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THE IMPACT OF OIL AND GAS DRILLING ACCIDENTS ON EU FISHERIES

NOTE

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DIRECTORATE GENERAL FOR INTERNAL POLICIES

POLICY DEPARTMENT B: STRUCTURAL AND COHESION POLICIES

FISHERIES

THE IMPACT OF OIL AND GAS DRILLING ACCIDENTS ON EU FISHERIES

NOTE

This document was requested by the European Parliament's Committee on Fisheries.

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POLICY DEPARTMENT B: STRUCTURAL AND COHESION POLICIES

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Abstract

Accidents occurring offshore in relation to the Oil and Gas (O&G) industry may produce significant damaging effects on the marine environment, and particularly on the fishing and aquaculture industries. The economic cost of the impact that major offshore accidents have on fisheries is most frequently assessed with the *Social Cost* method, accepted by the current international compensation framework. The cost of the impact of minor incidents is evaluated by the *Compensation* mechanism, and therefore known by the value of settled claims. Recently approved European legislation aims to maximize safety conditions in all stages of the offshore O&G industry, minimizing the number of incidents and alleviating harmful impacts to the environment.

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LIST OF ABBREVIATIONS

ACOPS	Advisory Committee on Protection of the Sea
CLC	Civil Liability Convention
CEDRE	Centre for Documentation, Research and Experimentation on Accidental Water Pollution
CFP	Common Fisheries Policy
FLTC	Fisheries Legacy Trust Company
EMSA	European Maritime Safety Agency
HSE	Health and Safety Executive
HELCOM	Helsinki Commission
ICES	Economic and Social Committee
IOPC	International Oil Pollution Compensation
IPIECA	International Petroleum Industry Environmental Conservation Ass.
IMO	International Marine Organization
ITOPF	International Tanker Owners Pollution Federation
MAIB	Marine Accident Investigation Branch
MARPOL	Marine Pollution
MOON	Mediterranean Operational Oceanography Network
OGUK	Oil and Gas United Kingdom
OPOL	Offshore Pollution Liability Agreement
OPRC	International Convention on Oil Pollution Preparedness, Response and Co-operation
OSPAR	Oslo Paris Convention
OSPRAG	Oil Spill Prevention and Response Advisory Group
PSA	Petroleum Safety Authority
REMPEC	Regional Marine Pollution Emergency Response Centre for Mediterranean Sea
SDR	Special Drawing Right
SINTEF	Stiftelsen for INdustriell og Teknisk Forskning
STCEF	Scientific, Technical, and Economic Committee for Fisheries
UKCS	United Kingdom Continental Shelf
UKPZC	United Kingdom Pollution Control Zone
WOAB	Worldwide Offshore Accident Databank

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EXECUTIVE SUMMARY

Background

The offshore Oil and Gas (O&G) and the Fishing industries coexist in the marine environment of European and non-European waters, sharing the physical space and making use of the natural resources. Both industries are considered human activities with an important impact on the environment and are intensely regulated, in order to maintain an efficient and safe use of the natural resources. The coexistence of O&G and fishing industries is characterized by adaptation and synergistic interactions, as offshore activities can take advantage of the fishermen experience and the power of their fleet. Fishermen in turn obtain an additional income complementing their revenue from fisheries.

The offshore O&G industry is mature in the North Sea and in development in the Mediterranean Sea, Black Sea, Norwegian Sea and Barents Sea. Particular challenges related to environmental characteristics affect the industry in different marine areas, requiring technological improvements and adaptation. Despite careful execution of activities, according to strict guidelines and regulations, some accidents occur as result of human error or failure of equipment. Historically the major impacts in European waters and shores have resulted from transport accidents, mainly grounded ships spilling thousands of tonnes of oil. However, other activities during exploration and production pose important risks of accident. The impacts of accidents on the environment are variable, depending on a number of factors that include uncontrollable natural circumstances. Preparation for immediate response after an incident, and remediation of effects, are crucial to minimize the impact of accidents on fisheries and on the entire environment. Identification of the factor causing the accident and preparedness for a timely reaction are essential for an improved and adequate response.

