European Association of Remote Sensing Companies

Sentinels Benefits Study (SeBS)

A Case Study

Clean Seas in the Mediterranean

May 2022

Client:	ESA
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Date of Delivery:	October 2022
Version:	1
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Version	Date	Comment
1st Issue	October 2022	

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Funded by the EU and ESA – ESA Contract Number: 4000119743/17/I-SBo.

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Setting the Scene

Lucas lived with his wife Francesca and daughter Karen in a small apartment over their cafe right next to the harbour in the small Corsican town of Solenzara. (Scaffa Rossa beach). He had moved to the town when they had gotten married. Francesca's family then ran the seafront bar, and it was understood that he and Francesca would take it over – which they had done.

For Lucas had grown up in Muxia in Galicia on the north-west coast of Spain where his family also ran a shore-front bar near the port. He had always wondered if their similarity in upbringing was a factor that attracted him to Francesca. It meant that they had similar roots even if grown in different cultures. And they both understood the cafe business. His family bar was closer to a restaurant than that in Solenzara and he had brought that know-how into their current business, so they also offered a good menu which was sought after from far around.

Karen came into the bar to see him with the news that there had been a collision between 2 ships close to the shore off Porto Vecchio. Her brother, Roberto, was in the local coastguard and had been called to go out to look at and assess the situation.

Lucas shuddered; the news brought back bad memories from 20 years ago before he left Muxia. In 2002, the oil tanker Prestige had broken up leaking some 60,000 tonnes of heavy oil into the sea. It was a tough time for their bar and for the whole local community. But they had been gratified and quite astonished at the reaction of people from everywhere in Spain and even from other countries.

He could see it clearly even now. The waves crashing onto the beaches were black, like a black cloak smothering everything. The sand, the rocks everything was black except those cleaning up the mess who were like ghosts, or aliens, all white. It seemed interminable as they cleaned one part, more oil was washed ashore onto another part, often parts which had been cleaned already. In the temporary beach camps, he had met students from as far away as Japan who had come to help. They told him that they had been walking the trail to Santiago de Compostella and had heard about the accident. They immediately turned north and headed for the coast to help the rescue effort.

Birds, seals, fish, mammals were all badly affected which had marked him for life. He had joined the movement *Nunca Mais* ("never again") as indeed had most of his friends and family. For there was anger and frustration in the small town at the squabbling between the Spanish government, the Galician authority and the town over who was responsible and who got credit. But all they cared about was restoring a form of normal life.

It had been a nightmare for the family bar as well. The local fishermen were unable to work for months until the fish and especially the shellfish had been passed by the scientists as being fit for eating. People were supported but times were hard for everyone, and the bar had struggled to stay afloat.

At first, they had offered free drinks and meals for those who had come to help. But as time went on, they could no longer afford to, and few people had money to pay. But they had been lucky. As they were in the centre of things, people gathered there in the evenings to share news. Other bars, less central lost almost all their business and closed. It lasted for nearly 18 months before things returned to normal as the following summer tourist numbers fell away as people decided not to risk holidaying by the beaches where the pollution had fallen.

As he thought about it, Lucas prayed that this would not happen again in Solenzara. They had just refurbished the bar, taking out a large loan to do so and they needed all their revenues to pay this off. There were a number of diving schools in the town which brought in a lot of visitors most of the year round. If the oil damaged the local marine ecosystem, then it could also discourage people from coming. He shuddered again at the thought of it.

That evening, Karen's brother, Roberto, came into the bar and Lucas rushed to ask him about the accident. One ship had sailed straight into another one which had been at anchor. It was a strange accident.

"And the oil?", prompted Lucas, "you recall that I lived through the Prestige accident, and it was a terrible time."

"Well, we have already received satellite pictures from the European service which show that quite a lot of oil has escaped" explained Roberto. "They estimate around 1500 tonnes of heavy fuel oil has leaked. They are monitoring the situation and the operation has started to confine and recover the oil. It is very different from when the Prestige went down as there were very few satellites at that time and no operational service. Nowadays, the European agency in Lisbon has access to several satellites and images are available within 20 minutes of the satellite passing over. Without them we should need to scramble aircraft but most of those are out on safety and rescue missions, so it will be hard to get good coverage from them."

"There are also ships on stand-by ready to support a recovery action. They are laying out booms to contain the oil and a clean-up ship is on the way to help recovery. It is very different from 20 years ago. We can also call on help from the Italian coastguard under the Ramoge agreement. I think our director is already calling his counterpart.

The current indications are that most of the oil will move away from the shore. The weather is forecast to remain calm over the next few days but with a strong storm coming in on Saturday there is a high risk of stopping the clean-up. Then the oil may be blown onto the shore but at the moment, we consider that the risk is small.

That is a relief said Lucas, I sure hope that you are right in that forecast.

It was a considerable strain over the next few days with a great deal of stress, but Roberto's optimism proved valid, and the shore saw very little oil on it. Even better for Lucas, the slick avoided the marine reserve where many of the diving clubs went. Business stayed firm and he was able to sleep soundly.

This story is entirely imaginary, although realistic based on our knowledge gained through the case interviews. It is introduced to provide an easy introduction into the core of the case. The places are real, although the characters, the conversation and the situation are entirely fictional.

Executive Summary

On 13th November 2002, the oil tanker Prestige started to break up off the coast of Galicia in Northern Spain. The French, Spanish and Portuguese governments all refused to allow the ship to seek shelter in a port and on 19th November, it broke up and sank about 200km off the Spanish coast, depositing over 60,000 cubic metres of oil into the sea. The spill polluted thousands of kilometres of coastline and more than one thousand beaches causing untold ecological damage. The cost of the clean-up operation has been judged as being as much as $2.8b[1].

The accident created high public awareness in Spain and across Europe and led to strengthened measures whereby countries co-operate to deal with oil spills. In 2002, as a measure to reduce the environmental damage and improve the efficiency and effectiveness capability to clean up oil spills, the European Union established the European Maritime Safety Agency (EMSA) which is charged with providing Europe-wide resources to improve the safety of the seas and to reduce pollution.

The Mediterranean Sea is one of the world's most sensitive marine environments and the location of one of the busiest shipping lanes in the world as vessels transit from the Suez Canal towards ports in Northern Europe. It is estimated that around 30% of all the world's oil passes through the narrow straits of Gibraltar, the Suez Canal or the Bosporus, with most of this passing close by the shores of Malta. Even if accidents are rare, ships captains save time and money by illegally washing their tanks whilst sailing. The consequent pollution causes considerable environmental damage to the marine ecosystem and leaves traces of oil on beaches otherwise enjoyed by bathers and holiday makers.

In April 2007, EMSA started providing a service called CleanSeaNet (CSN) using data from satellites to identify possible oil slicks, under a cooperation agreement between the European Space Agency (ESA) and EMSA on the use of Space-based Systems and Data in Support of Maritime Activities. Since 2015, this has included the use of Sentinel-1 images to produce the CSN service. EMSA's contracted experts analyse the images received to identify potential oil slicks and possible polluters, transfer this information to EMSA which in minutes sends alerts to authorised users nominated by the national competent authorities. For example, in Spain, one of the key organisations that has access to CSN is SASEMAR (Sociedad de Salvamento y Seguridad Marítima (literally: Maritime Safety and Rescue Society) and in Malta it is Transport Malta that receives the service.

The CleanSeaNet alert reports include not only the spill position and extent, but already a potential indication of the possible polluters by using vessel positioning information (e.g. automated identification system (AIS) coupled with forecasting or back casting models to try to identify the possible culprit. The process from acquisition of the images, analysis and delivery of the report by EMSA to the user usually takes less than 20 minutes as time is of the essence: spills drift, evaporate or dissipate and the verification activities conducted by the users need to start quicky. These involve

1 https://web.archive.org/web/20041208063142/http://www.newscientist.com/news/news.jsp?id=ns99994100

placing assets on scene of the potential spill, such as aircraft, helicopters or ships, that are sent to confirm and, if found to be positive, to seek further evidence on the nature of the slick. This will later be used to link the slick with the polluting vessel where possible.

Prosecutions will follow if the evidence is strong enough, but the surveillance process itself, which increases significantly the risk of being caught, is in itself a powerful deterrent. The number of polluting incidents has decreased over the last few years showing the importance of CSN to any enforcement mechanism. Furthermore, in the case of an accident as opposed to deliberate polluting acts, the ship's captain is discouraged from simply not reporting it since the risk of discovery is high.

Summary of Benefits along the value chain and Dimensions for CleanSeas in the Mediterranean.

In summary, since 2016, the Sentinel 1 data has enabled EMSA to monitor all European waters including the whole of the Mediterranean. As a result, illegal discharges are detected with a higher degree of certainty and the threat of subsequent prosecution has deterred ships captains from the actions leading to illegal oil spills. The amount of oil entering the marine ecosystem is strongly reduced so lowering the cost of any clean-up operation and increasing its effectiveness, and in any case reducing adverse impacts on sea life overall.

We have estimated the annual economic benefit from the use of CleanSeaNet and Sentinel data to protect the Mediterranean at between €41.7m and €81.1m. Even if the economic benefits are significant, the primary benefits from the use of Sentinel data lie on reducing the environmental impact and the capability to reduce the amount of oil and related products entering the marine environment.

We can conclude that the CleanSeaNet service operated by EMSA is making a major contribution to the cleanliness of the Mediterranean Sea. The economic benefit stemming from the use of Sentinel data is very high while many consider that the environmental benefits are even higher. Furthermore, EMSA offers training and collaborative reviews for the authorities in the coastal states which they are supporting. The networks so created provide important and crucial channels of communication when incidents occur, and action is required.

1 Introduction & Scope

1.1 The Context of this study

The analysis of the case study "Clean Seas in the Mediterranean" is carried out in the context of the 'The Sentinel Economic Benefits Study' (SeBS). This multi-year study is looking to develop cases showing how EO-derived products based on data generated by one or more Sentinel satellites deliver value to society and citizens. The Sentinel satellites form a crucial part of EU's Copernicus Programme, providing space-based observations on a full, free and open basis. Data coming from the Sentinels – together with other data collected by contributing missions and ground, sea or airborne instruments – is used to support key economic or societal areas such as agriculture, insurance, disaster management, climate change monitoring, etc. Sentinel data are thus a key component of the Copernicus Services, and a crucial source used by companies to deliver products and services helping different users across the globe.

1.2 What is the case all about?

Marine pollution is becoming an ever more critical problem affecting all waters around the world. International trade has led to ever higher volumes of ship traffic of which around 1/3rd is transporting oil or petroleum products. Fortunately, accidents are rare but when they occur the damage is immense. Unfortunately, illegal activities also lead to oil spills and consequent damage to the marine environment from oil.

A succession of accidents in the late 1960's (Torrey Canyon) and 1970's (Amoco Cadiz) stimulated governments to work together to introduce international legislation controlling the tankers transporting oil. Later, the Exxon Valdez, Erika and Prestige caused these rules to be tightened to prevent accidents and for governments to be better prepared to deal with spills when accidents do occur.

Our area of focus is the Mediterranean Sea which is host to one of the world's busiest shipping lanes. "Oil and gas tankers, the largest existing container vessels in the world, and ships transporting raw materials like ore and coal all sail close to the shores of the Mediterranean countries. The oil, either transported by sea, or used as fuel by ships, poses substantial environmental risks to the region. Because of this, effective measures are needed to prevent oil pollution from happening, as any such incident could lead to an environmental disaster which could take decades to overcome"[2].

Even before the Prestige accident in 2002, Europe was looking to strengthen the protection of the marine environment. This led to the introduction of legislation on Coastal Zone Management in 2002 and a Marine Strategy Framework directive in 2008. Concerns raised by this and previous accidents, also led to the formation of the European Maritime Safety Agency (EMSA) in 2002.

[2] REMPEC – Regional Marine Pollution Emergency Response Centre for the Mediterranean.

Since 2007, EMSA supports the routine monitoring of seas around Europe through the CleanSeaNet (CSN) service provided to all coastal Member States, EFTA countries (Norway and Iceland) and with partnership countries in the context of European Union Cooperation Projects. EMSA also performs other maritime surveillance activities especially for border monitoring in support of FRONTEX (the European Border Control Agency).

As a result, EMSA processes several thousand satellite images each year to detect possible oil spills which generate alerts which are sent to the EU member States. In 2020, 8276 SAR images were delivered to 35 coastal states and 8158 detections of possible oil spills. In cases of illegal oil discharges from a ship into the sea, CSN also provides information on the possible polluter and monitors the spread of the pollution supporting Coastal States during clean-up activities.

As a result, the number of illegal discharges, the time taken to respond when detected, and the threat from accidental oil spills have all been reduced so saving money and improving the marine environment.

1.3 How does this case relate to others?

There are very few direct, technical links between this case and others studied so far under the SeBS project (all cases can be found at https://earsc.org/sebs/all-cases/). However, cross-cutting analyses being performed within the SeBS project are exposing some interesting comparisons between this and some of the other cases in relation to the activity and responsibility of the public body concerned. For example in the case looking at Water Quality in Germany, the activity is helping the agency concerned to fulfil its mission more effectively. The satellite data allows the agencies to monitor much larger areas and more frequently thus providing better services for citizens, even going beyond what is required by current legislation (which was made in the absence of satellite data).

We have also noted similarities with the case of Forest Management in Sweden where, the service using satellite data is also changing the behaviour of the key actors. In Sweden, the 300,000 owners of forest are encouraged to behave according to best practice through the knowledge that their actions (or lack thereof) can be detected by the authorities. This is similar to the way we shall see that CleanSeaNet encourages ship's captains to not act illegally in creating oil pollution.

1.4 More About the Study

Each case study analysed in SEBS focuses on products and services which use data coming from Sentinel satellites, measuring the impact of that product or service throughout the value chain. The starting point is the primary user of the satellite data, followed by a step-by-step analysis whereby the operations of beneficiaries in each subsequent link of the value chain are analysed, all the way down to citizens and society. The full methodology which is used to analyse each case is described in detail in a dedicated report[3] which will be updated in line with findings of further cases as they are developed.

In this process, the main aim is to understand and demonstrate the value which is generated using satellite-based Earth Observations (EO) and particularly the data arising from the use of Copernicus Sentinel satellites. Each case study thus underlines the causal relationship between the use of Copernicus Sentinel satellite data and benefits resulting from their use, including increased productivity, more efficient and environmentally friendly operations, economic gains and improved quality of life, among others. The evaluated and demonstrated benefits can be used by:

- **Decision makers**: Having access to a portfolio of concrete cases where the benefits from the operational use of Sentinel data in decision making are clearly articulated, helps decision makers not only to justify future investments but also to direct them towards areas that most matter in their country or organisation.
- **Users:** Moving beyond a vague idea of how EO services can support more effective operations requires a concrete understanding of the benefits they can actually bring in similar cases. In this regard, it is both numbers and stories that can resonate with users and attract them to explore further or deeper uses of EO in their operational activities.
- **Service providers:** Solid argumentation around the economic and environmental benefits stemming from the use of EO, coupled with powerful storytelling, can become an effective marketing tool for service providers seeking to promote their solutions and for EARSC to promote the sector.

In the framework of this project, more than 20 case studies are being developed with reports to be published on each one. The study has started in March 2017 and currently is foreseen to continue into 2023.

1.5 Acknowledgements

Producing this case study report would have been impossible without the invaluable insights and kind assistance of key stakeholders. They helped us navigate across the various aspects of oil spill surveillance and operations. In particular, we wish to thank Teresa Cunha who introduced us to a number of the experts we have consulted. We wish to thank the following persons for their time spent talking with us to develop the case.

Teresa Cunha (EMSA)

Berta Blanco-Merula (SASEMAR)

Antonio Padial Sayas (SASEMAR)

Mevric Zammit (Transport Malta)

Juan Pena (OrbitalEOS)

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[3] SeBS Methodology, A practical guide for practioners, December 2020.

Angela Carpenter (University of Leeds)

Duarte Soares (International Tanker Owners Pollution Foundation)

Our time and availability to meet and discuss with experts was severely limited by the Covid pandemic and all interviews were conducted remotely. In more normal circumstances, the personal meetings, discussions and visits during field research lend a great richness to our understanding of the cases and the stories behind them. We should like to have the opportunity to meet with the various oil spill and environment experts cited in this report and to update with some personal perspectives. In the meantime, the story is still complete but maybe lacking in some details. We hope that you enjoy the read in any case.

This story is capturing the benefits obtained through the use of satellite data within the subject value chain. Assumptions were made throughout the value chain, based on the best of our understanding. We shall welcome expert suggestions to consolidate these assumptions, improve the used models and reduce uncertainties. Please contact authors at info@easrc.org with any question or observations.

2 Clean Seas in the Mediterranean

2.1 The Mediterranean Sea

The Mediterranean Sea immediately brings pictures in our minds of golden beaches, villages falling down hillsides, small ports, calm, warm water for swimming and maybe a sailing ship to enjoy the freedom of the seas. It may also conjure up pictures of old civilizations and archaeological ruins showing the importance of the region to our history in Europe.

But the Mediterranean Sea is also a very important water basin for other reasons. It is connected with the Atlantic by the narrow (14km) Gibraltar Straits and so is considered as a semi-closed ecosystem. It is only a small part of the global ocean surface (0.7%) but it contains some 6% of its marine species which is increasingly under threat from polluted waters. Some of the world's most endangered species, such as the monk seal, can be found in the Mediterranean. Fish stocks are down to 20 per cent of natural levels in some areas[4], and the Mediterranean region is now a net importer of fish.

Figure 2-1: Sentinel 3a image of the Gibraltar Straits.

The Sea stretches for around 4000km from the Gibraltar Straits (Figure 2-1) to the southern coast of Turkey with a surface area of about 2,500,000 km2. It is divided into 2 deep basins: the western Mediterranean including the islands of Sicily, Sardinia, Corsica and the Balearics (Mallorca, Minorca and Ibiza) and the Eastern Mediterranean including Malta, the Greek islands and Cyprus. In total, 21 countries have coastlines on the Mediterranean. It plays an important part in trade between these countries and hence has a strong economic importance.

4 The Alarming Decline of Mediterranean Fish Stocks, Vasilakopoulos, Maravelias, Current Biology, July 2014.

Countries bordering the Mediterranean are Spain, France, Monaco, Italy, Slovenia, Croatia, Montenegro, Bosnia & Herzogovenia, Albania, Greece, Turkey, Syria, Lebanon, Israel, Egypt, Libya, Tunisia, Algeria, Morocco, and the two island states of Cyprus and Malta.

Population pressure on the Sea is extremely high. Today, 529 million people live in the Mediterranean states[5] which is expected to increase to 611m in the next 30 years. Around 33% of the population, 200m persons, live in a Mediterranean coastal region[6] which is bolstered each year by an estimated 360m tourists leading to seasonal population pressures.

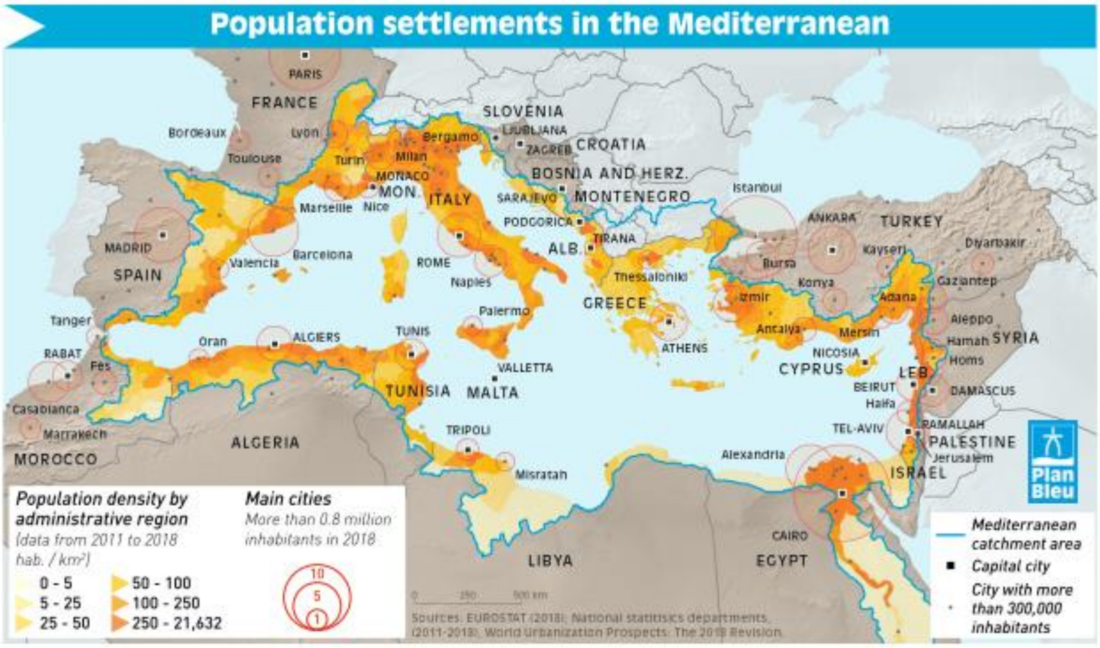

Figure 2-2: Population density around the Mediterranean[6].

In order to cater for this booming business, natural habitats have been replaced by modern resorts; breeding and nesting sites notably of the endangered loggerhead sea turtle (Caretta-caretta) have been destroyed to accommodate tourist facilities; and the extra pollution generated is often dumped untreated into the sea, threatening the entire eco-equilibrium of the region[7].

The State of the Environment and Development in the Mediterranean (SoED) Report[8] published in 2020 by the United Nations Environment Programme Mediterranean Action Plan (UNEP/MAP) provides a comprehensive assessment of the state of the environment in the region highlighting among others the following extreme challenges for Mediterranean marine ecosystems:

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[5] IEMed Mediterranean Yearbook 2020.

[6] Mediterranean Observatory on Marine Environment and Sustainable Development.

[7] *Explore Crete! https://www.explorecrete.com/nature/mediterranean.html*

[8] URL: https://www.unep.org/unepmap/resources/2020-edition-state-environment-and-development-mediterranean-soed

- Population densities in coastal areas have continued to increase at unsustainable rates over the last decade. Over 1965-2015, urban pressures increased in 75% of Mediterranean countries; particularly, built areas doubled or more than doubled within one kilometre from the sea. Consequently, biodiversity and especially natural coastal ecosystems and their services (e.g. carbon capture, flood control) decreased in contradiction with the Barcelona Convention Integrated Coastal Zone Management Protocol.
- Waste and its management remain a challenge in many countries. Around 730 tonnes of plastic waste end up daily in the Mediterranean Sea. Plastic waste represents 95 to 100% of marine floating waste and 50% of litter on seabeds. In tonnage, plastic could outweigh fish stocks in the near future. Many coastal uncontrolled landfill sites are found, particularly on eastern and southern shores.
- Fisheries practices threaten fish resources: 78% of assessed stocks are over-fished, while 18% of the catches are discarded. Fisheries represent the number one threat to fish populations in the Mediterranean Sea. Aquaculture is growing fast with high dependency on fish meal from sea catches, large nitrate and phosphorus effluents, as well as genetic modification of natural fish stocks.

As well as its ecological importance, the Mediterranean Sea is at the same time one of the busiest shipping regions in the world. It plays a critical role in trade within Europe and between Europe, other countries which border the Sea and key trade routes with Asia via the Suez Canal and with Russia and many former Soviet Union states via the Black Sea (see Figure 2-3). The Figure shows traffic over the previous 12 months with the areas showing red being the highest density. Mostly, the highest densities are around the ports, but other key choke points occur at the mouth of the Bosporus and (just off picture) the straits of Gibraltar, plus the extremely high density in the vicinity of Malta, shows the important role this island state plays.

And, whilst a very large proportion of this ship traffic are local vessels carrying goods between Mediterranean states, a significant proportion of the vessels are oil tankers as can be seen from this filtered picture (Figure **2**-**4**) taken at noon on 27th July 2021. This shows the position of each tanker at the designated time. It is estimated that around 1/3rd of the world's oil, transported by ships, passes through the Mediterranean[9]. Consequently, the exposure to oil spill risk is very high in a confined basin.

[9] Oil Spill Beaching Probability in the Mediterranean; Jimenez Madrid, Blanco-Merulo.

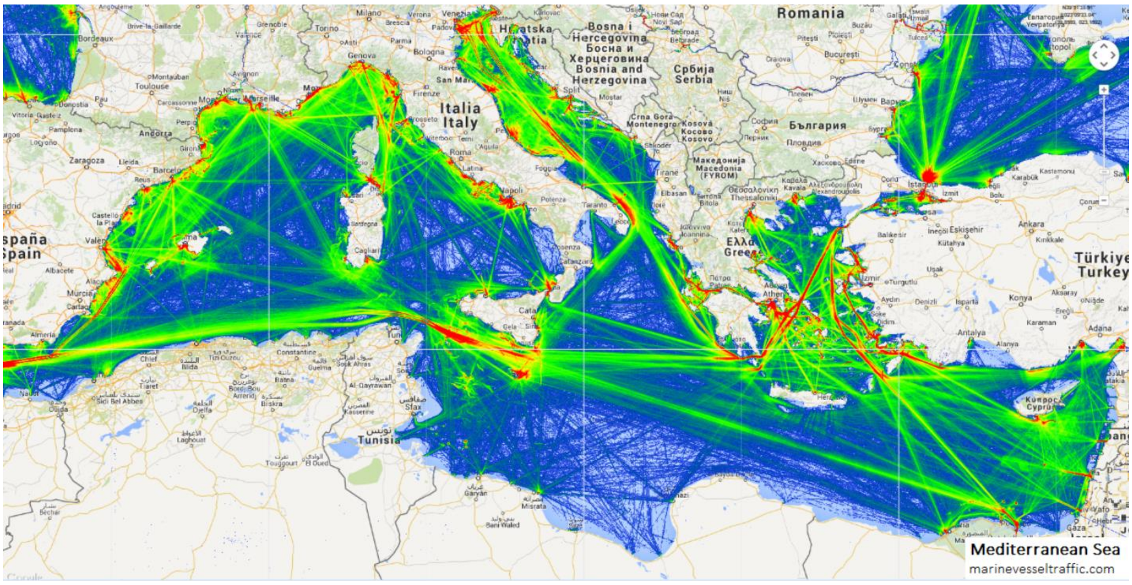

Figure 2-3: Density of Shipping in the Mediterranean (from www.marinevesseltraffic.com)

This high volume of shipping brings a problem of pollution and especially oil pollution. While, notably, 44% of the Mediterranean area is either contracted or designated for oil & gas exploration, the majority of spills from offshore drilling and exploration activities have been a minor source of marine pollution compared to the transport industry[10]. The passage of many, large oil tankers, some of which illegally wash their tanks at sea, leads to oil entering the marine environment. Although rare, shipping accidents also occur which can lead to significant quantities of fuel oil leaking into the sea. Even more serious are the rare accidents concerning the oil tankers themselves, when very large quantities of oil can be spilt.

As we shall discuss, the volume of oil entering the Mediterranean is not known with any great accuracy. To give an idea of the scale of the problem, REMPEC has produced maps showing the location of oil spills; see Figure 2-5 and Figure 2-6 for the spills and the major shipping routes.

