil spills and their evolution as they are influenced by oceanic and atmospheric flows. Lagrangian simulations have been performed to hindcast these flows using past observations for the Mediterranean Sea. Beaching probability maps for single point, traffic line and the whole Mediterranean basin are examined in detail and cover specific oil pollution releases from ships, sunken vessels and oil platforms. The proposed maps are seen as a first guess as to the percentage of spills that will beach on certain coastline segments, depending on their source [20]. It is noted that there is a high computational cost of carrying out simulations in the production of such maps and that there are a number of limitations in doing so including the need for improved spatial resolution, for long-term statistics and for information on drift, dispersion and fate processes (evaporation, emulsification and weathering, e.g.) for different types of oil [20]. However, the production of oil beaching maps through Lagrangian simulations provide highly valuable information to assist in the management of an oil spill emergency, and it is considered that the limitations can be overcome with increased computational resources; such maps can be generalizable and applicable in different types of situations and for different pollutants [20]. The maps can, when combined with vulnerability analysis, provide information to be used in preparedness and contingency plans [20].

While overall, in Part II of this volume, we concluded that levels of oil pollution in the Mediterranean Sea have, from the standpoint of the individual national cases, improved significantly over recent years, the chapters in Part I illustrate the continued need for cooperation between nations under the Barcelona Convention and through REMPEC, for example. They also identify that while the number of major oil spills from ships occur infrequently, there still remains an issue of small operational spills and illegal spills within the region [4, 10–12]. A number of countries have still not ratified the various protocols of the Barcelona Convention or developed agreements with neighbouring countries to deal with transboundary oil pollution, illustrating that there is still much to do at a legislative level. Much of the research into the development of models and tools is funded by the EU [17–19], as is the development of oil spill beaching probability maps [20], although there is some non-EU state cooperation in various projects. Satellite images of oil slicks can be provided by EMSA to non-EU states, while a range of oil spill recovery vessels and equipment is also available upon request by third-party states, if deemed necessary [16]. At first glance it therefore appears that there is only a limited contribution to these activities by non-EU countries. Unfortunately, chapters in Part II of this volume examining non-EU countries were only obtained from Turkey [28], Israel [29] and Algeria [31], all of which have in place activities and agreements to prevent or deal with oil pollution from ships and oil and gas exploration and exploitation activities. Additionally, the north African countries of Egypt, Libya, Morocco and Tunisia are signatories to the Barcelona Convention and at least some of its Protocols.

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