Aim

This document aims to identify the most significant accidents occurring offshore in relation with O&G activities, by type, by frequency of occurrence, and by magnitude of the impact on fisheries and on the entire marine environment. It also aims to describe the state of knowledge of the economic cost that accidents produce on fisheries and aquaculture in European waters. Through an intense literature review of academic papers, websites, reports, and public databases, current efforts to minimize the risk and occurrence of incidents, and to alleviate the impacts of eventual accidents will be identified and described.

Key findings

Despite intense regulations and guidelines, offshore O&G accidents occur in European waters. Accidents are recorded and characterized in databases, for investigation and assessment of risks. A decreasing tendency in the number of accidents since the beginning of the offshore O&G industry in European waters is noted, and the impact these accidents have on the environment is also decreasing. This decline is most likely the result of a continuous improvement of the technology used in offshore installations and the implementation of international liability mechanisms.

Historically, the most environmentally damaging accidents in EU waters have occurred during transportation of products by ship. Currently, fixed production units suffer the highest number of accidents, while among floating installations those for drilling have the highest risk. Explosions and structural collapse of structures are the most dangerous type of accident, and frequently involve human casualties. It has been found that exceptional accidents have the largest short-term impact on the environment and on fisheries, but small accidents have an unknown impact in the long-term.

Important concern about accidents rises after a major accident, triggering the development of new and improved regulations. All parts involved in the O&G industry have interest in augmenting the safety during operations and in reducing operational risks, and have an active involvement in research and regulatory activities, providing voluntarily relevant information for the assessment of risks.

A range of theoretical methods exist to evaluate the economic cost of the impact on fisheries and aquaculture produced by an offshore O&G accident. The *Social Cost* method is preponderantly applied for assessment of major accidents' economic cost for two reasons: market values in relation with fishing activities exist and are regularly updated, and it is accepted by the current international framework of compensation. Figures of landing losses after an accident are used as market value for appraisal of costs, although these data are recognized to reflect only part of the impact on fisheries. Estimation of costs may vary conditioned by the consistency of data, the period of reference, the area considered affected, and the fishing species accounted. Different figures of the global cost arise from expert estimations, estimation by claimants, and compensation paid to claimants. The economic cost of the impact of minor incidents is evaluated with the *Compensation* method, by the value of settled claims.