A number of serious accidents around the world from the Torrey Canyon in 1967 to the Erika in 1999 and the Prestige in 2002 have raised awareness of the risks and the imperative to prevent such spills happening. The list of accidents is long[11] but international collaboration has reduced the risk and frequency of major incidents and has improved preparedness in case one occurs. As part of this effort, the European CleanSeaNet service has been established as a tool to help reduce and manage the problem. But, before coming to that part of the story, let us first better understand the problem.

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10 UNEP's SoED Report (p. 136). URL: https://www.unep.org/unepmap/resources/2020-edition-state-environment-and-development-mediterranean-soed

11 https://en.wikipedia.org/wiki/List_of_oil_spills

Figure 2-4: Tankers in the Mediterranean at noon on 27th July 2021 (www.marinevesseltraffic.com).

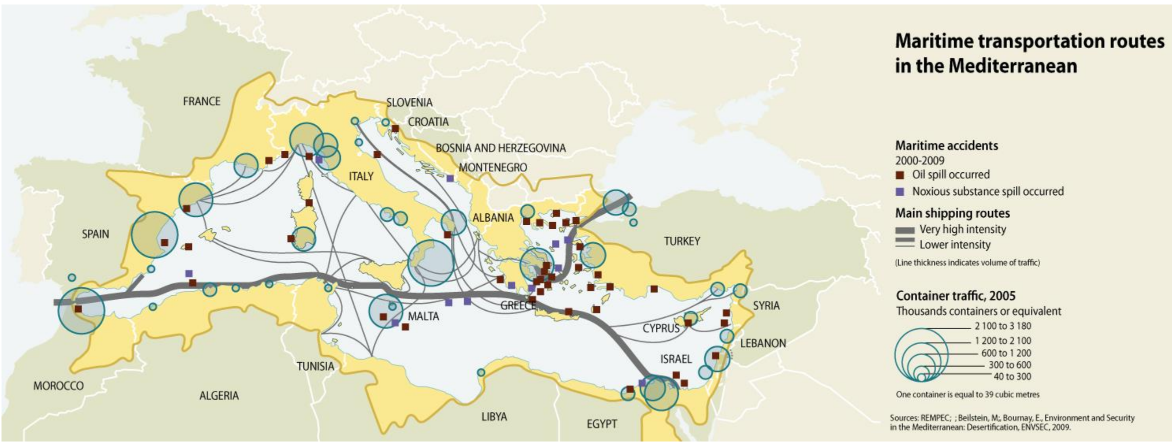

Figure 2-5: Shipping routes and Oil Spills in the Mediterranean[12].

[12] REMPEC. Environment and Security in the Mediterranean (2009)

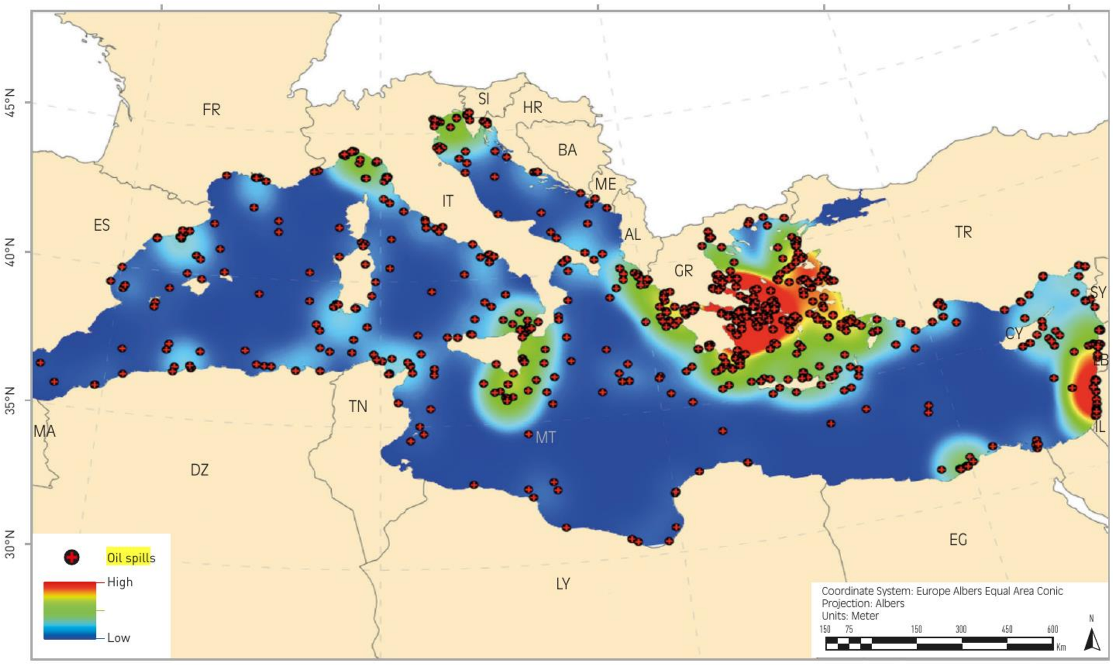

Figure 112 - Main oil spills in the Mediterranean Sea 1977-2017
(Source: Polinov, 2018 from REMPEC data)

Figure 2-6: Main oil spills in the Mediterranean 1977-2017

2.2 Oil Pollution in the Mediterranean

2.2.1 Where does the Oil come from?

Whilst perhaps the highest visibility and most newsworthy events, ship accidents leading to oil spills only account for around 8% of the annual amount of oil entering the seas[13]. However, their high impact acts to raise awareness of the problem of oil pollution amongst the general population and stimulates action against the more frequent cause of oil entering the marine environment which is due to deliberate and illegal action by the ships' captains.

Oil from deliberate operational discharges comes from the emptying of ballast tanks, effluent from the engines and the washing of oil tanks. The first two of which can come from any ship whilst the third is due specifically to oil tankers. Indeed, the latter, whilst illegal, accounts for 22% of the oil entering the seas annually. Notwithstanding, there is a high degree of uncertainty over the total amount of oil entering the marine environment each year.

At the time of writing, the most recent reported oil spill in the Mediterranean occurred in June 2021 when an oil slick was discovered off the southern coast of Corsica. Several tons of oil had been

[13] Spatial and Temporal Assessment of Oil Spills in the Mediterranean Sea, Polinov, S, Bookman R, Levin N. Marine Pollution Bulletin, 2021.

illegally released of which 4 tons were collected in a clean-up operation. Three ships are identified as possible culprits and an investigation is taking place.

Earlier that year on 16th February, an oil spill was discovered when tons of oil started to be washed ashore on beaches in Lebanon and Israel. This led to the closure of all beaches in Israel and much diplomatic activity to seek to establish the source of the pollution. Investigations are ongoing although a Greek registered vessel the Emerald which was transporting oil from Iran to Syria is suspected of having "spilt" the oil. More than 6 months after the incident, tar was still being washed up on the beaches giving a strong indication of the scale of the environmental impact. Clean-up costs are not available, but the operation was clearly extensive[14].

These two incidents were most likely deliberate and illegal acts of tank washing which occurs as ships captains try to save time and money. Although outlawed by the 1978 protocol to the MARPOL Convention, the practice still exists despite laws which oblige owners to have crude oil washing facilities fitted to all their tankers over 20,000 tonnes.

Sometimes, accidents happen of which the most recent example in the Mediterranean arose through a collision of two ships on 7th October 2018. The Tunisian ferry, Ulysse rammed the side of the container ship Virginia which was at anchor. Fuel started to leak from the side of the Virginia and drift towards the beaches and resorts of Southern France. The French emergency service CEDRE was called into action, and the Ramoge[15] convention was activated which led to sea operations to pump out the fuel and a large clean-up operation was necessary for beaches in the Var department in the Provence-Alpes-Côte d'Azur region of South-eastern France. The cause of the accident was attributed to human errors and the cost of the response was estimated at between €20m and €25m.

Another example of an oil spill can be found with a slick detected in August 2021 emanating from a Syrian oil refinery and threatening the beaches of Cyprus.

These incidents show how oil pollution is caused by both deliberate actions – termed operations – and accidents. Pollution in the Mediterranean is caused by shipping, coastal industrial activity, population waste and through its major river systems: the Po, the Ebro, the Nile, and the Rhone which carry substantial amounts of agricultural and industrial wastes. As the Mediterranean is almost entirely landlocked, its waters have a very low renewal rate (80 to 90 years) making them excessively sensitive to pollution.

Ships are not the only source of oil pollution, and a summary of the main sources is given below:

Operations:

With little doubt, the main source is oil coming from tankers washing their tanks at sea rather than doing so in the ports. For example, the recent oil slick detected off the coast of Corsica which was mentioned above. Tank washing can be performed legally if the ship is in open waters, out of

[14] Tar still washing up on Israel's beaches 6 months after oil spill. Times of Israel. 26th August 2021.
[15] Ramoge is a convention between France, Monaco and Italy to support operations combatting oil pollution.

jurisdiction and hence sufficiently far from the coast, when strictly following additional requirements (e.g. not exceeding the maximum allowed rate of discharge).

Accidents:

Fortunately, accidents in the Mediterranean are rare but if they occur, they can be catastrophic for the local ecosystem. The worst accident occurred in 1991 when a tanker, the MT Haven suffered an explosion whilst unloading oil. The ship broke up and sank off Genoa in Italy releasing an estimated 140 thousand tonnes of crude oil into the sea.

In 2018, a collision between two ships caused a spill of up to 1000 tonnes of oil off the coast of Corsica.

Oil Platforms:

The Mediterranean has a number of oil fields which are being exploited through offshore platforms (26 in total as of January 2018 according to Statista[16]) and 44% of the Mediterranean area is either contracted or designated for oil & gas exploration Oil spills are caused by accidents which are rare but do happen.

Oil Seepages:

These are natural events which occur when oil seeps out of oil basins and becomes visible on the sea surface. This has been used as an exploration method since, if the slick is persistent, it is a strong indication of an underground basin.

Oil Refineries:

Ports and especially refineries present a potential source of pollution. There are 40 coastal refineries around the Mediterranean[17] which contribute to an estimated 22,000t of oil entering the Mediterranean each year.

Bunker Operations:

Bunkering is the transfer of fuel for ships in ports and sometimes offshore fuelling points. It is a standard and safe operation, but accidents do occur, and leaks or spills result[18]. The process is regulated under the MARPOL convention.

Fish Farms:

The feeding of fish in fish farms releases fish or vegetable oil into the environment. Whilst the amount is relatively low, the persistent nature of regular feeding does introduce a form of oil pollution into the surrounding ecosystem. Fish farms are moved to new locations to avoid that the problem becomes extreme.

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[16] URL: https://www.statista.com/statistics/279100/number-of-offshore-rigs-worldwide-by-region/
[17] The Barcelona Convention and Its Role in Oil Pollution Prevention in the Mediterranean Sea Angela Carpenter and Tafsir Johansson. From Oil Pollution in the Mediterranean Sea part 1.
[18] Safety4Sea: Bunker Spills: A brief overview of cause, effect and prevention.

Estuarine Sources:

Oil leaks also occur from land-based sources i.e. refineries, storage tanks etc. which are then washed out to sea via rivers.

The ITOPF[19] maintain a database of global oil spills. If we consider spills caused by ships of >700tonnes, nearly 40% arise whilst the ship is steaming in open waters and 21% for smaller vessels of 7-700tonnes. In other words, they are due to tank washing whether legal when distant from the shore or illegal see Figure 2-7.

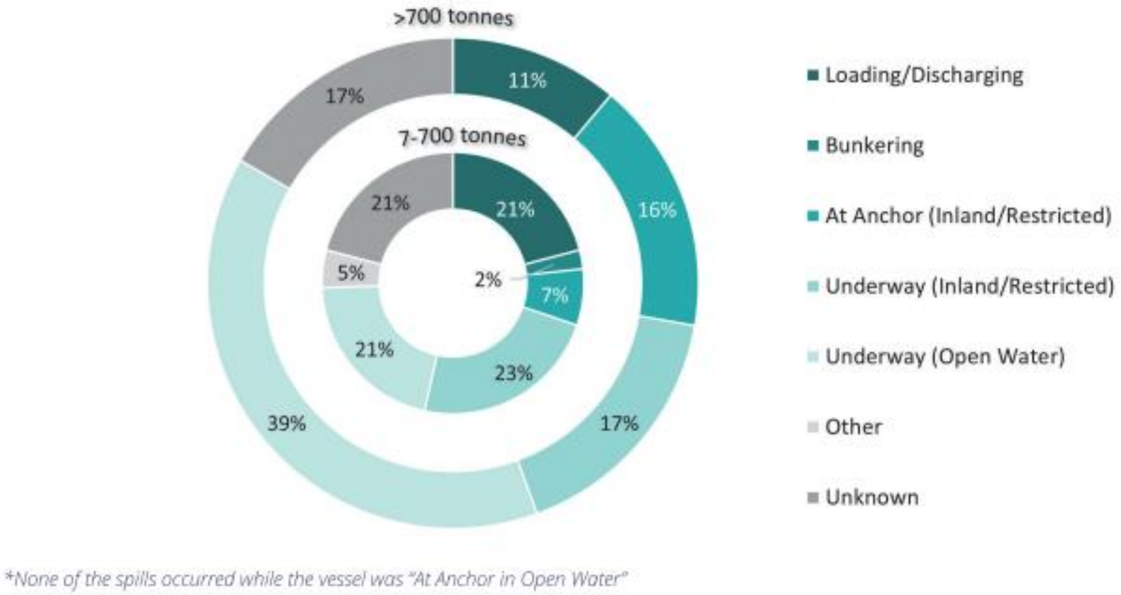

Figure 2-7: Cause of oil spills due to shipping (from ITOPF).

As well as this background infiltration of oil into the Mediterranean, the risk of a large oil spill incident is greater than ever due to the deployment of a series of offshore installations. 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 40% are refineries, 24% are ports, 26% are oil terminals and 10% are offshore platforms, whilst Statista reports 26 oil rigs in January 2018[20].

2.2.2 How much oil?

Opinions seem to differ quite widely on how much oil enters the Mediterranean each year.

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[19] https://www.itopf.org/
[20] https://www.statista.com/statistics/279100/number-of-offshore-rigs-worldwide-by-region/

REMPEC reports[21] that, based on the Mediterranean Alerts and Accidents database, some 32,000 tonnes of oil were spilled due to accidents between 1994 and 2013. This suggests an annual rate of 1,600 tonnes. On the other hand, from Wikipedia:

Approximately 370,000,000 tonnes of oil are transported annually in the Mediterranean Sea (more than 20% of the world total), with around 250–300 oil tankers crossing the sea every day. An important destination is the Port of Trieste, the starting point of the Transalpine Pipeline, which covers 40% of Germany's oil demand (100% of the federal states of Bavaria and Baden-Württemberg), 90% of Austria and 50% of the Czech Republic.[127] Accidental oil spills happen frequently with an average of 10 spills per year. A major oil spill could occur at any time in any part of the Mediterranean.

The discharge of chemical tank washings and oily wastes also represent a significant source of marine pollution. The Mediterranean Sea constitutes 0.7% of the global water surface and yet receives 17% of global marine oil pollution. It is estimated that every year between 100,000 t (98,000 long tons) and 150,000 t (150,000 long tons) of crude oil are deliberately released into the sea from shipping activities[22].

Hence, we have estimates from 1,600 tonnes to 150,000 tonnes released each year. In a more comprehensive analysis of Oil Pollution in the Mediterranean[23], Carpenter and other authors, suggest a higher figure of up to 1m tonnes per annum. The authors go on to conclude that the range of estimates is so broad that we do not truly know how much oil is entering the Mediterranean each year.

This view is also supported by the Global Marine Oil Pollution Information Gateway established by UNEP which provides some figures on the global quantities of oil pollution ranging from 450,000 tonnes up to 8.4m tonnes with up to half coming from land-based sources. The amount coming from operational sources is estimated to be between 24% and 37%. At the upper end, these figures would translate into levels of 1.0m to 1.55m tonnes per annum due to shipping operations.

Further figures are supplied by GESAMP (Group of Experts on the Scientific Aspects of Marine Pollution), established in 1969 under the UN auspices. In their latest report in 2007, GESAMP estimates a total on average of 457,000 tonnes of oil entering the sea each year due to shipping operations. Of this, 45% (200,000tonnes) is due to tank washing and 36% (164,000tonnes) due to accidents. These figures are global, and we have earlier seen the figure of 20% of global oil being shipped in the Mediterranean, suggesting that 40,000 tonnes is released in this sea due to illegal actions.

[21] UNEP-MAP Mediterranean Quality Status Report 2017.

[22] *Wikipedia https://en.wikipedia.org/wiki/Mediterranean_Sea#cite_note-123.*

[23] Oil Pollution in the Mediterranean Sea, Part 1. Angela Carpenter, Andrey G Kostianoy (editors). Chapter 2. History, Sources and Volumes of Oil Pollution in the Mediterranean Sea.

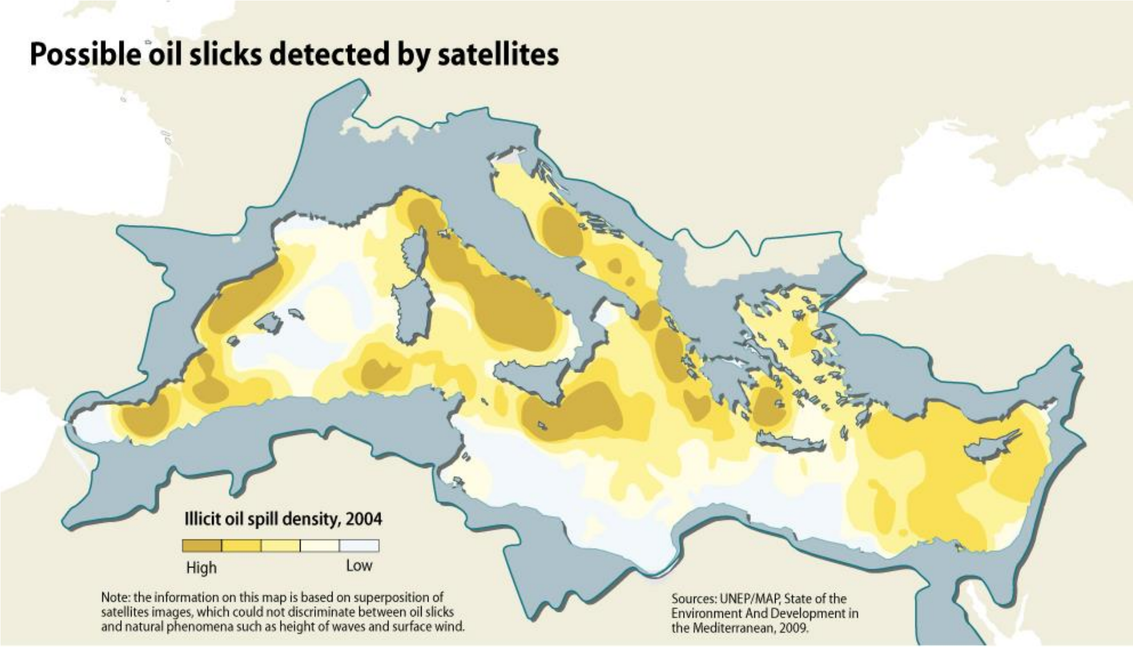

Figure 2-8: Density of Possible Oil Slicks[24].

Taking into account all these studies and views, a reasonable figure to work with seems to be between 10,000 tonnes and 50,000 tonnes from ship sources spilled into the Mediterranean each year.

2.2.3 How many incidents?

Since the CleanSeaNet service started using Sentinel data, the number of possible oil slicks detected each year has been steadily growing as is shown in Figure 2-9. Note that this chart is for the CSN service as a whole and not just the Mediterranean.

The increasing number of detections using Sentinel data (2016-2020) was accompanied by a significant increase of the overall number of images acquired by the service, due to the widespread use of Sentinel-1 data. Additionally, Sentinel-1 has also proven to be much more efficient in detecting smaller spills (at the same resolution) additionally contributing to the rise in the number of detections. For example, when comparing 2020 against 2019, there was an increase of 6% on the overall possible oil spills detected, compared with an increase of 15% in the number of delivered images. Overall, there has been a steadily decrease of the number of detections per million km2, proving the deterrent effect of the service.

[24] Source: UNEP, taken from GRID-Arendal, Norway.

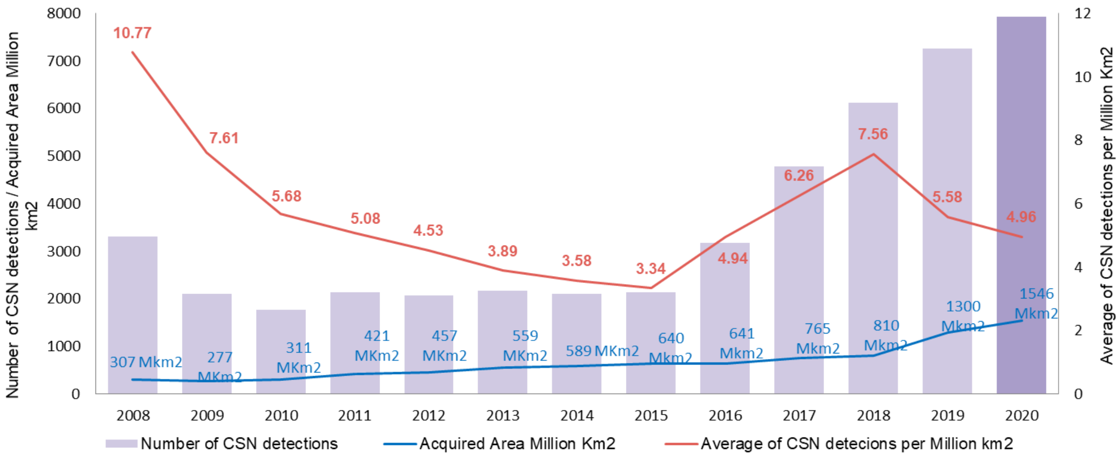

Figure 2-9: Numbers of CSN Detections since 2008.

Considering the Mediterranean, the distribution of the possible detections in 2020 is shown in Figure 2-10. Most are coastal or lie in the main shipping lanes i.e. those passing by Malta.

The tighter regulations from the International Maritime Organization[25] (IMO) together with better surveillance methods such as that offered by CSN that have a dissuasive effect to cause the number of incidents to be falling and this is borne out by the average of CSN detections per km2 shown in red in Figure 2-9.

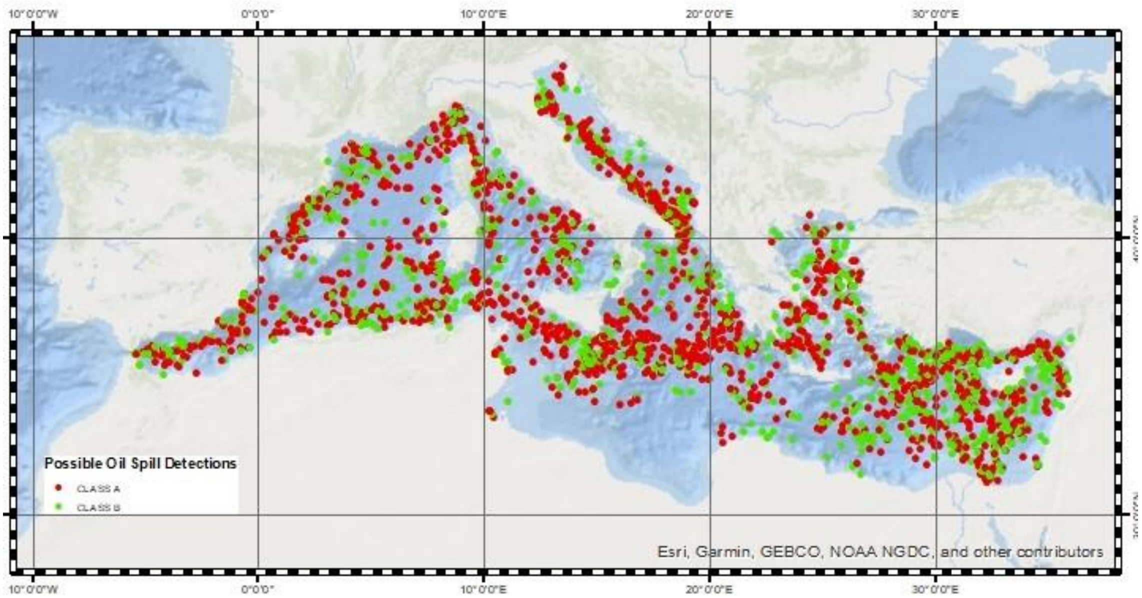

Figure 2-10: Possible Oil Spill Detections in the Mediterranean in 2020.

Information on the number of spills in the Mediterranean seems to be quite varied. A recent paper by Polinov[13] looked at the spatial and temporal distribution of slicks. It analyses 4 databases of oil

[25] https://imo.org/

spills (2 from EMSA from different periods and using different means). These show (see Table **2-1**) quite varied results possibly as a result of different classifications of oil spills i.e. accidents vs illegal discharges, confirmed or suspected, accident or operational spill.

Source	**Period Covered**	**Total Number of Oil Spills per period**	**Comment**
ITOPF	1970-2018	167	Accidental/tanker oil spills
REMPEC	1977 – 2000	385	Accidental/tanker oil spills
EMSA/Ferraro	1999 – 2004	9299	Detection of oil spills using satellites
EMSA/CSN	09/2015 – 10/2017	2066	Detection of oil spills using satellites

Table 2-1: Number of spills according to different sources (after Polinov[13]).

As a result, the number of possible spills differs greatly between the 4 databases examined by Polinov. What this does show is the high detection rate using satellite sources by CSN.

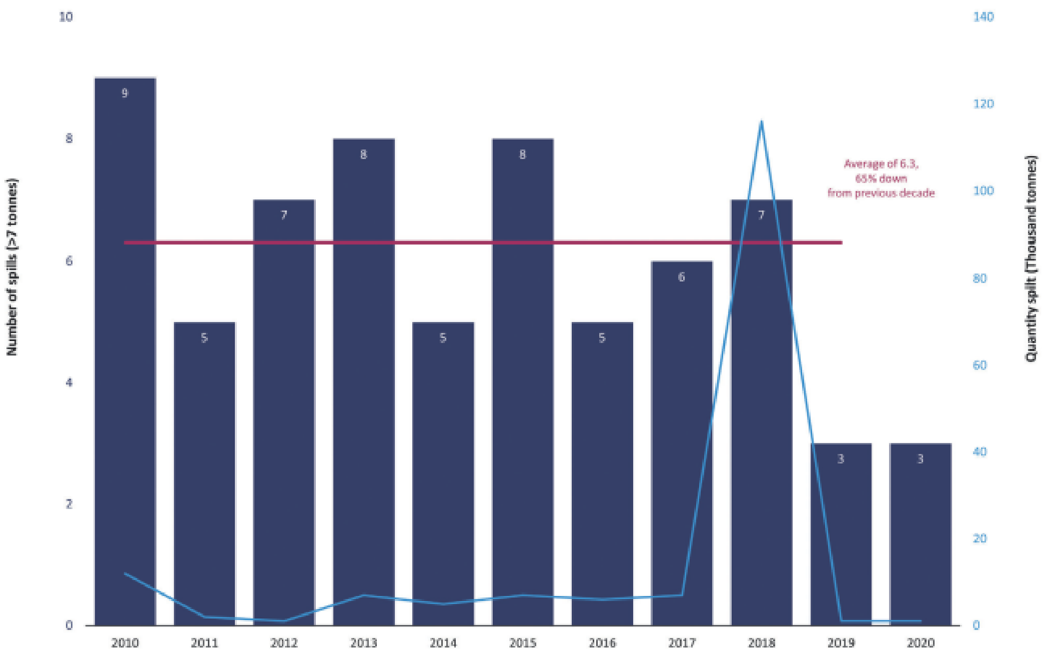

Figure 2-11: Number of oil spills and quantity spilt from 2010 to 2020 (ITOPF).

The ITOPF database can give us a further clue as to the evolution of oil spills, albeit those caused through accidents. The number of oil spills globally of over 7 tonnes each year is shown in Figure **2-11**.

The ITOPF reports that the number has fallen by 65% in the last decade compared to that previously. In 2020, there were only 3 spills over 7 tonnes which was the same as in 2019. This number is the lowest since 1970. In terms of quantity, a large spill occurred in 2018 which is clearly visible in the graph (blue line in Figure **2-11**).

If indeed the number of spills has been falling, then the CSN data indicates that the probability of detection has become significantly higher. This is strongly confirmed with data from Spain. Figure **2-12** shows the number of satellite images received by Spain for the period 2013 to 2020 together with the number of suspected polluters for the same period. Both are seen to rise sharply from 2016 onwards as the CleanSeaNet service included the use of Sentinel-1 data.

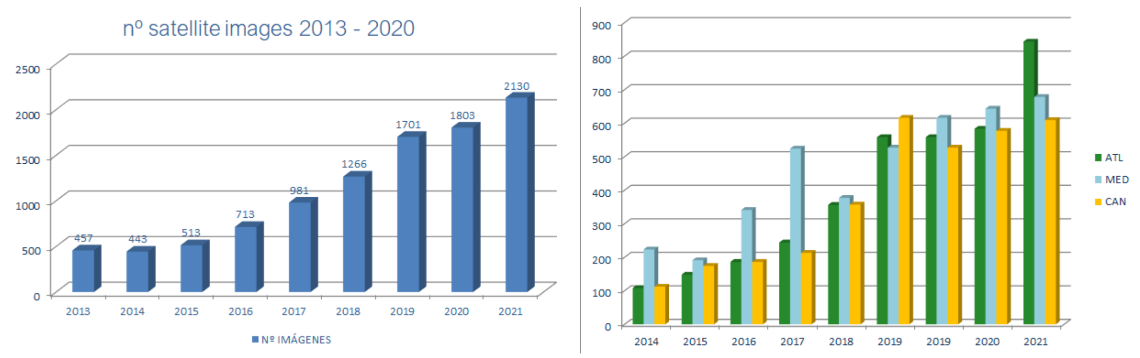

Figure 2-12: Satellite Images supplied from CSN to Spanish authorities (total left) and by maritime area (right) in Spanish waters (private communication from SASEMAR).

That this has not yet translated into successful prosecutions is due to the lengthy delays to instigate legal proceedings. However, the increased risk of detection is clear and appears to be leading to a relative reduction of incidents as we shall see later.

2.2.4 Other Pollutants

Although the focus of detection through CSN is on oil spills, these are not the only cause of pollution in the marine environment.

Plastics: In recent years, plastic waste entering the marine environment is proving an even greater problem than for oil. According to UNEP, 730 tonnes of plastics enter the Mediterranean every day. This gets broken down into micro-particles and enters the food chain threatening marine life. The major cause is from coastal cities and tourist beaches but there are others as well. The sea off the coast of Spain near Almeida is known as the plastic sea (“Mar de Plastico”) due to the influx of plastics torn off the extensive greenhouse tunnels.

Of the marine litter, plastics account for 95% to 100% of floating litter and more than 50% of the litter on the seabed. Once broken down into micro-particles, detection becomes impossible.

Ships Waste: in the same way that tankers wash their tanks out whilst sailing so causing the illegal oil spills, so other ships discharge wastewater whilst at sea instead of in the ports where it can be treated. The motivation is to save both time and money in port fees. This is a particular problem for the cruise liners which are increasing in numbers. The wastewater contains many chemical pollutants as well as oils and kitchen waste.

Chemicals: run-off from farms treating their fields with fertilizer cause harmful algal blooms. Indicators of excessive chemicals namely chlorophyl-p can be detected by satellites as discussed in another SeBS case[26].

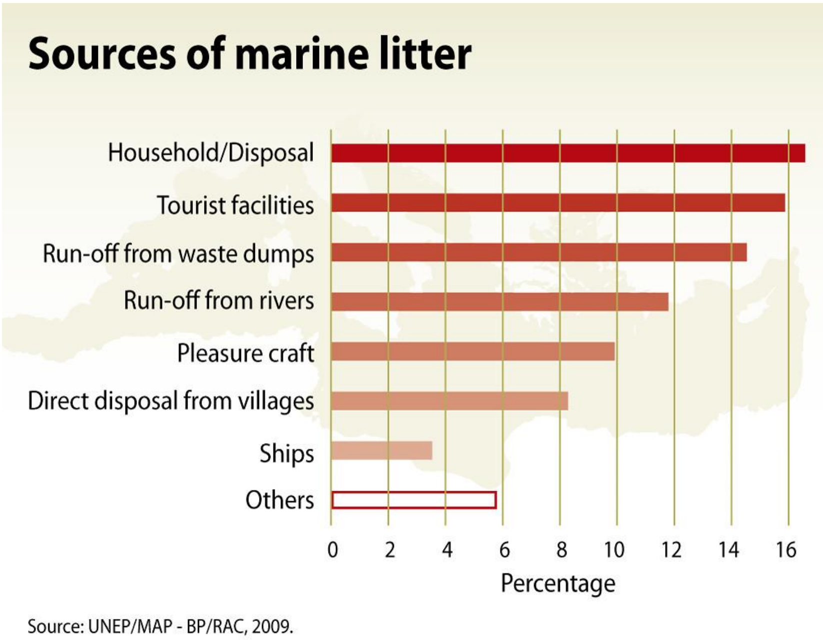

Figure 2-13: Sources of Marine Litter; mostly plastics. (source: GRID-Arendal)

Attention has also been increasing concerning the emissions of nitrous oxide and sulphur dioxide from the ships. Satellites are showing the capability to monitor these pollution sources if not yet to be able to pinpoint individual ships. Knowledge of the scale of the air pollution can at least inform future legislation.

2.3 What is the Impact?

When oil enters the marine environment, it may take several years for the impact to return to zero. In the meantime, it affects the environment and ecosystem, fishing industries, fish farming industries and tourism. All of these have an impact on society.

The Mediterranean, being an enclosed sea, is particularly vulnerable to pollution and therefore the environmental damage from oil spills may be is extensive. Furthermore, the sight of black tar on beaches leads to considerable economic loss as well as the cost of the clean-up. Oil spills are of very high concern in terms of the impacts e.g. oil cannot dissolve in water and forms a thick sludge that

[26] Water Quality in Germany; SeBS case, Sawyer, Oligschlaeger et al.

suffocates fishes, gets caught in the feathers of birds and blocks light from photosynthetic aquatic plants. Unfortunately, the true scale of oil pollution and its long-term effects are not well understood[27] and the wider availability of satellite images leading to detection will aid research on this topic.

Although the Mediterranean only covers 0.7% of the world's ocean area it is one of the major reservoirs of marine and coastal biodiversity, with 28% of endemic species and 7.5% of the world's marine fauna and 18% of its marine flora[28]. This little semi-closed sea is rich in islands and underwater beds and is also a major area of wintering, reproduction and migration of fish, birds and mammals.

The impact of an oil spill on the environment is difficult to predict. It depends more on the location and time of year than the quantity of oil spilled. A spill occurred in Prudhoe Bay, Alaska in 2006 when a corroded pipeline led to over 650 tonnes of oil being discharged into the landscape. The very cold conditions meant that the oil does not breakdown naturally and remains in the environment.

Fortunately, the Mediterranean water conditions are much warmer which means the oil breaks down naturally. The light oils evaporate very quickly meaning that an illegal discharge may no longer be visible to the naked eye after about 6 hours. This means that reaction must be quick to take samples, but it does not mean the danger has passed. The heavier oils may have disappeared below the surface and in any case remain in the water so that over time, they do coalesce and sink and either pollute the seabed or drift eventually reaching the shore. A recent example of an oil slick off the coast of Lebanon and Israel is still evident with tar being washed up on the beaches 6 months later[14].

In order to protect more sensitive areas of the sea, perhaps due to the presence of particular species or of excess human activity, Marine Protected Areas (MPAs) have been established (see Figure **2**-**14**. A good example lies in the region to the North of Mallorca. The 11,000-hectare (27,000-acre) MPA was set up at the request of the Cala Ratjada fishermen's association in 2007. Recently, the Marilles Foundation; a non-profit entity that works to make the Balearic Islands a world example of marine conservation, conducted a study[29] into the impact of the MPA. Their conclusion is that it has improved fishing in the area, made it easier to regulate leisure activities, slowed coastal erosion, and improved water quality and biodiversity.

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27 Carpenter, A.: Oil Pollution in the Mediterranean Sea: An Overview, EGU General Assembly 2020, Online, 4–8 May 2020, EGU2020-2982, https://doi.org/10.5194/egusphere-egu2020-2982, 2020

28 RAC/SPA, http://rac-spa.org/biodiversity

29 https://www.theguardian.com/environment/2021/aug/17/mallorca-marine-reserve-boosts-wildlife-as-well-as-business-report-finds?CMP=Share_iOSApp_Other

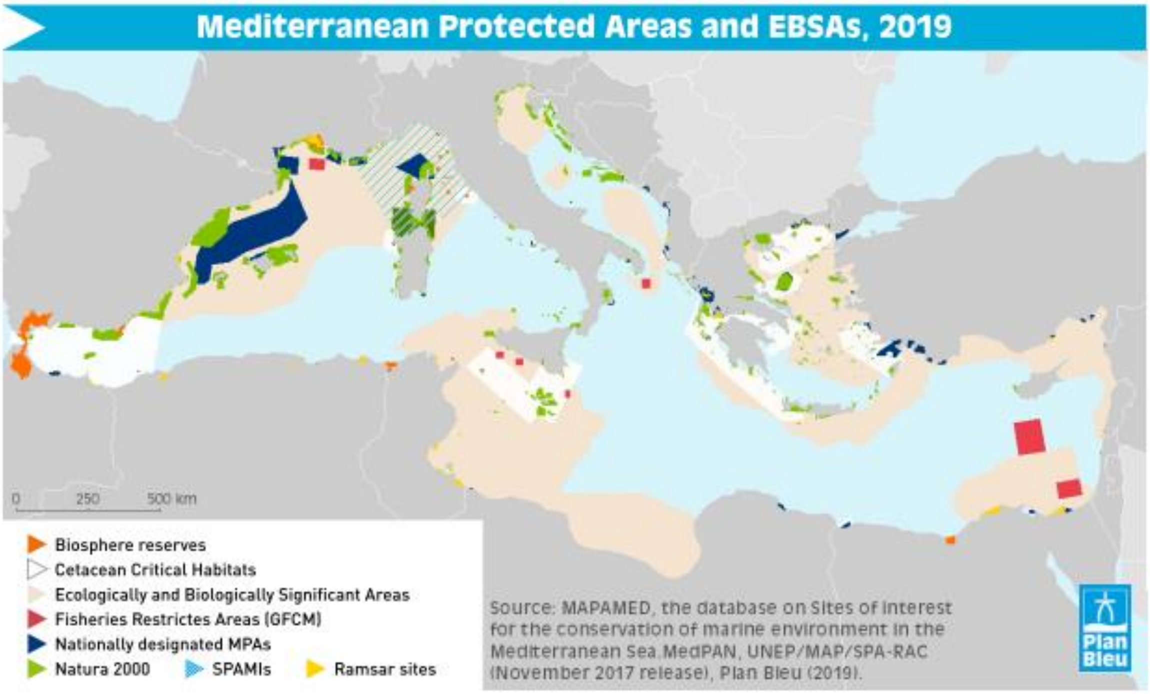


Figure 2-14: Marine Protected areas, fisheries protected areas, Sensitive Sea areas [30]

Oil contamination may persist in the marine environment for many years after an oil spill and, in exceptional cases such as salt marshes and mangrove swamps, the effects may be measurable for decades after the event. However, in most cases, environmental recovery is relatively swift and is complete within 2–10 years.

When oil spills occur, plants and animals will be contaminated, and some will be unable to survive. They can affect algae, plants, fish, birds and mammals which are at risk of being smothered, of toxicity, of hypothermia or chronic long-term effects. Fish may be exposed to spilled oil directly or through the food chain. They may then be physically affected, or the effects may pass through their eggs and into their young. Fish provide the most risk of exposure to spilt oil for humans.

Birds often provide the most photogenic images of the impact of oil spills. Most birds can simply relocate, but shore-based nesting birds and those that dive for their food are the most vulnerable. Even a small amount of oil can be deadly for a bird as the oil breaks down the natural waterproofing in their feathers without which they drown or are subject to hyperthermia or excess heating. The impacts can be long term and may even disrupt migratory patterns. Birds are also vulnerable as any fish they eat become contaminated.

[30] State of the Environment and Development in the Mediterranean, UNEP 2020.

Figure 2-15: Oil covered bird

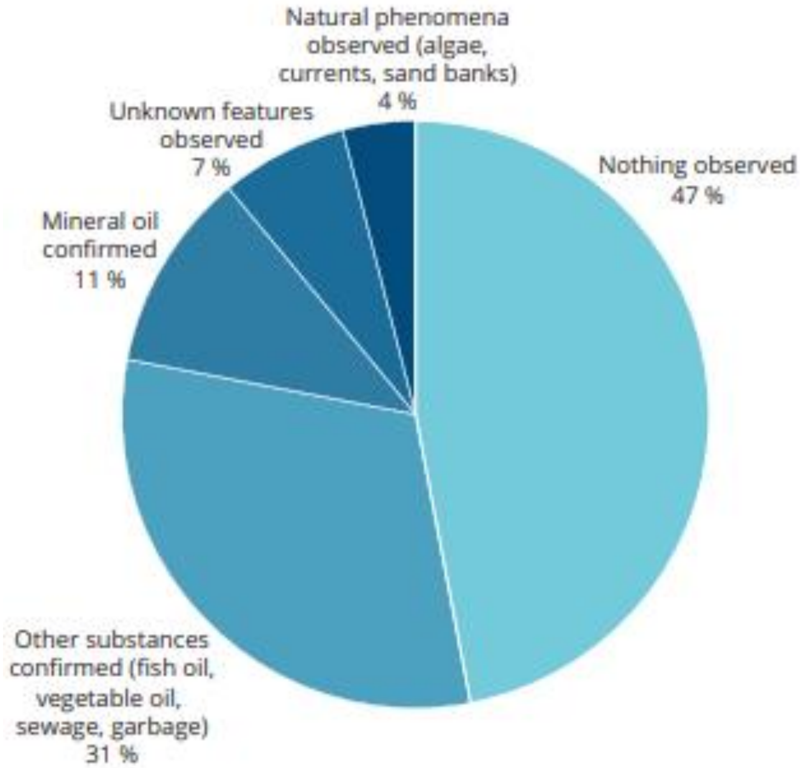
Amongst marine mammals, seals and sea otters are the worst affected since whales, dolphins etc can swim away from the oil and dive to deeper levels where the oil has not penetrated. But perhaps the biggest impact is through their food supply which does not escape, and which offers no direct sensory signs of contamination.

Even if not visible, oil rests in the water. A study carried out in 2008[31] shows that almost instant contamination occurs as the oil penetrates the water column to a depth of several metres and spreads over a large area. After a few hours, as little as 5m^3 of oil can spread over 8km^2 of sea surface. This clearly supports the view reported in the European Maritime Transport Environment report produced jointly by EMSA and the EEA in 2021[32] that rapid response is essential.

> *"The results of in situ verifications are clearly dependent on the interval between the time of the satellite image acquisition and the verification itself. The longer this interval, the higher the percentage of 'nothing observed' occurrences. In this sense, it should be highlighted that only 5 % of the verifications in 2019 were performed within 3 hours of the satellite observation. This resulted in a 42 % effective detection rate by the CleanSeaNet satellite service, calculated as all mineral or other substances (such as vegetable or fish oil) confirmed cases, divided by the total number of oil spills that have been verified (*Figure 2-16*)."*

31 Immediate ecotoxicological effects of short-lived oil spills on marine biota, Brussaard et al, Nature, April 2016.

32 European Maritime Transport Environment Report 2021, EMSA & EEA.



Source: Compiled from EMSA Services data.

Figure 2-16: Verification results for 2019 oil spill detections undertaken within 3 hours of the satellite image acquisition.

A good summary of the impacts of a spill are explained in the report[33] carried out after the Sea Empress accident off Milford Haven in the UK in February 1996. In addition to the environment, the spill damaged the local fishing industry and tourism which was affected both as a result of oil on the beaches and by the clean-up operation directly.

2.4 The International Legal Framework for Preventing Marine Pollution.

2.4.1 International Treaties

Oil pollution of the seas started to become recognised as a problem in the 2nd half of the 20th century. An international conference in 1954, led to the introduction of the first international convention OILPOL and subsequently to the Internal Maritime Organisation (IMO) (section 4.2.5) in

[33] The Sea Empress Oil Spill: Environmental Impact and Recovery. From ITOPF.

1958. OILPOL attempted to tackle the problem of oil pollution of the sea through establishment of zones of responsibility and liability.

Whilst most of the ocean's waters are international, the legislation that controls them is national. Furthermore, pollution does not respect national boundaries leading to issues of state's sovereignty and applicable legislations. For example, in the case of the Prestige, even if the spill took place off the coast of Spain, prosecution of the ship's captain and owners took place in London.

As the problem came to the public notice, arguably after the Torrey Canyon disaster in 1967, international efforts were mobilised to try to ensure that such a disaster did not happen again but that if it did, forces to clean up the oil could be more easily deployed. This effort led to the MARPOL Convention, which was introduced in 1973, strengthened in 1978 and ratified in 1983 when it came into force.

Even before MARPOL, the countries around the Mediterranean were seeking to extend protection of the marine environment through a regional agreement. In 1975, the UNEP drew up a Mediterranean Action Plan (MAP) which in turn led to the Barcelona Convention in 1976.

This also led to the establishment of a regional organisation to assist in the fight against pollution when REMPEC was created as a shared resource to aid in the combat.

MARPOL

The International Convention for the Prevention of Pollution from Ships (MARPOL) is the main international convention covering prevention of pollution of the marine environment by ships from operational or accidental causes.

MARPOL is a part of the regulatory framework established by the UN body the International Maritime Organisation (see 4.2.5). Shipping is an international industry, and it can only operate effectively if the regulations and standards are themselves agreed, adopted and implemented on an international basis. IMO, operating under the umbrella of the UN, is the forum at which this process takes place.

Adopted on 2 November 1973 at the International Maritime Organisation (IMO), the convention entered into force on 2 October 1983. MARPOL has been updated by a number of amendments through the years. The Convention includes regulations aimed at preventing and minimizing pollution from ships - both accidental pollution and that from routine operations – as a series of 6 annexes. In summary:

- Annex I covers prevention of pollution by oil from operational measures as well as from accidental discharges.
- Annex II details the discharge criteria and measures for the control of pollution by noxious liquid substances carried in bulk. No discharge of residues containing noxious substances is permitted within 12 miles of the nearest land.
- Annex III contains general requirements for the prevention of Pollution by Harmful Substances Carried by Sea in Packaged Form

- Annex IV contains requirements to control pollution of the sea by sewage; sewage which is not treated or disinfected has to be discharged at a distance of more than 12 nautical miles from the nearest land.
- Annex V deals with different types of garbage and specifies the distances from land and the manner in which they may be disposed of; the most important feature of the Annex is the complete ban imposed on the disposal into the sea of all forms of plastics.
- Annex VI sets limits on sulphur oxide and nitrogen oxide emissions from ship exhausts and prohibits deliberate emissions of ozone depleting substances.

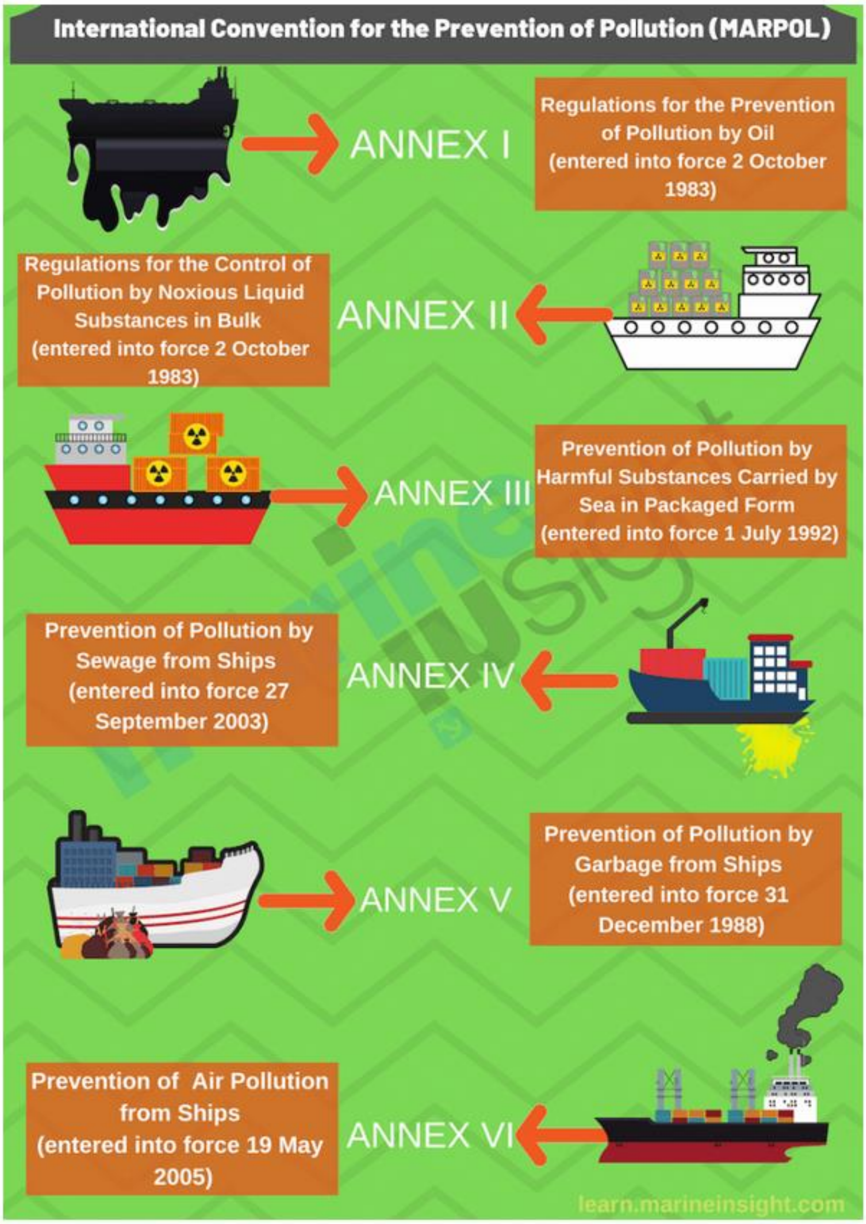


Figure 2-17: The MARPOL Convention illustrated

Barcelona Convention

The Mediterranean Action Plan (MAP) of the United Nations Environment Programme was established in 1975 by Mediterranean governments as the first regional action plan under the UNEP Regional Seas Programme with clear objectives to foster regional collaboration for combatting marine pollution and promoting integrated planning and sustainable use of marine resources. At the heart of MAP lies the Convention for the Protection of the Mediterranean Sea Against Pollution, which was signed on 16 February 1976 in Barcelona, Spain, and entered into force on 12 February 1978. Over time the Convention was complemented by seven (7) Protocols addressing different aspects of marine and coastal environment and resource protection and management.

This was modified in 1995 to become the Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean more conveniently known **as** the **Barcelona Convention.**

The 22 Contracting Parties to the Barcelona Convention are Albania, Algeria, Bosnia and Herzegovina, Croatia, Cyprus, Egypt, France, Greece, Israel, Italy, Lebanon, Libya, Malta, Monaco, Montenegro, Morocco, Slovenia, Spain, Syrian Arab Republic, Tunisia, Turkey, and the European Union.

In 1985, the parties to the Barcelona Convention decided to establish the R**egional** A**ctivity** C**entre for** S**pecially** P**rotected** A**reas (RAC/SPA)** located in Tunis. The RAC/SPA was entrusted with responsibility for assessing the situation of natural heritage and assisting the Mediterranean countries to implement the Protocol concerning **S**pecially **P**rotected **A**reas and **B**iological **D**iversity in the Mediterranean (SPA/BD Protocol), which came into force in 1999.

Within the context of the implementation of the Barcelona Convention, including the related strategies, programmes and decisions, such as the **M**editerranean **A**ction **P**lan (MAP) and the **M**editerranean **C**ommission on **S**ustainable **D**evelopment (MCSD), the specific objective of RAC/SPA is to contribute to the implementation of the SPA/BD Protocol especially in regard to developing and promoting **S**pecially **P**rotected **A**reas (SPAs) and reducing the loss of marine and coastal biodiversity.

International Convention on Oil Pollution Preparedness, Response and Co-operation (OPRC)

In 1989, after the Exxon Valdez disaster, and a number of other significant oil spills, had reminded the international community of the need for better preparedness, the IMO conference in Paris in July of that year asked that IMO prepare a new convention on Oil Pollution Preparedness, Response and Co-operation (OPRC). This new convention was adopted in 1995.

Parties to the OPRC Convention are required to establish measures for dealing with pollution incidents, either nationally or in co-operation with other countries. Ships are required to carry a shipboard oil pollution emergency plan. Operators of offshore units are also required to have oil pollution emergency plans or similar arrangements which must be co-ordinated with national systems for responding promptly and effectively to oil pollution incidents.

Ships are required to report incidents of pollution to coastal authorities and the convention details the actions that are then to be taken. The Convention calls for the establishment of stockpiles of oil spill combating equipment, the holding of oil spill combating exercises and the development of detailed plans for dealing with pollution incidents.

2.4.2 Regional Agreements

In addition to the framework of international treaties and conventions created and managed under the control of the UN and the IMO, several regional agreements have been made which help countries in the Mediterranean to meet their obligations under the international treaties.

REMPEC

REMPEC – The Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea was originally established in 1976 as the "Regional Oil Combating Centre" (ROCC) by the decision of the Contracting Parties to create a mandate to strengthen the capacities of coastal States in the Mediterranean region. The aim was to facilitate better cooperation between these States in managing massive marine pollution oil spills, developing national strategies to combat oil pollution, establishing a regional information system that could effectively and swiftly manage marine pollution emergencies.

Over the years the mandate was extended, enabling REMPEC to address pressing issues and respective global developments and also to manage preventive action concerning marine pollution from ships, thus, to pre-empt and not just to respond to pollution incidents. REMPEC is administered by the International Maritime Organization (IMO) in cooperation with the Mediterranean Action Plan of the United Nations Environment Programme (UNEP/MAP).

REMPEC assists the Mediterranean coastal States in ratifying, transposing, implementing and enforcing international maritime conventions. This includes technical activities such as workshops, training courses, experts' assessments, studies and proposals, to aiding the development of regional instruments and guidelines, as well as assisting the Mediterranean coastal States to implement relevant international maritime rules and regulations in a coherent way.