1. BACKGROUND

KEY FINDINGS

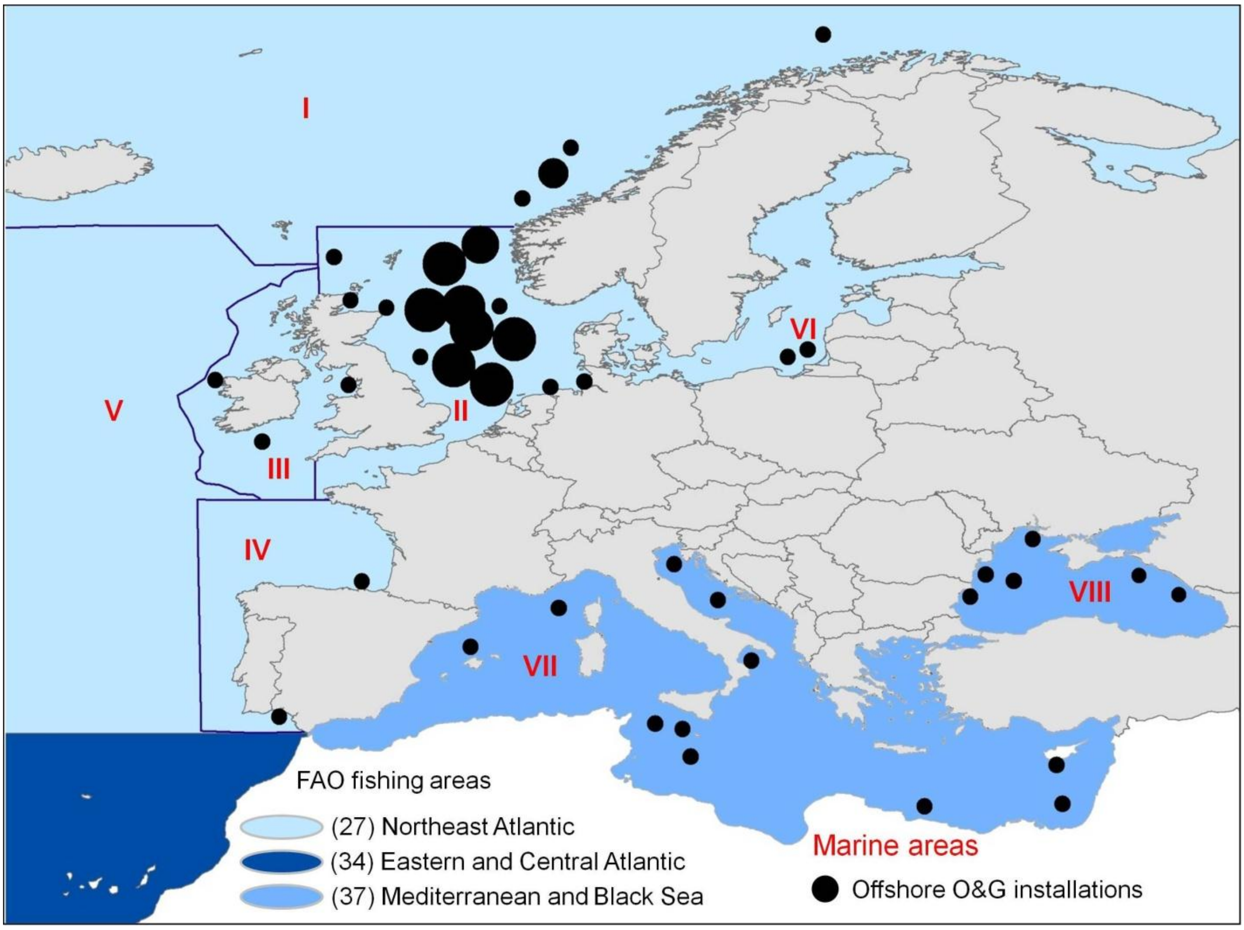
- The fishing industry in European waters is a relevant activity for some European countries, including fishing and aquaculture. However, total catches have declined in the last decade.
- Fishing stocks are deemed overexploited in the Northeast Atlantic and in the Mediterranean and Black Sea areas. Regulations and management plans are in place, aiming to achieve a sustainable level of catches.
- The offshore O&G industry is mature in the North Sea and in development in the Mediterranean Sea, Black Sea, Norwegian Sea and Barents Sea. Offshore production of oil and gas represents 85% and 65% of European primary production respectively. Norway and the UK are the main producer countries.
- Particular challenges related to environmental characteristics affect the offshore O&G industry in different marine areas. Drilling is technically more difficult in deep waters and production is more expensive.
- O&G and Fishing industries share the marine environment, interacting by adaptation and synergies.

1.1. European fisheries

Europe represents the largest market for fish in the world (STECF, 2012). Seafood consumption in Europe is increasing, although the EU fisheries production and revenue are decreasing. The total seafood production in EU countries for the year 2010 was 6.6 billion tonnes, of which marine fisheries accounted for 79%, while the aquaculture and inland captures shares represented 15% and 5% respectively. Fishery landings in 2010 were valued at 6.6 billion € (Eurostat, 2013) and the aquaculture production turnover is estimated at 3.6 billion € (STECF, 2012).