In 2001, with the intention of adopting the new Protocol concerning Cooperation in Preventing Pollution from Ships and, in Cases of Emergency, combating Pollution of the Mediterranean Sea (Prevention and Emergency Protocol, 2002), the Contracting Parties reaffirmed the involvement of the Centre in activities relating to prevention of, preparedness for and responses to marine pollution.

In order to facilitate cooperation between the signatories to the Barcelona Convention, its members created a specific body called **MENELAS - Mediterranean Network of Law Enforcement Officials**. This group meets under the umbrella of REMPEC **in order to improve the enforcement of the international regulations regarding discharges at sea from ships.**

RAMOGE

A further agreement exists between France, Monaco and Italy to protect the Mediterranean coasts. RAMOGE (for st RAphael, MOnaco and GEnova) was signed in 1976 at the instigation of the Prince Rainier of Monaco.

The agreement was called into operation in October 2018 when an accident occurred off the northern coast of Corsica after a collision between a Tunisian ferry ship (Ulysse) and a Cyprus registered container vessel (Virginia). The calm meteorological conditions meant that the oil spill of some 1000tonnes of fuel oil spread over a slick of some 35km was cleaned up without much oil reaching nearby coasts. However, some did reach the shore with consequences for the popular French resort of St Tropez.

Figure 2-18: Satellite optical image (Worldview) at 50 cm resolution showing the collided ships and subsequent oil trail off the coast of Corsica, Italy, © European Space Imaging.

The high quality of the data makes it possible to zoom in on the image and thereby identify the extent of the damage and surrounding clean-up efforts.

Bonn Agreement

Other regional agreements exist to cover other seas. For example, the Bonn Agreement is the mechanism by which ten Governments, together with the European Union, cooperate in dealing with pollution of the North Sea by oil and other harmful substances. The signatories to the

Agreement are the Governments of the Kingdom of Belgium, the Kingdom of Denmark, the French Republic, the Federal Republic of Germany, the Republic of Ireland, the Kingdom of the Netherlands, the Kingdom of Norway, the Kingdom of Sweden, the United Kingdom of Great Britain and Northern Ireland and the European Union.

Spain joined the Bonn Agreement in 2019 recognising its interests in the Bay of Biscay. Whilst not directly affecting the capability to react in the case of an accident in the Mediterranean, it does extend the area of co-operation for Spain.

2.4.3 The European Union

In respect of marine pollution, the **role of the European Union is constrained and guided by** the international agreements in place signed by the Member States. **The European Commission funds and oversees the operations of EMSA** and certain assets which improve the ability to respond to an accident or illegal discharge.

The first legislation at European level (Directive 2000/59/EC) was launched in 2000 aimed at improving port reception facilities to deal with waste and reduce marine pollution. This led to the creation of EMSA in 2002 to oversee these activities and the publication of a set of recommendations on Integrated Coastal Zone Management, which in turn led in 2008 to the publication of the Marine Strategy Framework Directive.

In 2005, the EU introduced a directive (the EU Ship Source Pollution Directive 2005/35) which creates rules that are applicable EU-wide on the imposition of penalties in the event of discharges of oil or other polluting substances from ships sailing in waters belonging to EU members. It ensures that deliberate pollution is a criminal offence and lays down levels of fines for offenders. **The Directive tasks EMSA to "work with the member states in developing technical solutions and providing technical assistance in actions such as tracing discharges by satellite monitoring and surveillance** and to comply with this task, EMSA developed the CleanSeaNet service.

The subsequent **Marine Strategy Framework Directive**, (2008/56/EC) had the aim to align issues concerning the marine environment with other policy areas including Integrated Coastal Zone Management (see Figure 2-19), the habitats directive, the Common Fisheries policy and the Common Agriculture Policy (concerning land-sources pollution). In its opinion, the European Parliament noted that[34]:

> *The marine environment is a precious heritage that must be protected, preserved and, where practicable, restored with the ultimate aim of maintaining biodiversity and providing diverse and dynamic oceans and seas which are clean, healthy and productive. In that*

[34] **POSITION OF THE EUROPEAN PARLIAMENT, adopted at second reading on 11 December 2007,** with a view to the adoption of Directive 2008/56/EC of the European Parliament and of the Council establishing a Framework for Community Action in the field of Marine Environmental Policy (Marine Strategy Framework Directive).

respect, this Directive should, inter alia, promote the integration of environmental considerations into all relevant policy areas and deliver the environmental pillar of the future Maritime Policy for the European Union.

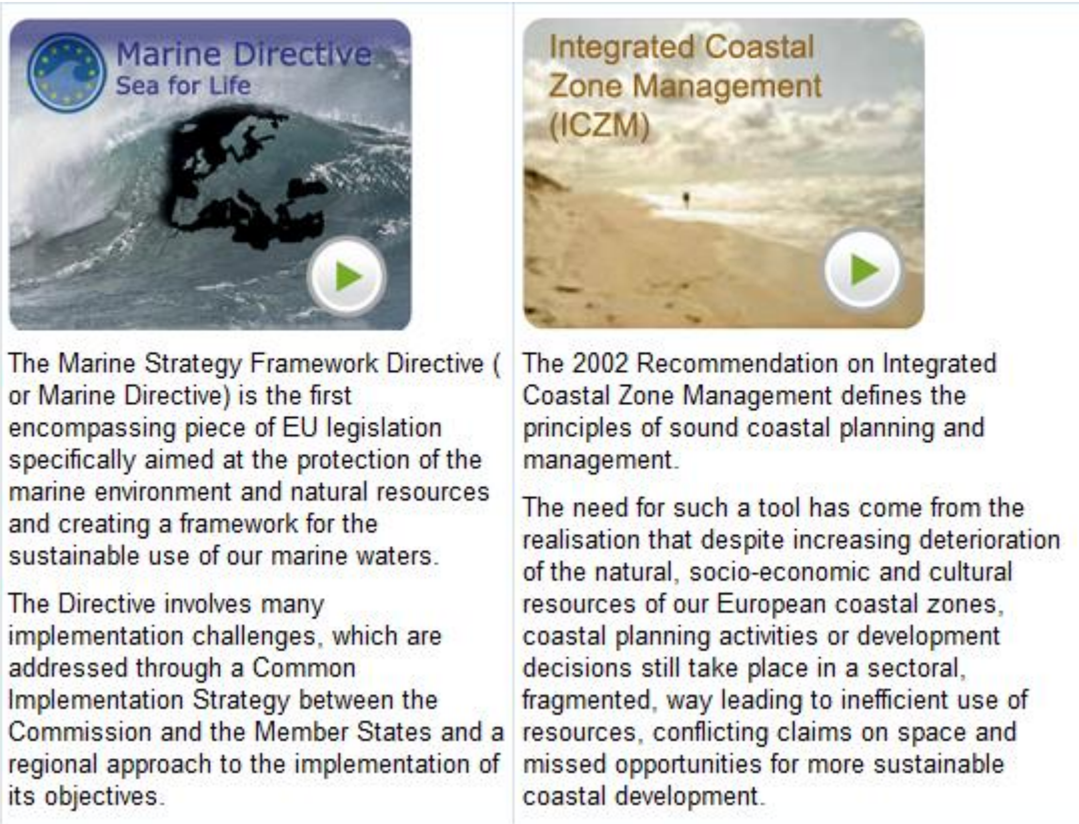


Figure 2-19: Progress by the EU towards protecting the marine environment.

Nevertheless, the legal framework is complex reaching across national boundaries and into international waters which makes prosecution and ultimately deterrence difficult. A guide to the application of Marine environmental law in the EU has been produced by Droit au Droit[35].

Since 2005, there have been significant developments in protection of the marine environment both in the UN International Maritime Organization (IMO MARPOL Convention) and in EU legislation (Directive 2019/883/EU which requires ships to deliver their waste in ports). In addition, EU rules on the protection of the environment through criminal law (Directive 2008/99/EC) have been found inefficient and in need for revision.

But, despite these existing EU rules for prevention of pollution from ships, increased surveillance and enforcement efforts including the increased detection capability provided by CSN, illegal discharges of oil and other polluting substances still regularly occur in European waters. Due to

[35] Addressing Environmental Crimes and Marine Pollution in the EU. Droit au Droit, 2013

lengthy legal processes, the number of prosecutions, remains low, and mainly based on evidence gathered using aircraft observations. Cases using evidence triggered by CSN will shortly feature in court cases in Spain and the number of prosecutions can be expected to increase as the number of detections builds up through the use of the CSN service

Hence, in the context of the Green Deal, the Commission launched a consultation in 2021 to revise the Directive 2005/35 on ship sourced pollution. Revisions to the legislation will be considered for adoption in 2023.

A further useful analysis of the prospective role and actions of the EU is made in the EEA publication, Balancing the future of Europe's coasts[36]. In the report, the policy context is analysed, and some proposals made for improved management of Europe's coasts. It includes a brief look at the use of **ecosystem capital accounting as a tool for improved management**.

2.4.4 Other Actions

Oil pollution does not only arise at sea and around 50% of the oil entering the Mediterranean is estimated to come from land-based sources. In this respect, the UN Environment Programme (UNEP) has established a **Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (GPA).**

The GPA was adopted by the international community in 1995 and "aims at preventing the degradation of the marine environment from land-based activities by facilitating the realization of the duty of States to preserve and protect the marine environment". It is unique in that it is **the only global initiative directly addressing the connectivity between terrestrial, freshwater, coastal and marine ecosystem**s.

The GPA targets major threats to the health, productivity and biodiversity of the marine and coastal environment resulting from human activities on land and proposes an integrated, multisectoral approach based on commitment to action at local, national, regional and global levels. In an era when coastal communities are threatened by new and daunting challenges, e.g. climate change, the holistic ecosystem approach advocated by the GPA is even more relevant today than when first negotiated in 1995.

The **GPA works to identify the sources of land-based pollution** or harmful activities and prepare priority action programmes of measures to reduce them. It concentrates not just on problems originating near the shores – such as discharges from megacities, other urban areas, harbours or industrial enterprises in the coastal zone – but **targets pollution from entire catchment areas**, taking in sources such as agriculture, forestry, aquaculture and tourism.

The GPA, although a global programme, addresses problems at regional, sub-regional and national levels, and thus helps to guide the efforts of the individual Regional Seas programmes to deal with land-based pollution.

[36] Balancing the future of Europe's coasts; EEA Report 12/2013

2.5 Who is Concerned?

Responsibility for dealing with oil pollution in their national water's rests with each country; in this case all 23 which border on to the Mediterranean. Their actions are largely governed by international agreements constructed under the umbrella of the UN and European Commission. These are augmented by regional agreements which bring together the countries concerned for a specific marine area i.e. the Mediterranean, the Black Sea, the Baltic or the North Sea.

Hence the countries, working in an international co-operative framework under the UN and IMO, agree to a common set of controls and regulations which are then implemented by each country. In some case, as discussed earlier, these rules are reflected in EU legislation so strengthening some of the controls. Of course, countries can go beyond the levels to which they have commonly agreed.

Each country is organised differently in terms of both the regulatory oversight and the means to respond when an incident occurs. However, in general, an agency with responsibility for the marine environment is the first in line and which is responsible to the government through an appropriate ministry. In Spain, the primary actor is SASEMAR reporting to the Ministry of Transport, Mobility and Urban Agenda and in Malta it is Transport Malta reporting to the Transport Ministry. But a number of other organisations are also concerned and, through the regional agreements, even organisations in other countries.

Hence, responsibility spans local, national, and international institutions. The stakeholders actively involved by the European coastal Member States in the implementation of these policies are marine **environment agencies often coastguards, inspectorates, police officers, prosecutors, and judges**[37].

- **Maritime agencies and institutes** are in charge of implementation and monitoring of compliance within the Member States. While their mandate is established and subject to national legislation, these are underpinned by the international agreements.
- **Inspectorates** are responsible for monitoring compliance and for identifying contraventions. Relevant are the supreme audit institutions (SAIs) – national bodies auditing other public authorities on their actions, including environmental aspects. (*e.g.,* overseeing construction works close to protected areas and potential overpassing of permits).

[37] These stakeholders are also present within the Environmental Compliance and Governance Forum – in charge of assisting the Commission with the coordination and monitoring of the implementation of the actions to improve environmental compliance and governance as well as in the preparation of legislative proposals or policy initiatives in the field of environmental compliance and governance and other similar tasks.
https://ec.europa.eu/transparency/regexpert/index.cfm?do=groupDetail.groupDetail&groupID=3574

- **Law enforcement entities** such as police forces, marine guards and task forces work together at local and regional levels. Their aim is to make sure that binding legal norms[38] are respected, and perpetrators identified, pursued, and deterred.
- **Judges and prosecutors** have jurisdiction over potential environmental crimes, and the challenging task of verifying whether laws and regulations have been breached, and to what extent. While prosecutors generally hold inquisitorial functions, it is the judges who impose appropriate sanctions, or provisionally suspend suspicious activities, pending decisive proof.

Other notable stakeholders in the field include the following:

- **Legislators** create norms and systems of environmental legislation. National legislators within EU Member States both create laws and incorporate principles transmitted through international or EU law.
- **The private sector** provides services and products (to other interested stakeholders) contributing to environmental compliance assessment. In the field of Earth observation, private companies often find themselves in a position to fill gaps in the available resources of public stakeholders, *e.g.* by providing data for monitoring and as evidence in stage of enforcement.
- **The scientific community** provides services and recommendations to legislators and other stakeholders and develops R&D applications, some of which eventually result in new standards for compliance monitoring, reporting, and forecasting.

2.6 Informed decisions, coordinated actions, and effective interventions.

2.6.1 What Decisions?

In dealing with marine pollution, authorities need to take decisions according to the nature of the pollution and the phase of operations. Mostly, these are defined or at least shaped by the international agreements put in place to mitigate the impacts of oil spills and subsequent pollution.

One of the key lessons coming from the large accidents has been the need to be prepared. The impact of an accident is severe where large quantities of oil are spilt, and a rapid response is necessary if the impact is to be minimised. In this respect, each country is required to make a plan showing how it will respond in an emergency. In many cases, through regional agreements, this includes having the resources available to contain and remove oil spilt in the marine environment.

The key decisions which need to be taken:

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[38] Legal norms encompass laws and other binding obligations imposed by legal sources, *e.g.* EU directives and regulations, regional/local legislative and normative acts, etc.

- When an oil slick is a potential threat to the coastline or marine ecosystem within the national waters of the country concerned.
- Are other countries involved / threatened by the risk and what collaborative measures should be taken.
- What measures should be taken to reduce the threat of the oil slick? Should it be contained and/or cleaned up?
- What resources are available to deal with the threat and how quickly need they be mobilized.
- What ship has been responsible for the oil slick and what evidence is there which could support a legal case of prosecution?
- Whether to request an interpolation of the suspect ship at its next port of call?
- Whether to prosecute a ship owner for an illegal discharge? Is there adequate evidence?
- Are further resources needed to deal with an incident?

Not really a decision, but one of the critical actions which is taken concerns raising awareness of the capability to detect an illegal discharge and eventually to prosecute. This acts to discourage ships captains from making illegal discharges. It also has an influence, sometimes strong, over the behaviour of the ship's captain in the event of an accident – as was seen during the Prestige disaster, when local ports and the ship's captain were in disagreement over the best course of action.

2.6.2 What Data?

Data to support the decisions to be taken include:

- The location of an oil spill, whether it lies in territorial waters or outside the 12km restricted zone.
- The weather and sea conditions where the oil spill is detected.
- The AIS data identifying the ships which were in the vicinity at the time the spill is calculated to have occurred.
- The registered route for the identified ship
- Characterisation of the oil slick i.e. the type of oil, the amount of oil.

Evidence takes the form of photographs, analysed samples along with the satellite information which is compared with observations made on the spot regarding the size, shape and characteristics of the oil slick.

If it is possible, through the use of aircraft, to track the slick over time then this provides additional evidence to be used in court against the offending ship's captain as well as a better understanding of the nature of the slick and whether it is necessary to mobilise other resources e.g. to mop up the oil.

2.6.3 Limitations of Conventional Methods

Before the advent of CSN and the use of Sentinel-1 data, some countries flew aircraft which carried a radar on board, and which flew over the areas of highest risk to detect if oil spills were present. Satellite data provides many advantages over the use of aircraft. Firstly, the use of satellite images for CSN enables a much wider area of coverage. Secondly, it is cheaper than flying aircraft over a long period of time.

A wider area of coverage enables a better performance and better dissuasion for illegal activities. A more systematic coverage is possible meaning that ships captains can be more fearful of being caught. For example, cases exist where 3 possible slicks were identified in a single satellite pass. Clearly, an aircraft could not be in 3 places at once and CSN led to identification of 3 spills instead of just 1.

The estimated cost for using aircraft over the Mediterranean is given in chapter 5.2.2. The cost to cover the whole area is too high to be a realistic option.

Nevertheless, aircraft still form a key part of the surveillance and response operation. Firstly, aircraft can remain in proximity of the detected slick and its evolution can be monitored. This may be performed using SLAR as was the case before the satellite SAR data became available. Secondly, validation of a suspected slick requires an observation of it, which is usually undertaken by use of an aircraft.

Consequently, the aircraft are not entirely replaced by CSN but are used in a complementary fashion. This saves flying time and cost and increases the performance as is discussed in chapter 5.2.

3 The Use of Sentinel Satellite Data

3.1 How can Satellites help keep Seas Clean?

A radar operates by detecting the amount of energy reflected from the surface of the Earth or objects on the surface. Over oceans or other water surfaces this means that when the surface is smooth (as it is typically when covered in oil), little energy is reflected, and the surface appears dark in the image. When the surface is rough (e.g due to surface winds) or there is an object, more energy is reflected, and the object appears brighter. In Figure **3**-**1**, can be seen the darker areas which are supposed oil slicks and bright points which are ships. When the object reflects a lot of energy, a cross may be seen, which is a characteristic of the radar, as is the case of several ships in the image.

An optical imager, as is carried on Sentinel-2, is like a camera and captures its images by measuring the amount of energy emitted or reflected from sunlight by the object. By measuring at different frequencies, the characteristics of the object or ground surface can be determined.

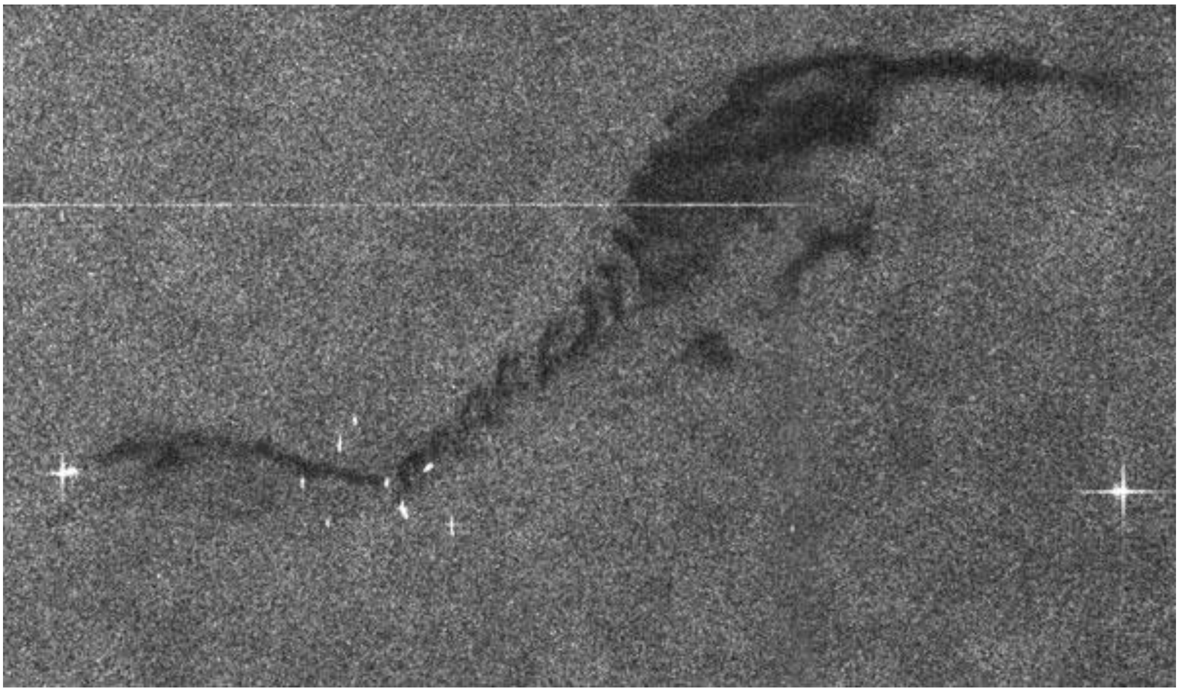

Figure 3-1: Oil slick as seen in a SAR image**.**

Radar can operate through cloud and at nighttime whilst optical imagers cannot. Hence, the great advantage of radar for measurements and images over the oceans.

Satellites are used in various ways to help detect, remove and ultimately prevent pollution at sea. Our case is focused on oil pollution, but other forms of pollution may also be detected using satellite images.

Oil Pollution:

Mostly, radar satellites are used to detect oil slicks at sea, due to their all-weather capability. The radar signal interacts with oil on the surface so that the reflected signal is changed. This leaves a visible trace in the imagery (see Figure **3**-**1**) which is characteristic of oil. The position of the suspected oil spill, its shape in the image, and comparison with an optical image if there is one, all help to characterise the oil as coming from an operational act, an accident or another source. The presence in a sequence of images over a moderate period of time, can indicate a natural seepage or the discharge from a wreck.

The quality of the image depends on many factors including the winds and waves at the water surface. These can also cause false alerts although the shape of the dark pattern in the image will often allow these to be detected.

The oil reflects less of the signal than the sea surface since the oil calms the water surface. Hence most slicks appear as dark features often ribbons in the image. The conditions for good detection are shown in Figure 3-2 taken from an information bulletin provided by EMSA[39].

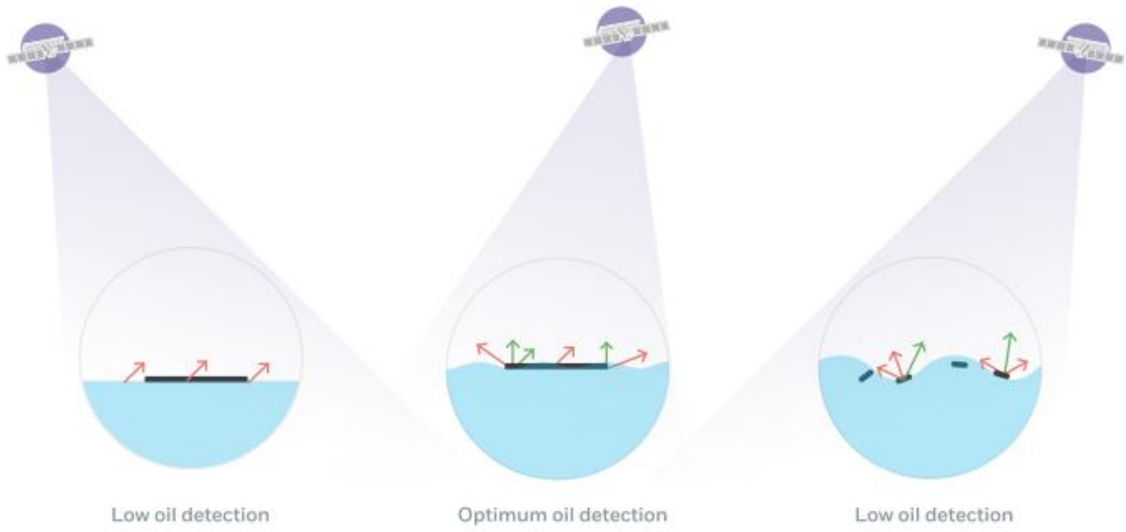

Figure 3-2: Conditions for detecting oil slicks on the sea surface.

If conditions are good i.e. no clouds, then optical images from Sentinel-2 can also help with detection and characterisation of the oil slicks. However, cloudy conditions at sea mean that routine observations are not made using optical imagers and the time to acquire an optical image of a suspected slick is often too long. Hence, oil slick detection is performed almost entirely with SAR imagers.

Chemicals:

Most chemicals are entering the sea from land-based sources of which the most important are fertilizers and pesticides coming from agriculture. An excess of nitrates in the water leads to eutrophication and algal blooms on the ocean surface. These occur primarily near the shore and alongside the mouths of rivers where the discharges occur.

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[39] CleanSeaNet information bulletin; CSN 2021 trifold.

One of the most pressing issues is the release of chemicals from pesticides and fertiliser such as nitrates and phosphates from agricultural fields that – if applied more than the plants are able to absorb – can run into the sea via rivers and ultimately lead to eutrophication and algae blooms that are harmful to aquatic and human life[40].

Satellites can show where a bloom is occurring and can help with more immediate and effective clean-up since the extent of the bloom is visible. However, prevention is more difficult since it requires action to reduce the excess use of fertilizers which is a long and difficult process.

The satellite data:

Sentinel-1 is the Copernicus radar mission, providing an all-weather, day-and-night supply of imagery of Earth's surface. The mission consists of two satellites embarking C-band synthetic aperture radars (SARs) in continuity of the ESA's ERS-2 and Envisat missions. the mission images the entire Earth every six days for the benefit of manifold applications such as, for example, monitoring of Arctic sea ice extent, surveillance of the marine environment, monitoring land-surface for motion risks, mapping for forest, water and soil management.

Copernicus Sentinels data are available under an open and free data policy.

Sentinel-2 data can be accessed at https://scihub.copernicus.eu

More info: https://sentinels.copernicus.eu

Figure 3-3: Sentinel-1 Satellites

Plastics:

Plastic pollution is becoming a widespread problem. Research is showing how optical imagers can detect plastics at sea but the difficulty to acquire good images is an issue. Research is ongoing into how satellite imagery can help combat marine pollution by plastics.

3.2 Copernicus and the Sentinels

Imagery used to support the Clean Seas monitoring in the Mediterranean and indeed the whole of European waters by EMSA is coming from radar satellites and specifically Sentinel-1 satellites which are part of the EU Copernicus programme[41]. Previously, imagery from ERS, Envisat and Radarsat have been extensively used. In 2020, 7300 Sentinel-1 images were delivered by CSN service corresponding to 88% of the overall CSN images delivered in the same year.

Copernicus is an EU flagship programme[42] with the goal of meeting European geo-information needs. At its heart is the most complete, operational satellite system in the world; owned by the EU and operated by ESA and Eumetsat and currently comprising six types of satellites, see Figure **3-4**.

[40] More details can be found in the SeBS case, Water Quality Management in Germany.

[41] https://www.copernicus.eu/en

[42] https://www.copernicus.eu/en

Our case is defined by the Sentinel-1[43] satellites (see Figure 3-3). There are 2 identical Sentinel-1 satellites in orbit. The twin satellites are flying in the same orbit but phased at 180°, in order to give a high revisit frequency of 5 days at the Equator and more frequently over the Mediterranean. The radars operate in C-band (5.4Ghz) so providing continuity with ERS, Envisat and indeed Radarsat which operate at the same frequency. Its ability to distinguish features on the ground (or over the sea) is determined by its spatial resolution which for the Sentinel satellites is between 5m and 20m.

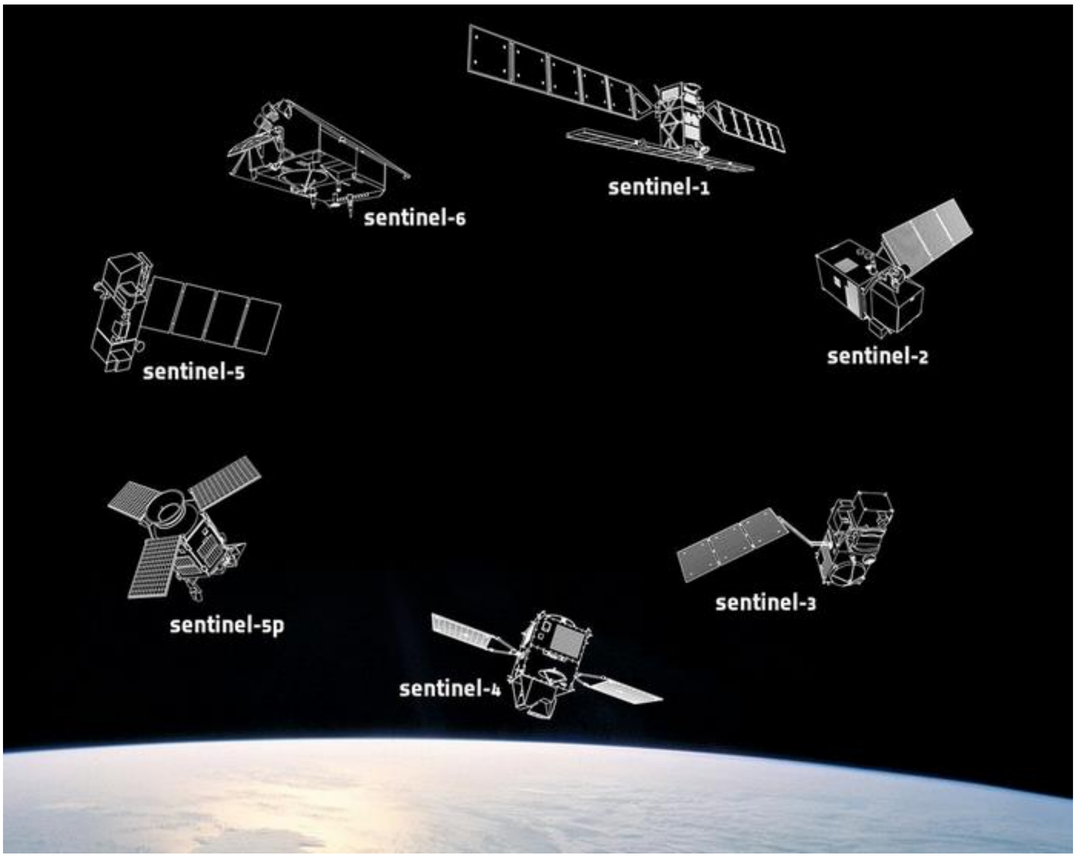

Figure 3-4: Current Sentinel satellites

Data over Europe is downloaded via several ground stations or the EDRS (European Data Relay Satellite) for data elsewhere in the world. Most of the data used by EMSA is coming from ground stations in Norway, Spain, France, Italy and Portugal.

3.3 The CleanSeaNet Service

The CleanSeaNet Service is a European satellite-based oil spill and vessel detection service operated by EMSA since 2007, which offers assistance to all coastal Member States, EFTA countries (Norway

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[43] https://sentinels.copernicus.eu/web/sentinel/missions/sentinel-2

and Iceland) and with partnership countries in the context of European Union cooperation projects for the following activities:

- Identifying and tracing oil pollution on the sea surface.
- Monitoring accidental pollution during emergencies.
- Contributing to the identification of polluters.

The service is financed through the EU budget and is free of charge at the point of use to EU authorities.

The CSN service is based upon the regular and widespread monitoring of European maritime areas using Synthetic Aperture Radar (SAR) satellite images mainly obtained from Sentinel-1 but also from other constellations such as RADARSAT-2, TERRASAR-X, Tandem-X and PAZ 1, providing night and day worldwide coverage of maritime areas independent of fog and cloud cover.

Very high-resolution optical satellite images can also be acquired upon request, depending on the situation and user's needs e.g. during emergencies.

Data from these satellites is processed into images and analysed for oil spill, vessel detection and meteorological variables. The information retrieved includes among others: spill location, spill area and length, confidence level of the detection and supporting information on the potential source of the spill (e.g. detection of vessels and oil and gas installations).

When a possible oil spill is detected, an alert message is sent to the point of contact in the relevant state. Time is of the essence in order to identify the culprit and specific efforts by EMSA have reduced the delay to 20 minutes from the time of image acquisition.

Following receipt of the CSN alert report, the national authority then decides what action to take. Generally, they receive and analyse the images to ascertain the significance of the spill and to deploy other resources to inspect the spill as rapidly as possible. They may send a patrol aircraft, a drone or a vessel to take a sample of the oil and to map its area in correlation with the satellite image. Sea conditions may change quickly and hence the need for a rapid reaction.

The national authority may also take further steps along with EMSA to correlate the spill with vessels in the area at the time. For this purpose, the images may help identify the ship as well as the use of AIS[44] as a tool to do this precisely. AIS is a tool whereby every ship above a certain size must continuously signal its presence to national and international maritime authorities.

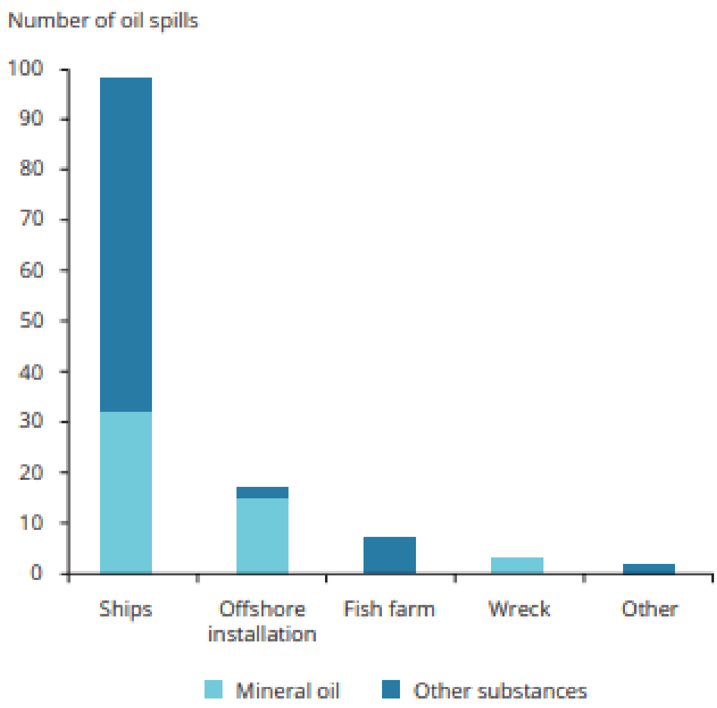
To help identification, a model is generally used. SASEMAR for instance use a US model called Oilmap. When an oil slick is suspected, the first step is to run the model forward to determine if there is a likely danger of oil striking the coast or other sensitive areas e.g. fish farms. As a second

[44] AIS = Automated Identification of Ships. It is a global system, whereby each vessel over a certain size is obliged to carry a box on-board which transmits information concerning the vessel for use by authorities (and others) and which permits accurate identification and tracking of ships.

step, the model is used to trace the possible course that the suspected slick has taken i.e. where it has moved from to identify which ships are suspects.

CleanSeaNet's near-real time service capabilities are crucial to a rapid response by coastal states as well as to increase the likelihood of catching the polluter red-handed. In the case of oil spill related accidents or emergencies the affected coastal State can request additional satellite images to monitor the spill area over an extended period of time, capturing the evolution of the spill and supporting any response and recovery operations.

As we noted earlier as reported by EMSA and EEA in 2021, the rapid validation of the spill is essential and in 2019, only 5% of possible spills were investigated within 3 hours of the image acquisition. The importance here is illustrated in Figure **3**-**5**, which shows that the large majority of validated spills are caused by ships.



Source: Compiled from EMSA Services data.

Figure 3-5: Distribution of possible sources of oil spills verified as mineral oil or other substances as reported by CleanSeaNet in 2019[32].

The CleanSeaNet service offers several benefits:

- In terms of monitoring of illegal discharges:
  - By covering large areas, increases the efficiency of Member States surveillance assets, both airborne and maritime, by pin-pointing the location of potential spills (thus reducing the overall number of hours required to search for slicks).

- To increase the rate of detection of slicks through improved precision compared to earlier systems, by covering larger areas and by providing alerts of suspected slicks in rapid time.
- To contribute to an overall deterrent effect, by ensuring systematic monitoring of European waters, fostering a long-term reduction in the number of oil spills.
- To support the identification of potential polluters in support to Coastal States (see 4.2.2) verification and enforcement activities.

- In terms of emergency support to large accidental spills:
  - Support pollution response operations, with the aim to reduce the environmental and related economic and societal impacts.
  - Increase the efficiency of clean-up operations by acting quickly and effectively.

- For all spills, to improve the common understanding across administrative – especially international – boundaries and hence help promote a coherent, co-ordinated response.

Figure 3-6: Sentinel-1 Image: Oil spill off Cyprus (EMSA 2021).

Sentinel-1 image of 29 August 2021 detected a potential oil spill affecting Cypriot waters. The source of this pollution was a leakage in a tank in a Syrian thermal station located in Baniyas.

The integration of Sentinel-1A data into the service from late 2015 has improved the detection capabilities. Its spatial resolution and intrinsic technical capabilities allow CleanSeaNet to detect smaller spills than before e.g. the average size of the spills detected in 2016 was 25% smaller than the size of the spills detected in 2015. In 2020, Sentinel 1 images showed 97% of delivery reliability and improved the volume of accessible imagery allowing an even more systematic surveillance of major shipping routes.

The launch and operation of Sentinel-1B has led to even better performance due to the increased frequency of observation that became possible. The subsequent loss of Sentinel-1B in January 2022 has a large impact on the service and some third-party data i.e. from Radarsat, will be used to partially fill this gap until Sentinel-1C is launched and deployed.

The number of detections made by CSN each year since 2008, was shown earlier in Figure 2-9. Note that this is for the full service and the figures for just the Mediterranean are not available. In 2020, nearly 8000 potential spills were identified. Based on this chart it would seem that the number of incidents is increasing. However, the area covered by CSN has also increased as shown by the blue line in Figure 2-9 and if the number of spills per million square kilometres of ocean is calculated, a decrease is seen since 2018 which is considered to be showing the deterrent affect i.e. dissuasion of ship's captains to discharge illegally oil at sea.

From the chart, we see that detections increased from 2016 which was when the first Sentinel-1(A) satellite entered into use by CSN, followed by the second Sentinel-1 (B) later that year. This doubled the imaging capacity and partly accounts for the sharp increase in detections. The regular high-quality imagery from the Sentinel-1 satellites also enabled detection of smaller oil slicks and a reduction of false alarms which also accounts for the increase in overall number of detections.

EMSA also operates the Copernicus Maritime Surveillance (CMS) Service which provides Earth Observation products (satellite images and value adding products) to support a better understanding and improved monitoring of activities at sea, within a wide range of operational functions such as maritime safety and security, fisheries control, customs, law enforcement, marine pollution monitoring, and International Cooperation. Implemented by EMSA, it is a Security Service of the EU's Copernicus Programme.

3.4 The Future Evolution of the Service

The CSN service seeks to provide the best possible service to the users, supporting new developments and state of the art technologies through the integration of new ground stations and satellites. In the future the expansion of the service may embrace new areas such as:

- Integrating optical satellite images (e.g. Sentinel-2) to provide an estimate of the spill volume, particularly in the case of larger oil spills (usually resulting from accidents).

- Promote the integration of new earth observation sensors and organise the transition of these new capabilities to operations to enrich the existing portfolio.

- Assess how satellite-based information can be used to monitor marine debris, with particular emphasis on plastics.

In parallel, a number of research projects and pilots are seeking to improve the understanding of how oil spills evolve in the marine environment. Several examples of use cases can be found associated to the Copernicus Marine Service. Some of those are specifically linked to the Mediterranean:

- Monitoring oil spills in the Mediterranean Sea;
- ATHENEA: Preventing and managing oil spills
- Oil spill drift monitoring in the Maltese waters.
- Sorrento accident: monitoring potential oil spills

The last of these relates to an accident in 2015 following a fire on the ferry "Sorrento" sailing between Mallorca and Barcelona.

4 Understanding the Value Chain

4.1 Description of the Value-Chain

The value chain is at the heart of the SeBS methodology divided into 4 tiers as shown in Figure **4-1**. Onto the value chain we map the key actors in delivering and benefiting from the CleanSeaNet service. In the rest of this chapter, these key players are described in more detail to explain the roles they play.

The service provider at tier 1 in our value chain is EMSA. EMSA is supported by private companies which receive and process the Sentinel data.

Tier 2 are the primary users of the CSN service which are the national points of contact in the European (coastal Member States. We have discussed with 2 of these in the Mediterranean region in Spain and in Malta.

In Tier 3 are the further beneficiaries of the CleanSeaNet service. These are other organisations either governmental or private which are able to improve their operations as a result.

The ultimate beneficiaries are the citizens who enjoy cleaner beaches and a richer ecosystem of marine wildlife.

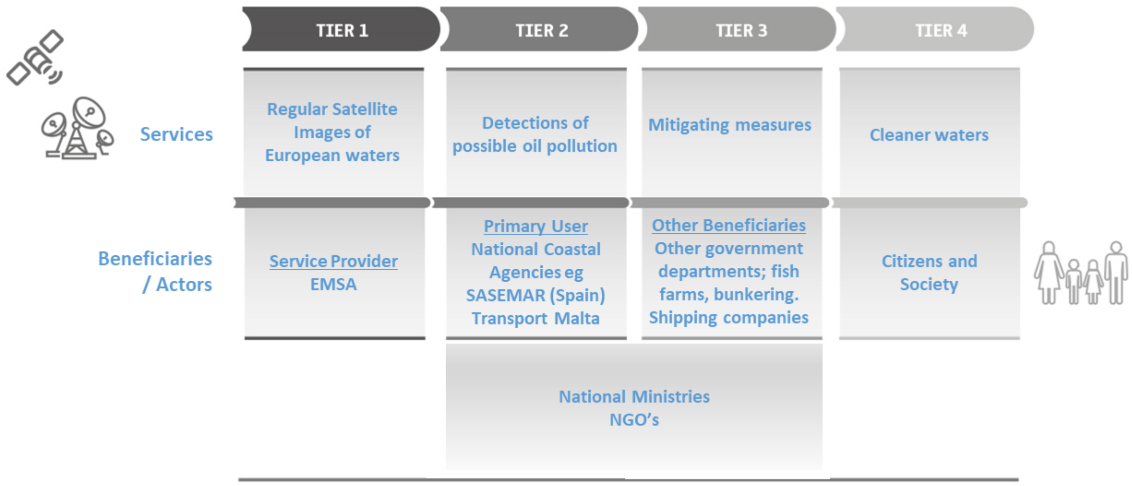


Figure 4-1: Value chain for CleanSeas in the Mediterranean.

Finally, several other actors are also involved such as national ministries which would take decisions over prosecution and of course future resources as well as local authorities which will be involved in the clean-up operations where necessary.

4.2 The Actors

4.2.1 Tier 1: Service Provider -EMSA

EMSA is the European Maritime Safety Agency, an operational agency of the EU, formed in 2002 and based in Lisbon. It is one of the 44 agencies of the EU. Its mission is:

> *to serve EU maritime interests for a safe, secure, green and competitive maritime sector and act as a reliable and respected point of reference in the maritime sector in Europe and worldwide.*

EMSA works as a service provider to the EU Member States, EFTA States (Norway and Iceland) and the European Commission all of which have representation on the EMSA Administrative board. Some 3rd countries, in candidate Countries or beneficiary countries of the SAFEMED and BCSEA projects, also have access to some of the services which EMSA provides. EMSA also provides advice on policy and expert opinion on regulatory aspects. It is an implementing agency to develop capacity in member states and to provide Europe-wide services on ship safety, vessel identification and tracking and accident prevention, mitigation and response.

EMSA operates three dedicated Earth Observation services which use satellite imagery:

- CleanSeaNet, the European oil spill monitoring and vessel detection service - which is the core subject of this case.
- Copernicus Maritime Surveillance (CMS) Service to support a better understanding and improved monitoring of activities at sea.
- Maritime Border surveillance on behalf of the EU border Agency, Frontex.

In addition to data coming from Copernicus, EMSA also uses vessel position information such as AIS, LRIT, VMS and others. EMSA operates the Copernicus Maritime Surveillance Service, part of the Copernicus Security Services, as an Entrusted Entity to the European Commission.

In a separate operation, EMSA provides the CleanSeaNet service which uses data coming from Copernicus. Note this is not a service provided under the framework of Copernicus but a service, provided by EMSA, which uses data coming from Copernicus Sentinel satellites.

Table **4-1** identifies the 30 European countries which have access to the CleanSeaNet service. 22 of these are in the EU with 2 in EFTA and 12 3rd countries. 17 of these border on the Mediterranean (highlighted):

EU	EFTA	3rd Countries
Belgium	Norway	Albania
Bulgaria	Iceland	Azerbaijan
Cyprus		Georgia
Croatia		Iran
Denmark		Israel
Estonia		Jordan

Finland		Lebanon
France		Libya
Germany		Montenegro
Greece		Morocco
Ireland		Tunisia
Italy		Turkey
Latvia		
Lithuania		
Malta		
Netherlands		
Poland		
Portugal		
Romania		
Slovenia		
Spain		
Sweden		

Table 4-1: Countries benefitting from the CleanSeaNet service with those bordering on the Mediterranean highlighted.

To support the supply of the CleanSeaNet service, EMSA works with suppliers in the private sector which are responsible for acquiring and processing the relevant imagery. The key criteria for EMSA are the geographical coverage of the stations to be used coupled with the time to deliver the pre-processed images, which should be less than 30 minutes. These suppliers are subject to a public tender procedure and the service providers may change over time. For the Mediterranean, 3 suppliers are key:

Collecte Localisation Satellites (CLS) which operates grounds stations in France with Sentinel-1 downlink reception capabilities.

Kongsberg Satellite Centre (KSAT) which has established its position as a ground receiving station, covering a large part of Europe, for the Sentinel satellites and especially linked to a near-real time service.

E-GEOS which operates a ground station in Italy and receives data from the Sentinels over Southern Europe and Northern Africa including the Mediterranean basin.

Together, these three ground station operators can acquire and process the imagery for EMSA in the time delay desired of less than 30 minutes.

EMSA's Earth Observation services also rely on contracts signed with license providers for other radar satellites namely MDA Geospacial Service Inc for Radarsat-2, Airbus Defence and Space GmbH for TerraSAR-X, TanDEM-X and Hisdesat for PAZ1.

With regard to pollution response services, EMSA operates a network of stand-by oil spill response vessels, see Figure **4-2**, with different types of oil-combatting equipment arrangements and dispersants which can be called upon by countries to assist in clean-up activities.

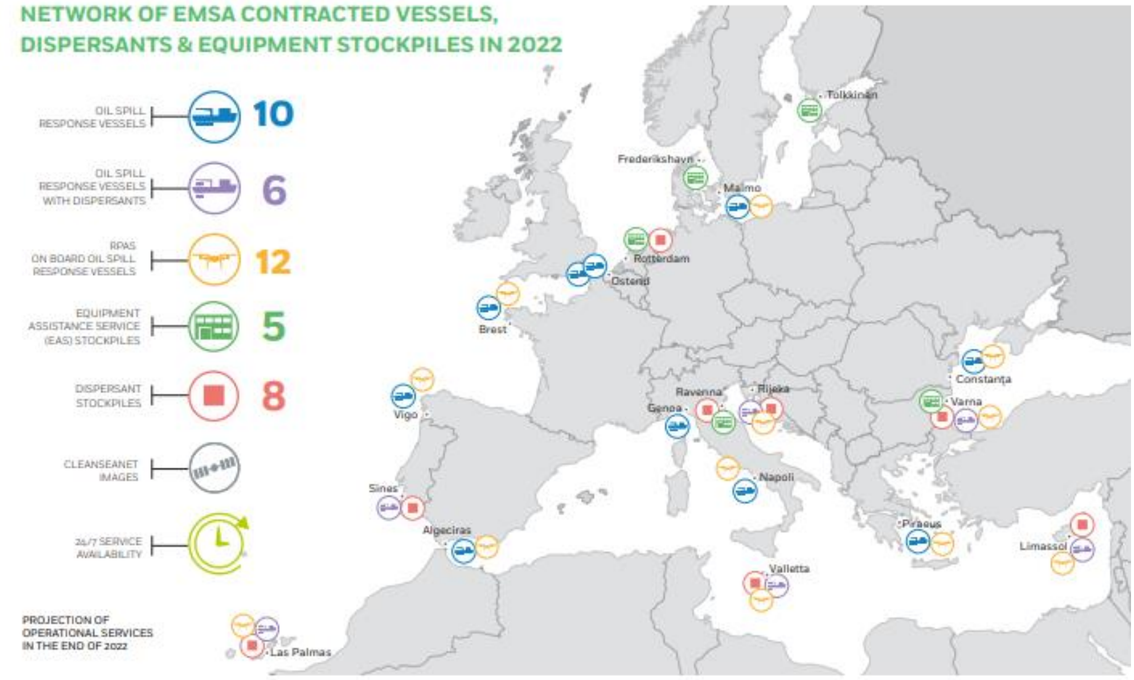


Figure 4-2: Network of EMSA available resources to support clean-up operations.

Capacity building is an important part of the services which EMSA offers, and which plays a significant part in informing the maritime transport community of the risks that they may face in the event of illegal or unsafe activities. EMSA provides regular training to national experts who will operate national services as well as ships owners and captains. By educating them into the CleanSeaNet service, this ensures that knowledge of the capability is spread further acting as a deterrent to the industry.

Some EMSA activities linked to pollution preparedness and response:

- Support the EC and provide advice concerning future legislation regarding the safety of vessels and how to reduce harmful emissions including pollutants.
- Training provided to experts from Member States on tools, equipment and best practices for the prevention and response to pollution.
- Maintaining a network of oil response vessels across Europe ready to respond to any incident. 4 vessels and several drones are located in the Mediterranean area with others nearby (ie. Galacia (Vigo), Canaries) which can be called upon.
- Operating the CleanSeaNet service to provide MS with images of suspected oil spills.
- Co-operation to maintain capability in MS.

4.2.2 Tier 2: Primary User(s) – National Agencies

The primary users are the points of contact, usually in national agencies, in each of the (coastal) Member States to which EMSA sends the CSN alerts see Table **4**-**1**. More usually for SeBS cases, we have a single primary user but since we address a region, the Mediterranean, there are 14 primary users. Since we cannot talk with all of these, two have been willing to engage with our analysis and the two primary agencies which have supported this study are in Malta and Spain.

SASEMAR (Spain):

The Sociedad de Salvamento y Seguridad Marítima or SASEMAR, also known as Salvamento Maritimo is the Spanish Marine Safety Agency, reporting to the Spanish Ministry of Transport and responsible for safety and pollution in Spanish territorial waters. SASEMAR employs 1300 people and operates out of 20 Regional Coordination Centres (RCC) around Spain. Their mission is summarised as "Protecting Life at Sea" by which is meant both humans and (marine) animals. Their two core missions are maritime safety and preventing pollution.

SASEMAR's two challenges are to protect life at sea and to preserve the marine environment, ensuring cleaner and safer seas. The types of emergencies that SASEMAR face are diverse, the most common arise from drifting ships, leisure activity accidents, groundings, illegal immigration, people falling into the water from land, accidents while performing underwater activities etc. To fulfil this mission, the agency operates a fleet of 19 vessels, 54 boats, 11 helicopters, and 3 aircraft.

As a part of this mission, SASEMAR aims to reduce the probability of operational and accidental discharges from ships and fixed facilities and minimize the environmental impact of all pollution on the marine environment. Spain has a coastal perimeter of about 8,000 kilometres and the Spanish area of responsibility extends over a sea surface of one and a half million square kilometres, which is equivalent to three times the national territory. This total area is subdivided into 4 zones: Atlantic, Strait, Mediterranean and Canary Islands. Maritime Rescue maintains close relations of cooperation and coordination with the rescue services of neighbouring countries.

SASEMAR operates 3 CASA CN235-300 maritime patrol aircraft (see Figure 4-3). These planes are used to locate shipwrecks and vessels at sea, detect spills in the marine environment and monitor and identify offending vessels. For these purposes, they carry several special sensors on-board. The aircraft carry out maritime patrol missions with a time in the air of more than 9 hours, so they can intervene in operations with a radius of action of 1,853 kilometres, with a cruise speed of 437 kilometres per hour.

These aircraft are also used for Search and Rescue (SAR) activities which takes priority over pollution detection. Recently, with high numbers of immigrants trying to make the crossing into Spain, the SAR demand has been very high and has severely limited the aircraft time available for pollution operations.

SASEMAR works very closely with the military services in Spain and the Head of the Military Marine Division (DGMM) is the president of the SASEMAR board of directors.

Three of the operations centres receive the CleanSeaNet service directly from EMSA; that is they receive the images in which EMSA has identified possible oil slicks.

Figure 4-3: SASEMAR CASA 235-300 Marine Patrol Aircraft.

CSN is having a very strong impact on the ability to identify illegal spills which has improved with the entry into use of Sentinel-1 data, firstly from S-1A and then S-1B, and again with the introduction of the rapid service in 2018. The high-resolution imagery, with wide-area and regular coverage, has led to a significant increase in the number of suspected slicks detected in Spanish waters as shown in **Error! Reference source not found.**.

The increase in detections as a result of improving performance over the period continued up to 2019 but shows a fall in 2020. From January to March 2021, there were 85 potential oil slicks detected with 83 of these resulting from CSN and if this trend continues, then a further fall can be expected in 2021 (figures not available at the time of writing). Since the performance of the CSN service has not changed, the fall may be the first signs of reducing pollution through deterrence.

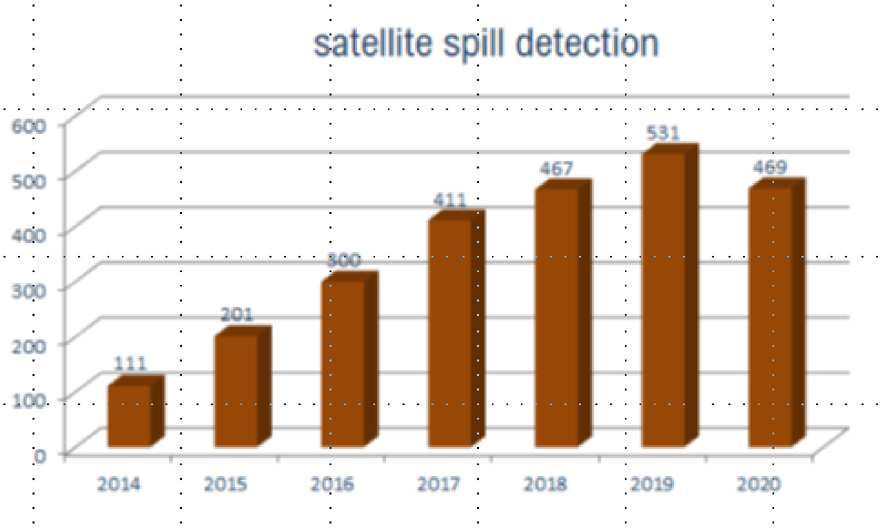


Figure 4-4: Number of potential spills detected in Spanish waters (SASEMAR)

Once verified by SASEMAR as being oil spills, the number of suspected polluters i.e. where the slick is confirmed as oil and a vessel is identified as being the likely source, has also risen (**Error! Reference source not found.**). Not only has the absolute number risen, but so has the success rate as is shown in Figure **4-6**.

The ability to deter vessels from discharging oil at sea is clearly a primary role for CleanSeaNet. However, the time scale for achieving this is rather long. In Spain, SASEMAR has successfully pursued 3 prosecutions of vessels for illegal discharges but none of these made use of CSN data as evidence.

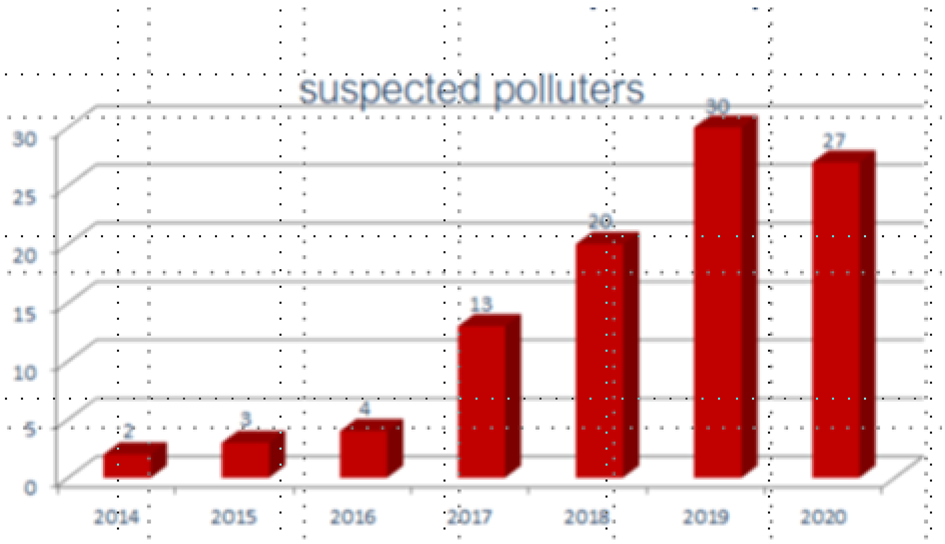


Figure 4-5: Number of suspected polluters following the potential spills (SASEMAR).

This will change and a further case is being processed in the courts for which CSN data has been used to detect and identify the culprit. The reason for the delay is the time taken to pass through the legal system. Only now are cases from 205/2016, where CSN was operating and provided data, coming before the courts. As more do so, the awareness of the risk of successful prosecution will become more well known, and the deterrence will become even higher.

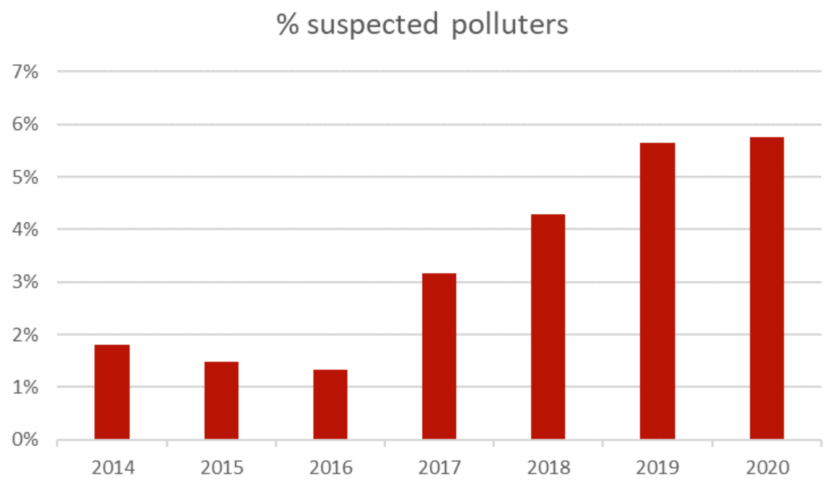


Figure 4-6: Success rate in identifying suspected polluter from potential oil spills (SASEMAR).

SASEMAR works with many international partners. Spain is a signatory to a number of international co-operation agreements. As well as the OPRC, Spain is a partner to the Lisbon agreement with France, Portugal, Morocco and the EU, to the Ramoge agreement with France, Italy and Monaco and has signed agreements with Algeria and with Morocco. Spain is recently a party to the Bonn agreement (covering the Spanish northern shores on the Bay of Biscay).

The Valencia Regional Co-ordination Centre is one of those receiving CSN data directly which is then analysed to identify the source of the pollution. The location is fed into a tracking model which uses AIS to seek to identify the ship at cause. The model processes the direction and speed of all ships passing the identified oil-spill and establishes which are the likely culprits. Further checks may be requested including intercepting the vessel in its next port of call or sending out aircraft to validate the CSN detection. Deployment of aircraft is becoming increasingly difficult as aircraft are by priority fulfilling their Search and Rescue role in response to the increasing flux of immigrants crossing the Mediterranean.

Of the 45-50 images received each month 50-70% of the oil spills will be inspected by sending an asset (ship, aircraft or drone) out to take samples of the pollutant, which needs to happen within 1 - 2 hours.

Transport Malta:

Malta lies at the centre of the Mediterranean and consequently is one of the maritime areas with the heaviest throughput of shipping traffic especially in the Malta-Sicily channel through which the majority of ships sailing between the west and east Mediterranean areas pass. The main traffic lane is about 14 nautical miles off the Maltese coast.

Transport Malta (TM) is the government authority charged with the oversight of the transport sector in Malta. The Authority's mission is:

> *to promote and develop the transport sector in Malta by means of proper regulation and by promotion and development of related services, businesses and other interests both locally and internationally.*

TM was formed in 2010 from the 2 previous authorities responsible for Maritime and Land Transport together with the Department for Civil Aviation. TM is organised into 4 operational directorates responsible for Merchant Shipping, Ports and Yachting, Land Transport and Civil Aviation. TM is responsible for overseeing over 13,000 ship movements each year and for 2.5m tonnes of fuel bunkering. Malta is also a prime destination for cruise ships bringing revenue to the island but also the need for vastly enhanced facilities such as ballast waters being discharged.

Responsibility for control of marine pollution falls within the Ports and Yachting Directorate and specifically, the Department for Marine Operations and Incidence Response. Captain Richard Gabrielle, FNI, former Head of the Department states that:

> *"Any oil pollution accident around our coast would spell disaster for Malta, both economically and environmentally. Similar disasters in recent years which took place on or off the shores of other countries are harbingers of what extent and magnitude such a devastation would be".*

In January 2021, new regulations came into force, reflecting the Malta state adherence to the OPRC. This sets out the regulatory response to the OPRC international convention, which organisations are responsible and how Malta would respond to an accident. It provides TM with the legal basis to take action in the event of an oil-spill accident.

TM has been using the CSN service for 11 /12 years as part of their monitoring programme. Assets are limited (engaging in border control, fisheries control as well as pollution) and CSN allows better deployment of the vessels.

Figure 4-7: Controlling Oil Tanker in Malta.

Fish farms are a source of pollution due to oil from the feed. TM monitors and controls fish farms for this reason. Largest problem is in the late summer as the tuna grow to maturity. Without CSN, inspections are roughly daily at the end of summer. With CSN, inspections can be reduced to one day in three. Early detection of pollution allows better and cheaper clean-up. TM notifies the environmental agency who performs the clean-up. There are 5 or 6 companies operating tuna fish farms in Maltese waters.

Regarding education, TM provides training for ships crews and other maritime linked activities. They show the students CSN which makes them aware of the fact that pollution can be detected, and action may be taken against those polluting illegally.

The bunkering industry is quite strong in Malta and represents a source of pollution and hence which needs to be monitored.

Captain Gabrielle goes on to say:

> *"Ultimately, the implementation and enforcement of the OPRC regulations will contribute to minimising pollution by responding in the most efficient and effective*

manner possible. This will result in better water quality, and a better quality of life for all those who frequent our bays and beaches as well as the tourism and fishing industries."

4.2.3 Tier 3: Secondary Beneficiaries

We identified three categories of other beneficiaries; there are certainly other ones.

Bunkering Operations

Bunkering is the act of refuelling ships. The operation can take place in ports or at designated sites offshore either from piers or jetties, or by ship to ship. The location of Malta makes it well suited to provide bunkering of large ships which are traversing the Mediterranean, especially between the Suez Canal and northern Europe via the straits of Gibraltar. As a result, Malta has developed a significant business in the provision of bunkering and has set a strategic goal to become a major hub for oil and gas particularly for blending and bunkering.

In 2020, the maritime sector was worth over €2.3b to the Malta economy with bunkering being the largest part. Bunkering operations within port limits is permitted at the various terminals, subject to the relevant regulations, namely the Dangerous Cargo Ships, Marine Terminals and Facilities and Bunkering Regulation are complied with, together with the appropriate pre-notification.

Offshore bunkering is carried out at various designated bunkering areas around Malta. Vessels will be allocated a relevant area by the Vessel Traffic Services, which forms part of the Ports and Yachting Directorate on arrival. Five different areas around the island are available and the area is allocated depending on weather conditions and type of vessel. A fleet of 17 bunker barges which are owned by different private companies currently operate within this service sector.

Fish Farming

A second area of economic activity where CSN has a role to play is aquaculture or fish farming. The high concentration of fish leads to oily waste which is controlled by legislation. The slicks can be detected within the CSN images and so monitoring of fish farms, which are often located in remote situations away from tourist centres, is a sort of by-product.

As traditional fishing has become more and more controlled to preserve fish stocks, so fish farming has grown as an industry. The Spanish fishing fleet used to be one of Europe's largest but dwindling stocks has led to decline. Consequently, fish farming is a relatively new industry in both Malta and Spain. Early fish farms started to appear in the 1980's. In the early 90's a study conducted by the university in Malta helped frame the legislation under which the new industry is controlled.

Aquaculture is generally referenced under the dual headings of Tuna Farming and farming of other smaller species (especially Sea Bream, Sea Trout). According to the published "General Review of Bluefin Tuna farming in the Mediterranean", Malta is particularly identified as being the most strategic location of all of the Tuna farming operations in the Mediterranean in terms of the migratory path of the Bluefin tuna. It can therefore be reasonably argued that the Bluefin purse seine tuna operation has directly impacted on what used to be a strong and thriving local traditional tuna fishing community resulting in few if any traditional tuna fishermen left.

Figure 4-8: Fish farm in Malta, "Dina" @ Malta Daily Blogspot

As wild stocks of Atlantic Blue Fin tuna continue to decline and are now on the cusp of collapsing beyond recovery, an entire species is at risk of extinction from over exploitation. These risks are recognised and monitored by various international environmental bodies like ICCAT, WWF (Tuna), CCSBT and others.

Shipping

Transportation of oil and LNG is an essential cog in the global economy, which will only become more important as Europe seeks to reduce dependency on Russian supplies. As noted earlier, Malta lies at the crossroads of the Mediterranean and hence plays an important role in secure and clean operations.

As mentioned earlier, EMSA provide training courses, including to ships captains and owners where awareness of the risks of illegal oil spills is communicated. Raising awareness of the risk of prosecution for illegal acts and indeed for actions which lead to accidents is a strong deterrent.

4.2.4 Tier 4: Citizens and Society

Oil spilled into the marine environment has a strong impact on society at the level of the local community. Whilst the most visible effect is on the environment as discussed earlier, the economic impact falls upon the local community and especially the small-craft fishermen and those forming part of the tourist trade.

Fishing including fish farms can be affected for a significant duration of time. Fish caught in oil polluted waters are contaminated and inspectors will normally designate the areas where any fish caught cannot be sold. After the Sea Empress accident, it was over a year before fish caught in the nearby waters could be sold.

Similarly, tourism is affected with the consequential loss of revenue for many local businesses. Tourists are not so keen to visit beaches covered with oil and even small amounts of oil in the form of pellets are disagreeable. Where oil spills have hit the beaches, the number of tourists can drop for some years[14,33].

Hence, the consequences for local communities if an oil spill reaches their shores is high and has a traumatic impact on the local populace. Those in Galicia who lived through the Prestige, the Bretons who saw the Erika oil on their beaches and even as far back as the Torrey Canyon leaving its oil on the coast of Devon and Cornwall, memories of the accidents rest. Knowing that either errant ships captains or those acting illegally can be traced and prosecuted can reassure those affected bring a sense of community justice.

4.2.5 Other Beneficiaries / Stakeholders

IMO – the International Maritime Organization – is the United Nations specialized agency with responsibility for the safety and security of shipping and the prevention of marine and atmospheric pollution by ships. IMO's work supports the UN SDGs. Formed in 1958, it allows governments to exchange information. IMO is not a beneficiary of CleanSeaNet but as the overarching governing body concerning marine law, is certainly a stakeholder to any action which reduces marine pollution.

Its main role is to create a regulatory framework for the shipping industry that is fair and effective, universally adopted and universally implemented. In other words, its role is to create a level playing field so that ship operators cannot address their financial issues by simply cutting corners and compromising on safety, security and environmental performance. This approach also encourages innovation and efficiency.

Oil spill detection services like CSN in Europe, provide a coherent picture not obtained by other methods. These apply across national borders and are a powerful way to bring countries together to fight undesired and illegal pollution.

REMPEC – Regional Marine Pollution Emergency Response Centre, REMPEC assists the Mediterranean coastal States in ratifying, transposing, implementing and enforcing international maritime conventions. REMPEC is based in Malta.

REMPEC carries out numerous activities, from technical activities such as workshops, training courses, experts' assessments, studies and proposals, to aiding the development of regional instruments and guidelines, as well as assisting the Mediterranean coastal States to implement relevant international maritime rules and regulations in a coherent way.

REMPEC is supported by several networks

- The Mediterranean Assistance Unit (MAU) can be mobilised at the request of the director of REMPEC. MAU provides access to experts to evaluate and advise on responses to emergency incidents. Most recently in 2018 it was activated for an oil spill off Corsica resulting from the collision of two vessels.

We spoke with 2 NGO's which have an interest in oil spills. Neither is a direct stakeholder in CSN since they are not given access to these products but clearly, they are a part of the overall picture.

ITOPF – International Tanker Owners Pollution Federation – is based in London and was established in 1968 after the Torrey Canyon disaster. The Federation supports its members (ship owners and operators) in the event of an accident to minimise the impact of any oil spill. The ITOPF makes extensive use of Sentinel data (1 and 2) to monitor reported accidents and to support any remedial operations. Analysis of images is made internally within the organisation. The Federation interest is on accident prevention and mitigation and much less on illegal activities which is unsurprising given their role.

WWF: the world wildlife fund - currently work with a private supplier (OrbitalEOS in Spain) to gather information on oil spills. Their goal is to assess the impact on the environment and especially on wildlife with a view to exposing illegal or bad practices. WWF does not have access to CSN data. The WWF is constantly monitoring for events and actions which impact on nature and biodiversity. They do use the freely available Sentinel data largely with the aid of OrbitalEOS which is a small start-up seeking to develop its business in oil spill detection.

5 Assessing the Benefits

5.1 Overview

In this section, we consider the actors in each of the tiers and analyse the benefits which they obtain through the use of the Sentinel data. We use 6 dimensions as the framework for analysis and the benefits are presented for each of the dimensions. However, before we dive into the discussion for each of the tiers it is instructive to make some high-level, general observations:

1. **Timing.**

Timing is critical to the detection of oil spills and specially to identify the possible polluter. The longer the interval between an illegal activity creating an oil slick and the fact being registered, the more difficult it is to identify which vessel is to blame. As a potential oil slick is identified, means to validate this are launched as well as a survey of the ships that have passed the area. The AIS data is examined, and the slick location and possible ships that were in the area are entered into a model to create a list of possible culprits. The model is used to establish the drift of the slick to pinpoint where the release of oil was started.

It takes around 20-30 minutes from the satellite pass for the S-1 imagery to be acquired, processed and made available to CSN users. The satellites are in a low earth orbit and even with multiple satellites available, it can take several hours between each opportunity to take an image. Speeding up the delivery further is unlikely to generate much benefit. The AIS data, identifying and giving the position and heading of each ship, is received continuously. Passing this data through a model enables ships which have passed through the region of the slick to be identified

2. **Attribution**

In most of the previous cases which have been analysed, we face the issue of attribution i.e. where there is shown to be an economic benefit, how much of this is due to the use of the data from Sentinel satellites? In the case of CleanSeas in the Mediterranean, this issue is quite complex. On the one hand, the role of the Sentinel data in the CSN service is very clear. The service is almost 100% dependent on the availability of satellite SAR data and even if this does not mean all depends on the Sentinels', in practice without this free data, the service would not be so extensive. It is true that commercial data could be used as images may also be acquired from TERRASAR-X, Tandem-X, PAZ-1 and RADARSAT-2, but whilst Sentinel-1 is operating, then it will be preferred for CSN.

How much does CSN contribute to reducing oil-pollution is a separate story. Experts consider that it has a strong deterrent effect, and for this to be successful two factors are important. Firstly, that the risk of detection is high. Early methods, without access to satellite data, were rather limited and the risk was low. Now, with many satellites available, the detection rate has strongly increased (see **Error! Reference source not found.** and **Error! Reference source not found.**). Secondly, there must al so be a significant risk of successful prosecution and fines which requires faster and more effective processing by the courts. The use of CSN is almost entirely causing the increased risk of detection and as cases are prosecuted using CSN data, the deterrent effect will become even stronger. Hence an overall high level of attribution is considered appropriate and, all savings attributed to CSN, will be 100% attributed to the use of Sentinel data.

3. Putting a Value on Nature

An emerging discipline is seeking to ensure that the true costs of environmental issues are recognised in investment decisions. Natural Capital Accounting places the value of an environmental asset for a specific asset or a country. This allows decisions to be taken which recognise and take into account the value of nature.

Natural capital accounting is a practical framework that can help public and private actors make better decisions through a better understanding of the interaction between the economy and the environment. Specifically, it provides a systematized process to measure and report the stocks and flow of natural capital, considering both biotic resources (habitats and species) and abiotic (water, soil, atmosphere, minerals ...) and the flow of benefits that these generate (services ecosystems). The premise of natural capital accounting is that the environment is essential for society and the economy, so it has to be considered as a valuable asset that must be properly maintained and managed, and the ecosystem services that it provides are properly integrated into the national accounts systems[45].

Can this help us better understand the impact of oil pollution on the marine environment? The UN has established the systematic framework called the SEEA (System of Environmental Economic Accounting – central framework), which has been adopted by the UN Statistical Commission in 2012. This Framework has enabled 90 countries up to the present time to consider including environmental valuations within their national accounting systems. For information on the SEEA, see https://seea.un.org/content/homepage and for more details on Ecosystem Accounting, see https://seea.un.org/ecosystem-accounting.

The Central Framework has been taken further with the concept of ecosystem accounting which constitutes an integrated and comprehensive statistical framework for organizing data about habitats and landscapes, measuring the ecosystem services, tracking changes in ecosystem assets, and linking this information to economic and other human activity. The SEEA-EA was adopted by the UN statistical commission in March 2021. So far, 34 countries have formally incorporated some form of ecosystem accounting into their national accounts.

The SEEA EA takes a spatial approach to accounting, as the benefits a society receives from ecosystems depend on where those assets are in the landscape in relation to the beneficiaries. The extent of the spatial domain may be at many scales depending on the analysis. At present, the main focus has been around countries scale corresponding to the national accounts. However, a recent project led by the Marilles Foundation; a non-profit entity that works to make the Balearic Islands

[45] Marilles Foundation;

a world example of marine conservation. In a report published in July 2021, an analysis has been carried out of the quantified benefits of investment into Marine Protected Areas (MPA) around the Spanish Balearic Island of Mallorca. The study shows a €10 benefit for every €1 invested in the Marine Protected Area of Llevant.

Since the 11,000-hectare (27,000-acre) MPA was set up at the request of the Cala Ratjada fishermen's association in 2007, it has improved fishing in the area, made it easier to regulate leisure activities, slowed coastal erosion, and improved water quality and biodiversity, according to the study[46].

Nevertheless, there are few examples of marine ecosystem accounting but, according to David Álvarez, Executive Director of Ecoacsa[47] a partner to the study,

"Natural Capital Accounting provides irrefutable evidence of the relationship between a marine protected area and the real economy. It is an especially useful tool to assess changes of marine areas and oceanic ecosystems over time. It offers essential data to support decision-making that results in the greater and better protection of the wealth and health of marine ecosystems, which is vital to combat biodiversity loss crisis and guarantee the provision of the necessary services that sustain blue growth".

A further example of growing interest, oil pollution is also a factor impacting on the UN Sustainable Development Goals (SDG's). SDG 14, Life Below Water has the goal to *"Conserve and Sustainably use the Oceans, Sea and Marine Resources for Sustainable Development."* This includes recognition of the role of local fishing communities and how these may be affected by oil pollution.

Work under these initiatives should lead to improved methods of valuing the impact of oil pollution on the marine environment. In the meantime, we shall look at qualitative measures and not attempt to place quantitative values on this aspect of the CSN at this time.

4. **Extrapolation.**

The CSN service operates at European scale and EMSA is providing the selected images to all the countries identified in Table **4-1**. In our analysis, we are focusing first on the benefits in Malta and Spain before extending or extrapolating those to the whole of the Mediterranean. In this respect, we are not able to address specific issues which arise in the other 22 MS and 2 EFTA users of CSN, nor are we able to consider in detail whether another state extracts the same benefits as one of our primary subjects. Hence, our assumptions will, as always, err on the cautious side to avoid creating apparently excessive or fictive benefits.

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[46] https://www.theguardian.com/environment/2021/aug/17/mallorca-marine-reserve-boosts-wildlife-as-well-as-business-report-finds?CMP=Share_iOSApp_Other

[47] **Ecoacsa Reserva de Biodiversidad** is a Spanish company created with the aim of disseminating, promoting and developing tools that allow natural capital valuation and biodiversity integration into the business sector.

We are always grateful for more information and if we can develop deeper understanding in other users of CSN then we shall try to incorporate these into the story. Note that we shall also draw upon some data coming from outside the Mediterranean region where it may be more accessible e.g. Litigation and prosecution data from UK.

5.2 Benefits along the Value-Chain

5.2.1 Tier 1: Service Provider - EMSA

The CleanSeaNet (CSN) service operated by EMSA provides coastal member states (CMS) with an effective warning if an oil spill is detected in their waters. It enables the CMS to decide what further action to take including to clean up the oil if deemed appropriate and to prosecute if the spill is illegal as opposed to accidental.

This is creating value in several ways:

- By reducing the cost of acquiring data,
- Providing a more performant service,
- By avoiding the duplication of resources within each national entity,
- Increased co-ordination between separate entities.
- Regular monitoring provides important statistical data which can inform policy makers.

Reduced data costs (Cost Savings)

We consider here the costs that would be incurred by EMSA were it to replace the use of satellite data by that from marine patrol aircraft (MPA). The MPA's would in reality be flown by each coastal state and hence it can be argued that the cost benefit should be attributed to tier 2. Nevertheless, since it is a counterfactual to the current situation of EMSA supplied CSN, we have included this benefit under tier 1.

Prior to the use of satellite imagery, (some) countries would systematically fly aircraft over critical areas to detect oil discharges. Since aircraft coverage is limited, the areas would be selected according to the perceived risk and likelihood of a spill. If a spill was detected, it would be observed regularly to track the movement and evolution of the slick. In the case of an accident, then regular surveillance would take place to detect if oil was leaking to the surface from the wrecked or abandoned vessels. This provided a partial solution since the aircraft are limited in their capability:

- Coverage is only a part of the coastal waters since the cost and the need for an aircraft fleet makes it too expensive to cover all national waters.
- Aircraft are limited in their capacity to operate in bad weather conditions
- Real time detection was not used and the delay before a possible spill can be inspected is long. Note that improved systems could be developed to overcome this limitation.

Now that the satellite data is routinely available, the use of CSN means that the need for aircraft is reduced. Aircraft offer more flexibility and allow human observation of the slick which is necessary for verification. Hence, both aircraft and satellite imagery are used by the coastal states. The satellite observations and aircraft in combination saves aircraft flying hours or at least makes them available for other maritime missions (fisheries, safety and security, customs/border control).

A marine patrol aircraft (MPA) such as the CASA 235 operated by SASEMAR, costs between €2k-€2.5k per hour to fly[48,49]. It has a normal range of 1,800km and a cruise speed of around 400km per hour, implying mission durations of about 4 hours. An MPA can carry a variety of instruments for observing the sea-surface including cameras and radars selected according to the mission.

A side looking airborne radar (SLAR), which operates in a way similar to the SAR on Sentinel-1, is widely used to detect oil on the sea surface. According to remote sensing experts, flying a SLAR or similar costly instrument, approximately doubles the operating cost largely through depreciation of the capital cost of the radar. We shall take an overall operating cost of the aircraft with a radar on board as being €4k to €5k per hour.

Assuming 4-hour missions, then the operating cost is €16k to €20k per day or between €5.8m and €7.3m per annum.

The side looking airborne radar (SLAR) "looks" out to the side of the aircraft. The range at which the radar can detect oil is dependent on its power as well as the flying altitude. In a paper by ESA[50], the daily coverage of this type of set up is stated as being 50,000km2 to 60,000km2 or 12,500 to 15,000km2 per hour. This implies a radar range of around 20km either side of the aircraft (40km in total) which whilst reasonable does imply a quite powerful radar. We shall choose to be more conservative and take 20km (10km to each side) as the radar range leading to an hourly coverage of 25,000km2 to 30,000km2. We shall use the latter figure in our calculations.

The area of the Mediterranean is 2.5million square kilometres so around 80 aircraft would be required to cover it. Note that in reality, at least twice this number of aircraft would be needed assuming each can fly 180 days per year, but this does not affect the cost calculation as it is based on the hourly cost. To achieve full daily coverage over a full year the cost lies between €460m and €580m with a nominal figure of €520m. This would be the cost to achieve full data equivalence using aircraft with the CSN using satellites.

However, reducing the frequency of observations and covering less area will not reduce the performance linearly. Further, whilst the marginal cost of additional observations is high for an aircraft it is very low for CSN. In consequence, a strategy which uses aircraft to detect the oil spills is unlikely to provide such frequent or wide area coverage as does CSN. This was in fact the situation prior to the introduction of CSN which seems a reasonable base for comparison. Note that we shall introduce a figure for the superior coverage of CSN in the next section.

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48 https://www.aircraftcostcalculator.com/AircraftOperatingCosts/658/CASA+235?a=658
49 https://myaircraftcost.com/casa-235/
50 https://www.esa.int/esapub/br/br128/br128_1.pdf

Reduced coverage with aircraft would result in less frequent observations and limited to a part of territorial waters. If observations are made one day in three, and 30% of the waters are covered every 3 days, this yields about 10% of the total daily coverage. In our discussions, we considered that if the system were to rely on aircraft, it would provide between 5% and 10% of the coverage now offered by CSN.

This leads us to an overall economic benefit from reduced data costs, of between €26m and €52m when considering the source of the images.

It should be noted that the use of CSN does not completely replace the use of aircraft. These are still used to validate a possible detection using CSN and to follow the evolution of any spills which occur. The same aircrafts are used for other maritime missions such as fisheries, search and rescue and coastal patrols. This would be the case even if CSN were not available and would be needed irrespective of the means used to detect the spills.

Drones, or unmanned aircraft, are increasingly being used in many applications to replace the use of aircraft. Some may consider that their use could cut the costs of data gathering so narrowing the advantage for CSN. In reality, the cost of flying a drone is not so much less than the cost of an aircraft. There are some advantages with larger drones which can stay on station/mission longer than an aircraft but, for the present at least, drones are limited to flying within the line of sight of the operator with severe air traffic control restrictions. The cost saving is not so significant.

This is the cost of achieving data equivalence i.e. the costs required for operating the service over the Mediterranean, which would achieve the same performance as was achieved prior to CSN and which CSN replaced. Full data equivalence would cost around €520m whilst we have assumed that some reduction in performance would be acceptable as a cost trade off leading us to the figure of €26m to €52m as the economic benefit from the use of Sentinel data. In our terms these are the costs that are saved as a result of using Sentinel data.

The savings are offset by a cost associated with the supply of CSN. Even if the Sentinel data is free, there are ground station costs as a result of the rapid delivery chain and processing costs (with sub-contractors) to receive and analyse the images for potential oil slicks. The value of these contracts is commercially confidential, and no precise figures are available. As a round number, we shall make the assumption of a cost of €1m p.a. as a reflection of the costs associated with acquiring the Sentinel data, analysing it and sending it in near-real time to EMSA.

Further, if Sentinel data is not available as is the case at the moment after the failure of Sentinel-1B, EMSA procures commercial data to fill the gap as it has recently with imagery coming from the Canadian Radarsat, from TerraSAR-X, and from PAZ. EMSA is unwilling to disclose the contractual purchase costs, but this is likely to add a further €1m to the overall costs. We shall not include this benefit as we are not considering costs of the Copernicus system in any of our calculations. Suffice to note that the CSN benefits from the Sentinel free and open data policy[51].

A more performant service (Improved product)

The baseline considered above is referenced to the situation before CleanSeaNet was introduced. The CSN service improves the performance for slick detection by overcoming some of the limitations of using aircraft by providing coverage of the whole region and with a more rapid reaction time. Can we place an economic benefit on this?

We do not have enough information from the Member States to be able to calculate the value of the incremental improvement in performance. The dissuasion is higher because the ships' captains know that they cannot hide from the surveillance. The probability of a successful prosecution is higher since the reaction time is much faster meaning that the oil slick can be validated better, and the offending ship is more likely to be identified. All these are benefits arising from the use of satellite observations for CSN. But we do not have any basis on which to place a value on it.

In calculating the benefit from reducing input data costs, we took the coverage using aircraft as being 10% of that provided by daily, full ocean coverage from CSN. This does not mean we should take the increased performance of CSN as being 90%! We have stated that this relationship is not linear and that 10% of the coverage would still deliver a high benefit. However, we have not found any data which can show a relationship between the extent of the observations and the deterrent effect on the ships' operators.

Where we do not have a precise value, we make assumptions. In this case we propose to assume a global improvement in performance of 10% to 20% of the baseline. We acknowledge that the rationale for this number is weak but also feel that it is very modest given the ability to cover much wider areas of the sea with less restrictions on the frequency of observation.

Avoiding duplication (Efficiency Gains)

The provision of CSN at EU level means that individual Member States do not need to retain their own resources hence are able to save costs and personnel. Hence, the economic benefit of CSN applies to the countries using the CSN service and not to EMSA. We shall consider this under the tier 2 benefits.

Improving co-ordination amongst users (Improved Oversight)

In providing this service, EMSA is at the heart of a network of national maritime organisations. The CSN service helps bring these organisations together and foster co-operation across national

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[51] Note that EMSA does not acquire data through the CCM (Copernicus Contributing Missions) as the arrangement does not provide for the rapid delivery of data which is necessary for CSN.

boundaries. It helps to establish best practices as well as contributing to capacity building in the countries.

Providing statistics (Better regulation)

As we have seen earlier, the amount of oil entering the marine environment is not accurately known. Estimates vary widely leading to one leading researcher to conclude that the number is not known.

Data coming from the use of CSN is changing this as a more precise picture is revealed of how many slicks there are each year and the area covered. More especially, the location of the slicks is also revealed meaning that the authorities can plan better responses leading to a reduction in the oil.

Legislation controlling the washing of tanks as well as that to maintain the marine environment can be designed better with these data.

Source	**Annual saving**	
	Min	**Max**
Reduced data acquisition costs (use of satellite not aircraft)	€26m	€52m
Cost of acquiring satellite data in NRT	(€1m)	(€1m)
Benefit from Increased performance (10%-20%)	€2.6m	€5.2m
Total	€27.6m	€56.2m

Table 5-1: Operational cost benefits due to the use of CSN.

The monetary benefit shown in Table **5**-**1** are ascribed to EMSA as a counterfactual to the present situation rather than to National Agencies where the costs would be most likely to fall. It does not change the overall benefit but only within which tier of the value chain they will be considered.

5.2.2 Tier 2: Primary User – National Agencies

The CSN service is supporting the Mediterranean states and offering them benefits in different ways. We shall examine these and quantify them where possible or express their qualitative value where it is not possible.

Operational Role

Satellite monitoring of the seas has become a well-used means to detect oil pollution. In order to monitor national waters without CSN, each country would need to monitor their own waters or be exposed to the risk of oil pollution. The CSN service from EMSA identifies where an oil spill may have occurred, delivers the analysed images to the users and sends the alert notifications to their national contact points. This pre-selection of images reduces the effort required by each country which would otherwise need to ensure resources were maintained for this purpose. This benefit is effectively included in the previous section through reduced cost of data acquisition.

Even if the CSN service provides a wide-area surveillance, most countries do maintain an airborne capability in order to survey their national waters for security purposes. These aircraft provide various functions to the national authorities including that of observing the possible slicks detected through CSN.

In our discussions, it was clear that for Spain and Malta, the use of CSN enables their use of the aircraft to be more effective when used for security and other purposes as well as for detecting oil slicks. Hence, there is an additional value to each coastal Member State coming from CSN acting as a replacement for some of the time when it is required to fly aircraft. In our discussions with SASEMAR and with Transport Malta we understand that these savings are real and enable the countries to use their aircraft for other missions.

There are 17 countries around the Mediterranean using the CSN service. We shall make the assumption, supported by our discussions, that on average each saves 10 days of aircraft time in a year or rather, they are able to use the aircraft for other purposes for 10 days per year. This is an average figure which will be higher for countries with longer coastlines and lower for others. This leads to an estimated average saving of €160k to €200k for each country each year based on the aircraft costs used earlier, or a total saving of €2.7m to €3.4m.

In addition, without the CSN service, each country would need to employ experts to interpret the satellite imagery. SAR imagery is collected night as well as day hence a small team is needed to analyse the data. For full 24/7 operations a team of between 5 and 6 persons is required[52]. An expert with the knowledge and skill to analyse the satellite SAR images would cost[53] around €100k per annum. Since many of the Mediterranean states are lower wage economies, we'll take a conservative view of the cost of €80k per annum. Hence, the savings induced in each country through using the CSN service is around €400k per annum. If we assume that all 17 countries would otherwise deploy such a team, then the total cost saving is €6.8m.

In other words, each country is saving approximately €0.6m through having the CSN service provided at EU level.

Source	Annual saving
Cost savings from centralised analysis	€400k
Cost saving from less aircraft use	€200k
Total	€0.6m

Table 5-2: National operational cost savings due to the use of CSN (per Member State)

52 https://www.quora.com/unanswered/How-many-FTE-do-I-need-to-cover-24-7

53 The emphasis is on cost as this is not the salary but the cost of the person plus equipment, employment and organisational overheads etc.

Reduce cost of clean-up.

The trigger to establish better monitoring facilities and a capacity to respond to oil spills was driven by major accidents in the past. Whilst accidents are rare, their environmental impact is devastating and the international agreements discussed in section 2.4, seek to reduce this risk. Consequently, the capacity to monitor and map an oil spill makes a large contribution to reducing the impact.

To this effect, the key indicator apart from the amount of oil spilt, is the cost of cleaning it up. The cost of clean-up operations is highly dependent on where the spill takes place and its extent. It also depends on the threat to coastlines and hence other economic activities or to Marine Protected Areas and hence a threat to the environment.

We learn that the clean-up operation after the Prestige accident was in excess of €100m[54] and could have reached as much as €2.5b[55]. The amount of oil spilt is estimated as 60,000tonnes so an upper cost of around €40k per tonne. For reference, the damages ultimately awarded as a result of the accident were €1.5b[56].

A further reference point can be made for the Exxon Valdez accident where it is recorded that the clean-up costs were $2.8b[57] for 37,000tonnes of oil spilt which is equivalent to around €50k per tonne.

Dagmar Schmidt Etkin has attempted to estimate a universal cost for clean-up operations[58] but concludes that an accurate figure is not possible due to the complexity of the factors concerned.

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54 Wikipedia https://en.wikipedia.org/wiki/Prestige_oil_spill but citation missing.

55 The Prestige: one year on, a continuing disaster. WWF November 2003

56 The Prestige, 16 years on.

57 Economic Impact of Oil Spills. US Department of Energy. 1993.

58 Estimating Clean-up costs of Oil Spills, Dagmar Schmidt Etkin, Oil Spill Intelligence Report 1999.

He uses a model, shown in Figure 5-1, to indicate the relationship between the multiple factors.

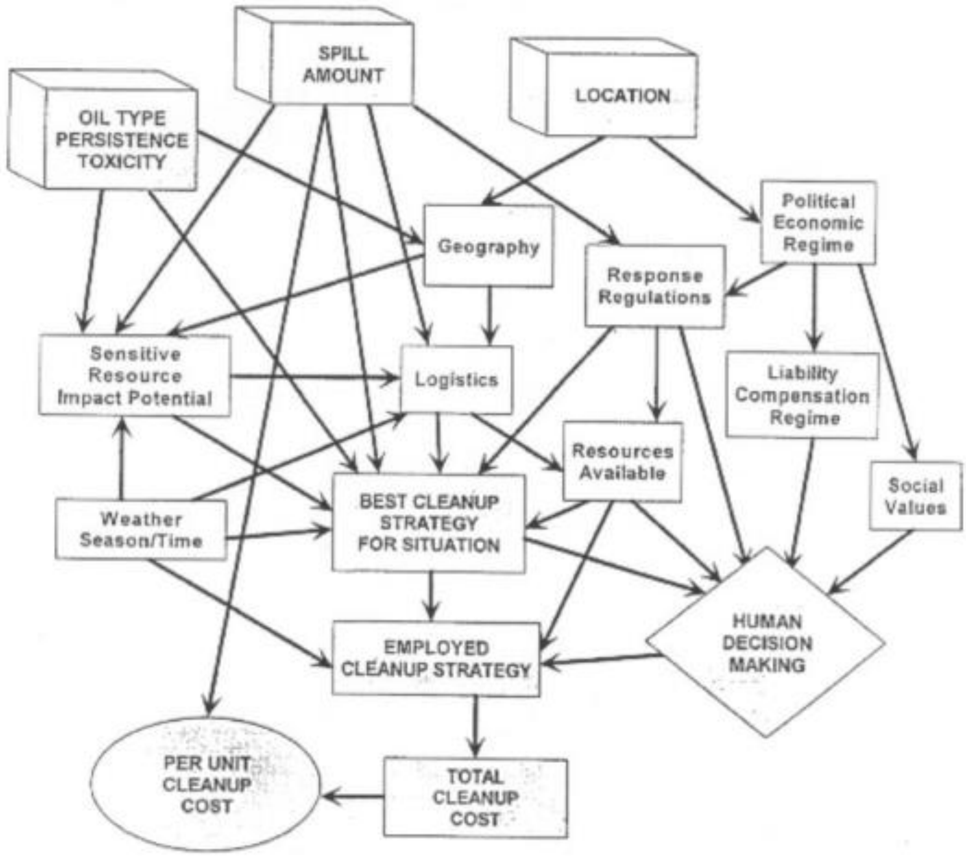

Figure 5-1: Etkin model for oil spill cleanup costs[58].

Location is the most important factor affecting the costs and this is modified by the political will and culture as well as the geography of the coastline near where the spill has occurred. Next is the environment and if there are any environmentally sensitive areas nearby. The distance from the shore, the type of oil spilt, the amount of oil spilt and the presence or otherwise of platforms or human resources in the locality.

Costs have increased over the years but are much lower where the oil can be dispersed or captured whilst on the open sea. Costs here lie in the range of €10k to 20k per tonne. Whilst, if the oil is on the shoreline, then the costs increase significantly to between €120k to €250k per tonne i.e. 10 times more costly.

In 2006, in a report looking at the socio-economic benefits of GMES, PwC took figures from Etkin and from GESAMP as the basis for calculating that the annual cost of cleaning up oil spills in Europe is €120m (for 50,000tonnes) or €2.4k per tonne, and that the cost of environmental degradations comes to €7.5b per year (€150k per tonne). These values seem conservative compared to the others being published.

Source	Clean-up cost	Comment
Prestige Accident	€40k per tonne	Cost of €2.5b to clean up 60k tonnes of oil, with a long coastline affected.
Exxon Valdez	€50k per tonne	Cost of $2.8b to clean up 37k tonnes of oil in a remote and highly sensitive area.
Etkin's model	€3k for light oiling €4k for moderate €20k for heavy oiling	General approach based on modelling.
PWC analysis	€2.4k per tonne	Modified approach from Etkins for the Mediterranean.

Table 5-3: Various figures for clean-up costs of oil spills

For our analysis, we shall use two figures. For the cost of cleaning up illegal discharges the figure of €4k per tonne and for accidental spills where the amount of oil is greater and the impact often more important, the figure of €10k per tonne.

How much does the CSN contribute to reducing costs and environmental impact, and how often are accidents likely to occur in the Mediterranean?

For the first measure, the contribution of CSN is to increase the knowledge of the oil drift and so contributing to saving overall costs. Aircraft also support this but at a much higher cost. Let's take a figure of €4k per tonne for clean-up costs and assume that 10% can be saved through the use of CSN, meaning a saving of €0.4k per tonne.

We said earlier in chapter 2.2 that we do not really know how much oil is discharged into the Mediterranean each year with figures ranging from 1,600 tonnes up to 150,000 tonnes and even outliers suggesting 1m tonnes. Taking account of this we postulated a figure between 10,000 tonnes and 50,000 tonnes each year. Taking the GESAMP figures, 45% of this is illegal dumping and 35% is due to accidents. It has been suggested to us that illegal discharges are generally not cleaned-up. Nevertheless, we have seen an incident off the shore of Israel earlier this year which led to a large clean-up operation lasting many months. We shall assume that 10% of illegal discharges lead to clean-up operations the rest being in positions which do not threaten the coast.

The above is due to illegal actions, but accidents are the more threatening. GESAMP informs us that 35% of the oil spilled is due to accidents so, based on our earlier assumptions this suggests between 3.5k tonnes and 17.5k tonnes of oil on average each year. Here we shall make the assumption that 50% of the oil spilt due to accidents is targeted by a clean-up operation.

Finally, what is the contribution coming from CleanSeaNet to saving clean-up costs? Having better information on the spill and more quickly suggests that CSN should have an impact on clean-up operations. We have not been able to find any analysis which considers this benefit, but which is clearly real. We propose to take the very low figure of 10% for this contribution.

Putting this all together we calculate a cost saving due to CSN use of between €0.5m and €2.7m per annum, see Table 5-4.

Illegal Spills		Minimum	Maximum
Total per annum		10,000	50,000
Percentage which are illegal	45%	4,500	22,500
Percentage subject to clean-up operations	10%	450	2,250
Cost of clean-up	€4k per tonne	€1.8m	€9m
Savings due to CSN	10%	€180k	€900k
Accidental Spills		Minimum	Maximum
Total per annum		10,000	50,000
Percentage which are due to accidents	35%	3,500	18,000
Percentage subject to clean-up operations	50%	1,750	9,000
Cost of clean-up	€20k per tonne	€3.5m	€18m
Savings due to CSN	10%	€350k	€1.8m
Totals			
Overall savings in the Mediterranean		€530k	€2.7m

Table 5-4: CSN induced savings for clean-up operations.

Legal Action

Prosecution of offenders is infrequent but is also very important and necessary pour *decourager les autres.* Indeed, the dissuasive impact of satellite monitoring of oil spills is one of its most important aspects as only by preventing oil pollution is the environment really protected.

Catching and successfully prosecuting offenders is a key tool in the armoury to fight oil pollution. The role of CSN in this overall process is quite limited and very few cases have used CSN data as evidence. One case of the use of satellite images in court was reported by EMSA which took place in the UK in 2012. Other cases have been triggered by CSN data even if there was no subsequent use of the images in court.

How effective is the use of CSN for catching and prosecuting offenders? Fines for tank washing, at least in Spain, are set at €400k. The goal is not to cover costs of any operations but to act as a deterrent to others. This is very difficult to put a value on and so we shall not try to do so. Nevertheless, it does contribute strongly to deter potential polluters and hence has a high value to society.

Deterrence

This seems to be the greatest benefit but is the hardest to calculate! It seems clear that the CSN service acts to deter illegal polluting actions. But where do we assign this benefit in our value chain?

As this is often considered a goal for the public agencies concerned, we shall include it as a benefit for the agency even if it is the whole of society which is benefitting[59]. Can we quantify the benefit? Few figures seem to exist due to a reluctance of Member States to publish them. The ITOPF reports a 65% fall in slicks over the last 10 years so let us assume a fall of 50%. This means that the amount of oil which is not spilt ie deterred, is equal to the amount of known spills ie 4,500 tonnes to 22,500 tonnes and the avoided costs of clean-up are €1.8m to €9m (from Table 5-4) assuming again that 10% would be addressed.

How much of the benefit of deterrence can be ascribed to CSN? All the experts consulted consider that CSN has been a strong factor in reducing illegal discharges. In which case, we shall ascribe the full benefit to CSN. CSN makes a much stronger contribution through deterrence than as a support tool for clean-up actions.

This has the further strong benefit of reducing the environmental impact. If we take the figure quoted earlier of €150k per tonne of oil as being the environmental cost of oil pollution, then with a saving of 4,500 tonnes to 22,500 tonnes per annum, the environmental benefit in economic terms is very high; €540m to €2.5b.

Use of Assets

Both aircraft and ships are used by agencies to inspect and validate if a suspected oil slick is indeed oil. From the agencies we talked to, the access to these assets has become harder in the last few years due to the increasing demand for Search and Rescue services when both ships and aircraft are given priority for search and rescue missions.

The use of CSN is helping to reduce the demand for the use of the assets by pre-filtering possible detections without which both aircraft and ships would need to do more operations to find the oil. In some way, this is accounted for in the deterrent effect of CSN. But the use of CSN is also reducing the need for these assets and so is creating value for the agency concerned. Freeing up assets from oil detection duties is enabling the agency to perform another of its roles – Search and Rescue – more effectively. We have accounted for this benefit earlier where we judged that 10 days per year of aircraft use is saved.

This applies as much to investigating a suspected slick as it does to monitoring the evolution of the slick once it is known about. Where a slick threatens the coastline, clean-up operations seek to reduce the risk of coastal contamination. Without satellite data, an aircraft is flown to monitor the situation and indeed this was the only way before the regular use of satellite imagery was introduced. Hence it would be possible to consider that the benefit of the use of Sentinel can be calculated using a counterfactual of the cost of the aircraft being flown for several days over the polluted area.

If we assume a clean-up operation over 5 days and that the aircraft costs 20k per day, we are saving 100k per operation. However, we have chosen to address this in a different way by working out the

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[59] We could say this is generally true for the actions of public agencies, since they are acting on behalf of society and the general public. So, even if deterrence is not a direct part of their mandate, reducing pollution is, and hence the benefits of deterrence shall be considered here.

benefit from reducing the clean-up costs. If we include a further asset cost benefit for the clean-up, we would be double accounting.

5.2.3 Tier 3: Secondary Beneficiaries

The organisations and sectors which we assign to tier 3 are those which benefit from the operations of the primary user(s). For CleanSeaNet, these are organisations with an interest to detect oil slicks other than those arising from ships. We look at 2 sectors to which this applies.

Monitoring Fish Farms

Fish farming is an important commercial activity in many Mediterranean countries[60]. Spain, Italy and Greece have many farms of Sea Bream and Sea Bream, whilst Malta has a number of farms of Tuna.

Fish farming causes pollution due to nitrates coming from the feed as well as chemicals used to control disease. The feed also releases fish oil into the water. The quantity of oil is an indicator of the risk of environmental damage. The location of the farms is subject to much local debate (and dispute) in the tension between easily accessible cages and other maritime operations especially tourist beaches. Early detection of pollution allows better and cheaper clean-up.

In Malta, Transport Malta uses CSN to monitor the farms for oil slicks. The information is then used by the Department of the Environment which monitors the farms by sending inspectors to visit during the critical growing period which normally falls in July and August. Use of CSN enables visits to be made every 3 days rather than daily so saving manpower and time.

Let's make the assumption that one person can be saved i.e. not employed, over the 8 to 12 week period at a cost (salary, travel, office overheads included) of €1k per week.

This leads to a saving for the agency concerned of €8k to €12k per annum.

Fish farming is an industry present in most if not all coastal countries. We shall use the extrapolation factor of 20 to give an economic value across the whole Mediterranean ie €160k to €240k per annum.

Monitoring Bunkering Activities

Malta has quite an extensive industry supplying fuel to other ships – bunkering. The stations are located offshore and whilst controlled effectively do sometimes leak oil into the sea. Inspections are carried out on a regular basis and will almost certainly be maintained even if better information is available through CleanSeaNet. The benefit comes from being able to react quicker with the knowledge that a leak is occurring.

In the lack of any further, more detailed information, we shall assume the same level of savings as for the fish farms ie €8k to €12k per annum.

60 Fish farms in Mediterranean blamed for pollution.

Bunkering occurs to a greater or lesser extent in all coastal countries. We shall use the extrapolation factor of 20 to give an economic value across the whole Mediterranean ie €160k to €240k per annum.

5.2.4 Tier 4: Citizens and Society

Much of the ultimate benefit from CSN is environmental and could be considered as accruing to society. Placing an economic value on this is beyond the scope of this study. We have noted earlier work to place a value on Marine Protected Areas which is showing very positive results, but we lack the tools and resources to extend this to considering the economic impact of oil pollution. We can attempt to place a value on the loss of leisure facilities arising from an oil spill and hence an economic benefit of reducing this. It will be a very rough calculation but is in any case there to be challenged!

Contamination of coastal areas with high amenity value is a common feature of many oil spills. In addition to costs incurred by clean-up activities, serious economic losses can be experienced by industries and individuals dependent on coastal resources. Usually, the tourism and fisheries sectors are where the greatest impacts are felt. However, there are also many other business activities and sectors that can potentially suffer disruptions and loss of earnings.

Fisheries:

The total value of fish caught in the Mediterranean is calculated as $3.4b by the UN-FAO[61]. This is estimated to yield an economic benefit of $8.9b. In terms of ships and jobs, some 83% of the vessels are small, and these lead to 57% of the jobs in the region. However, these small-scale fisheries only account for 29% of the revenue leading to the FAO considering that the small-scale fishermen are mostly seasonal and that they depend on other jobs for their livelihood. These will often be tourism, but many are farming small holdings. Overall, the local communities are heavily dependent on the fisheries sector and disruption to it caused by an oil spill can have severe consequences.

Nevertheless, whilst an oil spill causes short term disruption through bans or limitations on fishing, in the longer term, fish populations quickly rebuild and even seem to benefit from the restrictions such that, 12 months after the bans around Milford Haven (UK), catches were being recorded at record levels so offsetting the months of inactivity[33]. The longer-term impact is clearly dependent on the scale of the spill. In the case of the Deepwater Horizon accident in the Gulf of Mexico, large-scale affects have been noted with greater consequential damage to fishermen's occupations.

Tourism:

Disruption of recreational activities such as swimming, boating, angling and diving caused by oil contaminated shores is usually relatively short-lived. Once shorelines are clean, normal trade and activities would be expected to resume. However, more long term and damaging economic impacts

[61] The State of the Mediterranean and Black Sea Fisheries 2020.

can occur when public perception of prolonged and wide-scale pollution remains long after the oil has gone.

A search on the impact of oil spills on tourism yields results heavily skewed towards the Deepwater Horizon disaster. This was an exceptional event which does not enable a generic or average assessment of the costs to the tourism industry. The location is also of major importance and, as our anecdote at the beginning illustrates, the clean-up operation itself brings people and money into the towns which in some way offset the loss of tourists.

This is not to argue that the loss is not significant, but the issue is complicated, and we even heard about instances where the compensation paid to businesses was of more interest to them than the lost revenue! Hence, we shall note the impact on the local community, but we shall not attempt to monetize this impact due to its complexity.

In summary, a return to normal trade for the tourism sector requires not only an effective clean-up programme, but also a strategy to restore any loss of appeal to tourists that the area may have suffered.

Overall, there are significant economic benefits to the local coastal communities from reducing the threat of oil spills and their impact when they do occur. However, putting a figure on these is difficult. Oceana, a public relations organisation, put together some figures following the Deepwater Horizon disaster suggesting tourism losses running into hundreds of millions and even billions of dollars. This is an extreme case in reaction to an exceptional event. But if we consider the spill in February 2021 (Lebanon / Israel). Beaches were closed for some months and the impact is still being felt 6 months later. It would not be unreasonable to estimate a loss to the community of €1m to €2m. But this figure is essentially a (conservative) guesstimate as a placeholder in our calculation of the economic benefits.

5.2.5 Other Beneficiaries

Other beneficiaries may be local or have a sectoral or thematic (i.e. environmental) interest. At present, CSN is available to the EU Member States and the 2 EFTA states and in addition some 3rd parties. In an emergency, DG ECHO may authorise others to have access.

Some of the other governmental organisations which benefit have been highlighted in chapter 4 and mostly their access to CSN is via the principal contact in each country i.e. the National Competent Authority. In this case, the benefits to them have been broadly accounted for in the discussion for National Agencies in chapter 5.2.3.

5.3 Summary of Benefits

In this chapter, we draw together the different benefits to the stakeholders identified along the value chain, grouping them by the six dimensions of the value-chain analysis framework.

5.3.1 Economic

The summary of the total economic benefits is shown in Table **5-5** below.

Tier	Total Case benefits		Min	Max
1	Service Provider (EMSA)	Savings on data acquisition	€26m	€52m
		Cost of NRT satellite data	(1m)	(1m)
		Increased performance	€2.6m	€5.2m
	Total Tier 1		€27.6m	€56.2m
2	National Agencies	Operational Role	€10.2m	
		Reduced clean-up costs	€530k	€2.7m
		Deterrence value	€1.8m	€9m
		Support legal action	Not evaluated	
		Better use of assets	Not evaluated	
		Fish farms	€160k	€240k
		Bunkering	€160k	€240k
	Total Tier 2		€12.8m	€22.4m
3	Secondary Beneficiaries	Fish farms	€160k	€240k
		Bunkering	€160k	€240k
	Total Tier 3		€320k	€480k
4	Citizens and Society		€1m	€2m
	Total		€41.7m	€81.1m

Table 5-5: Summary of total economic benefits for whole Mediterranean.

We have considered that the benefits in economic (or monetized) terms fall primarily with the National Agencies responsible for reducing the impact of oil spills. Whilst there are large economic benefits also for society, there are expressed here as environmental benefits which have not been monetized. Those included in tier 4 are derived from the benefit of reduced losses from tourism.

- Avoided data acquisition costs
- Reduced costs through efficiency savings in national agencies
- Reduced clean-up costs due to improved information on oil spills
- Reduced costs due to avoidance of oil spills (deterrence)

5.3.2 Environmental

Without doubt, the main benefit of CSN is to reduce the quantity of oil entering into and damaging the environment. Having very recent imagery of the oil spill and being able to monitor the evolving situation means that the impact of oil spills can be reduced as is the quantity of oil entering the environment. The satellite imagery is providing a synoptic picture of the area including the presence of marine protected areas or delicate environments which can be overlaid.

Many measures have been taken by the IMO to reduce oil pollution most notably by improving the safety of oil tankers and so reducing the number of accidents. But CSN is responding to some of these measures to improve preparedness and complementing others by improving oversight, prosecutions and deterrence. As a result, the amount of oil entering the environment has reduced considerably over the last decade despite the increase in traffic through the Mediterranean.

- Reduced oil entering the environment due to improved cleanup of oil spills and through deterrence of illegal actions.
- Reduced damage to the marine ecosystem; flora and fauna.

5.3.3 Regulatory

CSN supports the regulatory dimension of reducing oil pollution primarily by providing the means to detect where pollution has occurred and supporting the legislative process to prosecute offenders. The rapid response time improves the chances to detect an illegal polluter and the wide-scale data enables more informed decision making.

- Improved enforcement of legislation due to improved and rapid surveillance.
- Improved knowledge of compliance with existing legislation – compliance monitoring.
- More accurate knowledge of compliance to promote the legislation impact.

5.3.4 Entrepreneurship & Innovation

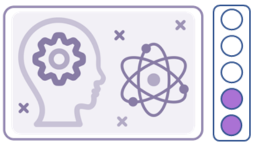
EMSA has driven the introduction of an innovative process to make imagery of suspected oil spills available in less than 20 minutes. This requires special facilities at the ground station and in the organisations concerned.

- CSN is driving innovation in the supply chain to deliver results at speed; from satellite overpass to results in less than 20 minutes.
- Innovation in large-scale image analysis and application of AI techniques.

5.3.5 Science and Technology

Only using satellite surveillance is it possible to gather a macro picture of how much oil is being spilled into the oceans each year. Even then, since many of the slicks still go undetected as they disperse to the extent to be less visible or even not visible at all in the intervals between satellite passes, the quantity of oil being released is really not well understood. As we have noted earlier, estimates vary widely.

As surveillance improves through better systems and software and more data, so R&D will develop to better understand this issue. Only satellite data is able to make this contribution to research.



- Wide-scale nature of the measurements possible with Sentinel data is enabling research projects into oil spills.
- Research into drift models to understand where the oil is moving.

5.3.6 Societal

The value to society of CSN is immense. Whilst it cannot prevent accidents, it can make the ships captains more vigilant through the knowledge that they may be personally held liable (as for the Prestige) and it can play a strong role in the clean-up that is subsequently needed. By this means and through helping to identify potential threats to beaches, CSN helps reduce the impact of oil pollution which does occur. Further, and perhaps more importantly, it plays a strong role in reducing illegal actions.

This leads to reduced social impacts including loss of business due to oil on tourist beaches and loss of income for local fishermen.

Overall, reduced oil pollution leads to an improved environment and a better quality of life for citizens living on the coast; a section of the population which is often among the less wealthy parts of society.

In other cases, we have seen the importance of satellite imagery and derived products to provide a common picture to people concerned. When the next major accident happens, giving all concerned access to the same pictures so building a common picture can play an important role for those concerned.

- Cleaner marine environment
- Reduced pollution impact on tourism, associated business and local fishermen
- Improved quality of life for coastal communities (less oil on beaches).
- Common picture for Communities affected.

6 Key Findings and Final Thoughts

6.1 Key Findings

The CleanSeaNet service, operated by the European Maritime Safety Agency (EMSA) using Copernicus Sentinel data is enabling countries to improve their knowledge of oil spills occurring in their waters and reduce their impact when they occur. It helps to gather evidence against those acting illegally and, in the event of spills, whether illegal or due to accidents, to help guide subsequent clean-up operations. It helps national agencies prioritise the deployment of aircraft, drones or ships to intercept the suspected oil slick, to take samples and to gather evidence as to the offender in the case of illegal actions.

Cost savings are significant as the centralised operation means that countries can reduce their own resources in terms of both people and aircraft needed to monitor and detect spills in their waters. The number of people is reduced since surveillance is made at European level whilst fewer days of aircraft time are required for flying surveillance missions. The use of satellites, where the coverage is inherently large, improves the operation as more of the sea-surface can be monitored and observed more often.

Where accidental oil spills occur, the clean-up cost is usually very high. This is certainly true for the large accidents such as the Prestige or Torrey Canyon where the name of the ship is sufficient to evoke images of black seas, that occur, happily infrequently. Having a clear, synoptic picture of where the oil is makes the clean-up more efficient and faster so reducing the impact.

When dealing with illegal spills the quantity of oil is less and more usually located away from the shore. But the impact on the marine environment is still significant, and, whilst there may not be a clean-up operation, the benefit comes from deterring ships from making an illegal discharge to avoid oil entering the marine environment. Knowledge that detection of and prosecution for causing an illegal spill is likely has certainly reduced their frequency. Based on figures from the ITOPF, we consider that there has been a reduction of 50% but, more time and more prosecutions are required before this can really be quantified.

The service is estimated to generate an economic benefit of between €41.7m and €81.1m per annum for the area of the Mediterranean. This is perhaps modest considering the size of the area being monitored. However, the environmental and social benefits are even more significant and are arguably, even the main drivers for the service.

For each of the different types of benefit a subjective assessment is made of the relative importance that it plays. This is discussed for each of the dimensions in the previous chapter and the summary is presented in Figure 6-1.

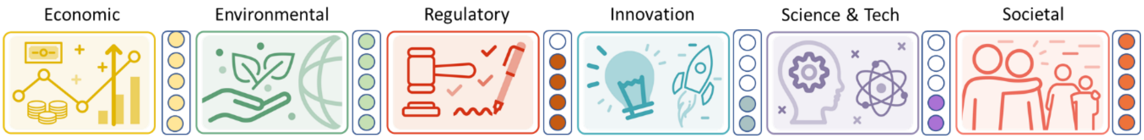


Figure 6-1: Delivering value across the full range of dimensions.

In chapter 4, we presented the value chain for the case and in Figure 6-2 we extend this to show the types of benefit and the primary way in which value is manifest at each tier. We call this the "developed" value chain. It is presented to capture the key elements of the case in one picture.

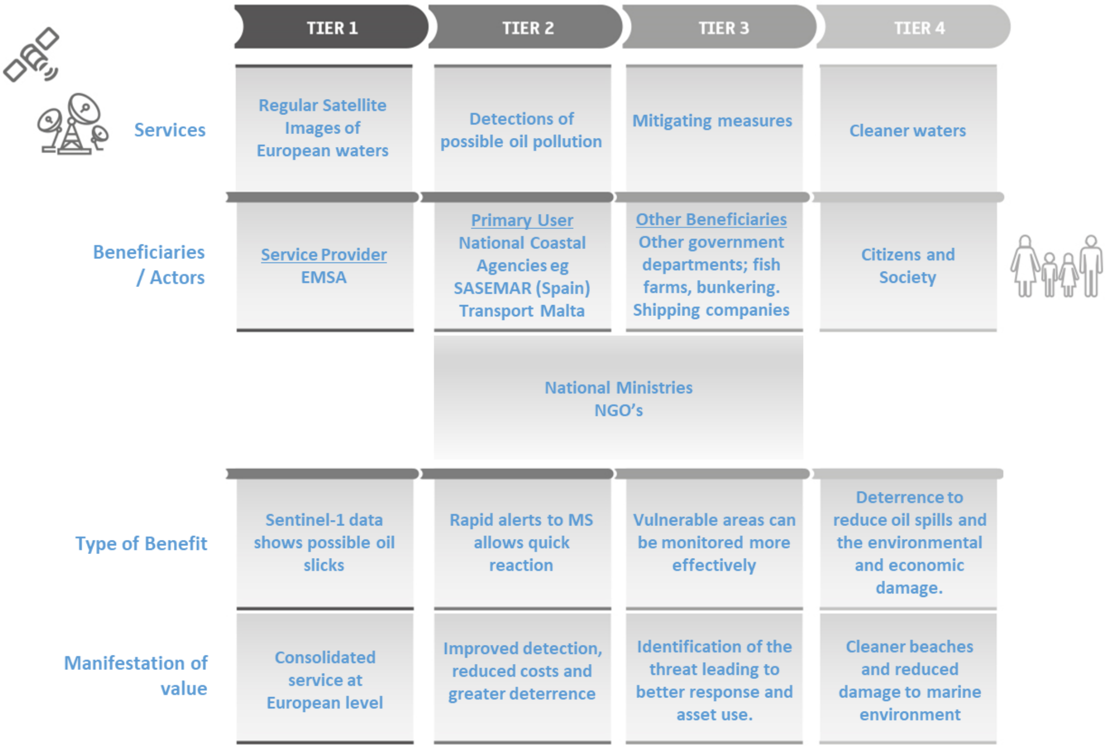


Figure 6-2: Developed Value chain for Oil Spill Monitoring.

Whilst the economic benefits are significant, even more important is the impact to reduce the quantity of oil entering the marine environment. We have also noted some similarities with other cases which emerge when we look at cross-cutting benefits. For example, the ability to deter illegal activities or to encourage people to behave correctly is also seen in the case of Forestry Management in Sweden. The knowledge that offenders will be observed is often sufficient to induce the correct behaviour.

EMSA has been given the responsibility to provide the CleanSeaNet service and, from the outset has used satellite data in its execution. The availability of more regular and frequent imagery coming from the Sentinel satellites, enables EMSA to fulfil its role more effectively.

CSN also supports other aspects of the operational role of EMSA. For example, the network of national agencies with which EMSA interact are working more closely together as a result. EMSA provides training, encourages best practice and supports capacity building in the coastal member states which are served. Whilst this is a function of the EMSA role, CSN adds to it by offering synoptic, wide-scale views of the Mediterranean so encouraging closer working relationships and stronger collaboration.

6.2 The Impact of Sentinel Data

EMSA started using Sentinel-1A data from late 2015 for the CSN service which had previously been using data from the Canadian Radarsat-2 satellite. With the launch of Sentinel-1B, starting in 2016 coverage became much more extensive and more frequent observations were possible. The importance was highlighted with the failure of Sentinel-1B in December 2021. To maintain the level of service, EMSA has procured data from other (commercial) satellites.

Before CSN, some Member States used aircraft to conduct relevant surveillance of their own waters. The use of Sentinel data has allowed those countries using aircraft to reduce their use for oil slick surveillance and redeploy them for other missions (often to Search and Rescue). In addition, the wide area coverage that satellite data provides improves the performance of the overall system.

Hence the impact of Sentinel data has been to:

- reduce the overall cost of surveillance,
- widen the areas covered by making surveillance possible in areas which were not monitored previously,
- improve the service with more extensive and regular coverage of European waters,
- enable more reactivity by reducing the time from observation to detection
- Make savings by reducing the need to buy commercially available radar data.

Overall, the Sentinel data has transformed the ability to monitor territorial waters for oil spills and reduce the overall amount of oil entering the marine environment.

6.3 Widening the Perspective

Geographic Extension

The CSN service receives and processes imagery and locates suspected oil spills, in all European coastal waters. Our analysis has evaluated the benefits for the Mediterranean Sea, drawing on information focused on Spain and Malta. Data from the latter have been extrapolated to the whole of the Mediterranean Sea.

The indicators used are not specific to the Mediterranean region and an extrapolation can be made beyond this to other European waters ie, the Black Sea, the Atlantic, the North Sea, the Baltic and a small part of the Arctic Ocean. In each of these areas, regional agreements exist, and countries use the service within their own oil spill detection and clean-up operation. The primary factor to change will be the area to be covered and the quantity of oil which passes through the area.

Out of interest, what could be the total economic benefit of the CleanSeaNet service?

It is not our goal to assess the indicators for each of the 5 regions listed above which are covered by CSN. The Mediterranean is by far the largest of the basins and has the most oil in transit. To make a simple extrapolation we shall use the surface area of the seas to provide a scaling factor. Some of these have defined limits and a figure for the surface area is available from Wikipedia. For the Atlantic and Arctic Oceans this is not the case. For the Atlantic, the size of the EEZ for Ireland (437), France (345), Portugal (315) and Spain (561) are available from The Flanders Marine Institute database at Marineregions.org. Including these gives a total of 1660kkm2 for the Atlantic region. The Arctic has limited coverage in near real time and hence we add a nominal 100km2 whilst the French overseas departments which in total cover 10,000kkm2 have not been included.

Basin		Surface Area (thousand km2)	Source
Mediterranean Sea		2,500	Wikipedia
Black Sea		436	Wikipedia
Baltic Sea		377	Wikipedia
North Sea		570	Wikipedia
Atlantic Ocean		1660	Marine regions
Arctic Ocean		100	Assumption
Total		5,643	

Table 6-1: Area of European Maritime Basins covered with CleanSeaNet

The results are shown in Table **6**-**1**, leading to the conclusion that the total economic benefits generated by CleanSeaNet in monitoring the European continent is in the order of €93m to €180m per annum.

For the record, if French overseas departments were to be included, the total rises to an astonishing €260m to €505m per annum.

Improved Technological Maturity

Overall, the system delivering the CleanSeaNet service is operational and reliable and, whilst some changes could improve it, questions will be open about the relative value. For instance, additional satellites would improve the frequency and hence reliability of detection but at a large cost.

The benefits of using Sentinel data for reducing the level of oil pollution can be increased through some technological improvements. For example, increasing the percentage of oil spills detected would improve deterrence, whilst increasing the reliability of the detection would reduce the cost of processing false alarms. It is possible that both of these factors may be improved in the future through the use of artificial intelligence as a means to rapidly identify potential spills in the images. Research is ongoing in this area.

Increasing knowledge of the type of oil could also help as is being investigated through the use of Sentinel-2 and data from other multi-spectral sensors.

CSN could potentially be developed in other ways. Plastics have become a major threat to marine ecosystems. Research is ongoing to detect masses of plastic waste floating in the oceans as a first step to cleaning them up. In the near future, other satellite-based sensors may provide crucial information in this respect.

6.4 Final Thoughts

CleanSeaNet has become a well-established service, providing information across Europe to reduce the quantity of oil entering the marine environment. It helps EU coastal states to detect where an oil spill has occurred and to identify the source. In the case of larger, or threatening spills, it helps with the clean-up operation.

The economic benefits are really significant largely driven by efficiency savings. The benefits of a collective operation are quite clear. Whilst it would be possible for each country to establish its own service, the economy of scale for the whole of Europe yields a significant benefit. In this domain, Member States are fully responsible and, although controlling oil pollution and its effects is subject to a number of international agreements and regional collaborations, the CleanSeaNet service has also helped to foster greater co-operation amongst the coastal states concerned. For example, by introducing standard training courses and improving familiarity and knowledge by public and private stakeholders.

Copernicus Sentinel data is central to CSN. Whilst data is available from other sources; Radarsat-2 (Canada) or several commercial missions (e.g. the German TerraSAR-X and Spanish Paz-1), that from Sentinel is free so monetizing some of the value of the European investment in Copernicus. Whichever the source, EMSA pay additional costs for a near-real-time delivery service which greatly enhances the value of CSN.

The most important economic benefit is one that is difficult to measure; that is to dissuade ships captains (and owners) from making illegal discharges. All the experts agree that this is happening yet the numbers of possible oil spills being detected is still rising[62] probably due to the superior performance of CSN using more regular imagery which is collected more rapidly and with a better capability to detect oil spills.

We also find that the level of prosecutions is lagging behind the service due to delays in the legal systems. In some countries, Illegal discharges detected 5 years ago are only now being introduced into the courts. Consequently, whilst the risk of detection has strongly increased, the risk of punishment is still not fully realised. This is set to change shortly as the first case in Spain based on CSN is being processed with others to follow.

[62] We discussed in chapter 3 that, whilst actual detections are rising, this is also due to a larger coverage area and that the number of detections per million square kilometres is falling. Further, the performance of the overall CSN system is improving leading to more potential spills being detected.

Yet the most important benefit of all is to reduce the impact of oil on the marine environment. Putting an economic value on this is not possible due to the real difficulty in understanding the impact and its direct cost. “Ecosystem Accounting” as a discipline may help in the future, but for the moment does not provide the tools to make this type of economic impact assessment.

In conclusion, the CSN service plays a crucial role to reduce the amount of oil entering the European marine environment, reducing the impact on marine flora and fauna and protecting valuable marine ecosystems.

Annex 1: References and Sources

The list below covers the main sources used throughout the study. The reader can find more references in the form of footnotes or hyperlinks throughout the report.

Balancing the future of Europe's coasts, EEA Report 12/2013.

Estimates of Oil entering the Marine Environment from Sea-based Activities. GESAMP/IMO report 2007.

Oil Pollution in the Mediterranean Sea: An Overview. Angela Carpenter, EGU 2020.

Oil Pollution in the Mediterranean Sea: Part 1. Angela Carpenter & Andrey Kostianoy (editors)

Oil Spill Intervention in the Mediterranean Sea, Neil Bellefontaine, et al. Handbook of Environmental Chemistry, 2016.

On the Monitoring of Illicit Vessel Discharges: EC-Joint Research Centre 2001.

Spatial and Temporal Assessment of Oil Spills in the Mediterranean Sea, Polinov, S, Bookman R, Levin N. Marine Pollution Bulletin, 2021.

The Prestige: one year on, a continuing disaster. WWF November 2003

Annex 2: List of Acronyms and Abbreviations

AIS	Automated Identification of Ships
CCM	Copernicus Contributing Missions
CCSBT	Commission for the Conservation of Southern Bluefin Tuna
CMS	Copernicus Maritime Service
CSN	CleanSeaNet
EC	European Commission
EEZ	Exclusive Economic Zone
EFTA	European Free Trade Area
EMSA	European Maritime Safety Agency
EU	European Union
GNSS	Global Navigation Satellite System
GPA	(UNEP) Global Programme of Action for the Protection of the Marine Environment from Land-based Activities
IMO	International Maritime Organisation
ICCAT	International Commission for the Conservation of Atlantic Tuna.
ITOPF	International Tanker Owners Pollution Foundation
LNG	Liquified Natural Gas
MAP	Mediterranean Action Plan
MCSD	Mediterranean Commission on Sustainable Development
MPA	Marine Protected Area
NRT	Near Real Time
OPRC	Oil Pollution Preparedness, Response and Co-operation
RAC	Regional Activity Centre
RCC	Rescue Co-ordination Centre
REMPEC	Regional Marine Pollution Emergency Response Centre
SAR	Synthetic Aperture Radar
SAR	Search and Rescue
SASEMAR	Spanish Agency for Maritime Safety
SEEA	System of Environmental Economic Accounting
SLAR	Side Looking Airborne Radar
SPA	Special Protected Area
TM	Transport Malta
UNEP	United Nations Environment Programme
WWF	World Wildlife Fund

Annex 3: General Approach and Methodology

This case has been analysed as a part of the Sentinel Benefits Study (SeBS), which looks at the value being created by the use of Sentinel data. It follows a methodology[63], established during a previous study, looking at a value chain for the use of a single EO service.

For each case, a value chain is established with a service provider and a primary user. The value-chain is validated with these two key players. Through a combination of desk and field research, we develop our understanding of all the actors in the value chain, the role that they play and how they may benefit through the use of the satellite-derived products.

The value-chain is divided into a number of tiers where the supplier is Tier 1, and the primary user is Tier 2. The last Tier is always "Citizens and Society". The number may vary according to the complexity of the value-chain. The benefits are then analysed against each of these tiers.

Once written, the draft report is then shared with all the persons with whom we have spoken, and their comments are incorporated, or a further discussion is held to establish a common understanding. Note that we are not asking these experts to endorse our findings but to indicate any gross errors or sensitivities which may have been introduced. At the end of this process, the report is made public.

As work has proceeded and more cases analysed, some modifications have been made to the methodology described in reference 3. The first of these has been to expand from the two dimensions used earlier, namely economic and environmental benefits, to add those connected to societal, regulatory, innovation and entrepreneurship and scientific and technological. These six dimensions are described in the table A2-1 below.

Dimension	Definition
ECONOMIC	Impacts related to the production of goods or services, or impacts on monetary flow or volume, such as revenue, profit, capital and (indirectly, through turnover generation) employment.
ENVIRONMENTAL	Impacts related to the state and health of the environment, particularly as regards the ecosystem services on which human societies depend.
SOCIETAL	Impacts related to societal aspects such as increased trust in authorities, better public health or secured geostrategic position.
REGULATORY	Impacts linked to the development, enactment or enforcement of regulations, directives and other legal instruments by policymakers.
INNOVATION-ENTREPRENEURSHIP	Impacts linked to the development of new enterprise and/or the introduction of technological innovation into the market.
SCIENCE-TECHNOLOGY	Impacts linked to academic, scientific or technological research and development, the advancement of the state of knowledge in a particular domain.

63 SeBS Methodology; June 2017.

Table A2-1: Definitions for the benefit dimensions

For each of these, a ranking has been introduced to give an immediate, visual impression of the scale of the benefits under each dimension. To aid in the quantification of these, a guide has been introduced which is shown in Table A2-2.

Rank	Benefit status	Criteria
0	**Null**	The case presents no perceivable benefits in this dimension, and no potential for such benefits to emerge is anticipated.
1	**Latent**	The value chain described in the case may, in general, present potential benefits in this dimension, but none have been identified or described in this particular instance.
2	**Manifest**: At least one benefit in this dimension has been identified through the value chain within the case. Its significance in the context of the case overall is judged to be:	**Low**
3		**Moderate**
4		**High**
5		**Exceptional**

Table A2-2: The ranking of the benefits.

In order to introduce further basis for comparison, a systematic approach has been developed for the analysis of the benefits. A series of indicators have been defined for each of the benefit dimensions against which each case can be considered.

The indicators used in the case are listed in section 5.3.6, and a full list of all indicators considered is provided in Table A2-3.

Dimension	Indicator	What it can mean.
Economic	Avoided costs (AV)	Alternative means to gather data
	Increased Revenues (IR)	Increased production/sales
	Reduced Inputs (RI)	Less time spent or material saved
	Improved Efficiency (IE)	Better use of resources
Environmental	Reduced pollution (RP)	Reduced amounts of pollutants in key resources e.g. water, air
	Reduced impact on natural resources (RR)	Reduced environmental impact e.g erosion, habitats/biodiversity.
Societal	Improved public health (IPH)	Less toxicological risk
	Common Understanding (CU)	Better control and communication of remedial efforts i.e through common maps.
	Increased trust and better transparency (ITT)	Improved preparedness / response
	Strategic Value (SV)	Common societal value to a country or region.
Regulatory	Improved policy / regulation design/drafting	Better information (scale, accuracy) leading to better regulation
	Improved efficiency in policy/regulation monitoring	Better information available to monitor adherence to regulations.
Innovation & Entrepreneurship	Innovative products	Sentinel data leads to creation of new products / services
	New Business models	New ways to generate income.
	New markets	Global nature of sentinel data enables international business development
	New businesses	Creation of new companies; start-ups
Science & technology	Academic output	
	Research exploitation	Applied science to operational services
	Research contribution	New product enabling scientific research

Table A2-3: Complete list of indicators considered within SeBS analyses.

Annex 4: About the Authors

Geoff Sawyer, BSc (Electronics), MBA

Geoff is the former Secretary General of EARSC having held senior management positions in the space industry and numerous representative positions in the UK and Europe. Geoff was the radar systems engineer responsible for the ERS-1 synthetic aperture radar and after many steps was, until 2011, EADS Vice President Corporate Strategist for Space. In addition to his extensive industrial experience, Geoff spent three years working for the European Commission where he was responsible for supporting the creation of the GMES initiative (now Copernicus). Geoff is now Strategic Advisor to EARSC.

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His expertise is mathematical modelling and optimization under uncertainty. Dr. Khabarov joined IIASA to strengthen the team in charge of quantifying benefits of improved Earth observations. Since then he has been a principal investigator and contributor to a range of research projects focusing on economics of adaptation, estimation of the value of information, disasters modelling, reduction of risks through innovative financial tools. khabarov@iiasa.ac.at

The SeBS Study Team

The SeBS study is conducted by a team of experts under the direction of ESA (the European Space Agency) and led by EARSC (the European Association of Remote Sensing Companies. The team is of a variable geometry and different experts work together on the different cases. The full team and the organisations for whom they work, is shown below.

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Geoff is the former Secretary General of EARSC having held senior management positions in the space industry and numerous representative positions in the UK and Europe. Geoff was the radar systems engineer responsible for the ERS-1 synthetic aperture radar and after many steps was, until 2011, EADS Vice President Corporate Strategist for Space. In addition to his extensive industrial experience, Geoff spent three years working for the European Commission where he was responsible for supporting the creation of the GMES initiative (now Copernicus). Geoff is now Strategic Advisor to EARSC. geoff.sawyer@earsc.org.

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Lefteris is a strategy consultant with solid knowledge of programmatic, strategic and business aspects of EU Space Programmes (Copernicus and Galileo). In the past 10 years, Lefteris has been extensively involved in various studies and projects related to the development, market uptake and exploitation of EO downstream applications. He has been advising clients and partners across the full spectrum of the EO value chain, including EU institutions (EC, EEA, SatCen, ESA), universities and private companies.

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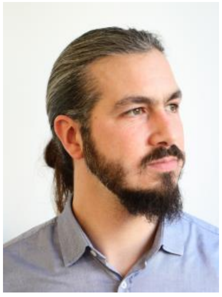

Dimitrios Papadakis, M.Sc. Research Methods

Dimitrios is a strategy consultant and communication/dissemination expert with over ten years of experience in the commercialisation, uptake and exploitation of space-based data and applications, primarily as concerns the Copernicus programme and its services. He has provided expertise on a range of major market, cost-benefit and user uptake studies in the EO domain, for clients including the EC, ESA, EEA and the SatCen.

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His expertise is mathematical modelling and optimization under uncertainty. Dr. Khabarov joined IIASA to strengthen the team in charge of quantifying benefits of improved Earth observations. Since then he has been a principal investigator and contributor to a range of research projects focusing on economics of adaptation, estimation of the value of information, disasters modelling, reduction of risks through innovative financial tools. khabarov@iiasa.ac.at

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Dáire is a consultant with the Brussels-based consultancy Evenflow, who work in collaboration with EARSC on the Sentinel Benefits Study (SeBS). Dáire worked as an engineer for a large upstream oil & gas company in Aberdeen, Scotland for 4 years before moving to Belgium to complete a Masters in International Business Economics & Management. Daire has extensive root cause analysis and statistical analysis skills developed through both his professional and academic career. He currently acts as exploitation manager for the H2020 CYBELE project. daire@evenflowconsulting.eu