The majority of catches of fleets under European flag occur in the Northeast Atlantic (71%), Eastern and Central Atlantic (13%) and Mediterranean and Black Sea (10%) (Figure 1). In 2011 catches by EU-27 countries in these areas accounted for 4.3 million tonnes. Norway and Iceland catches in the Northeast Atlantic were 3.3 million tonnes. The fleet of some European countries work in other waters further away, such as Southwest Atlantic, Western Indian Ocean, Northwest Atlantic, and Southeast Atlantic.

Figure 1: European waters (FAO fishing areas), where most fishing catches occur. Marine areas (adapted from OSPAR, 2013). Approximate location and symbolic relative frequency of offshore Oil and Gas installations.



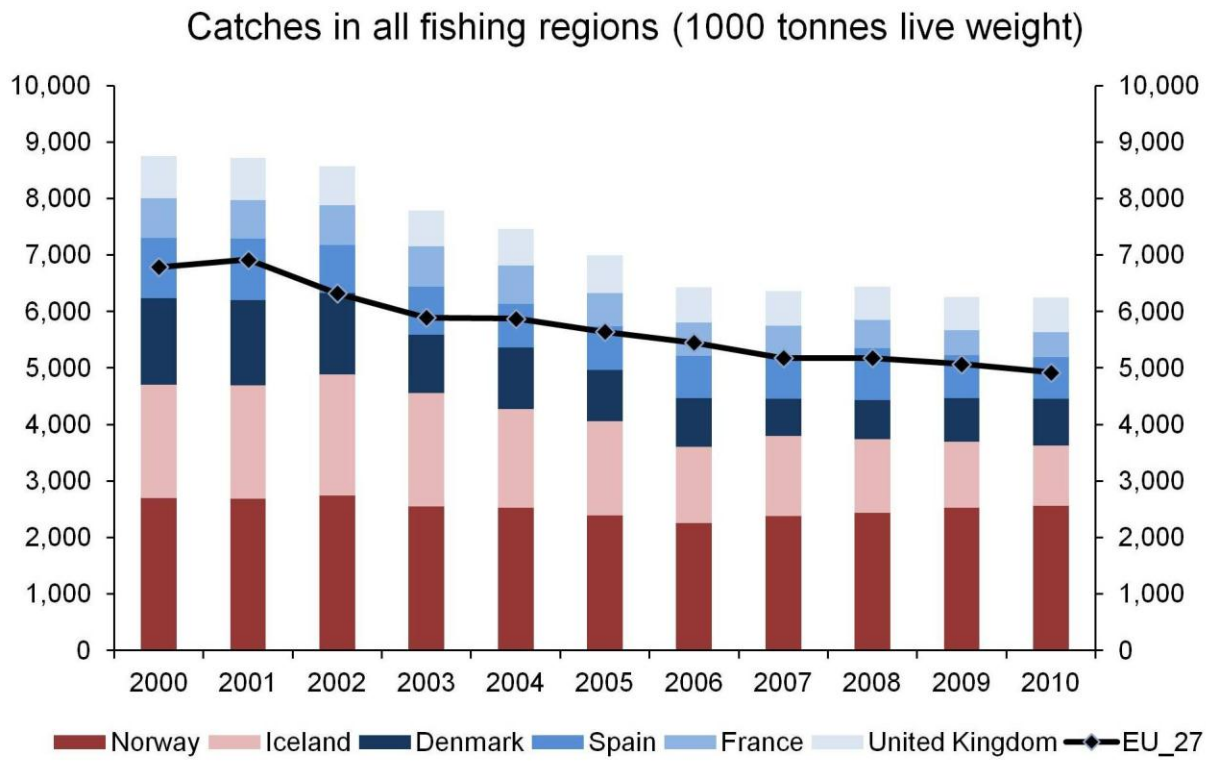
Source: Adapted from OSPAR (2013) and Medoilgas

More than a hundred species are captured by European fleets from both pelagic and demersal habitats. Among commercial species, herring (*Clupea harengus*), whiting (*Merlangius merlangius*), cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), sole (*Solea solea*) and saithe (*Pollachius virens*) are captured in the Northeast Atlantic area, and hake (*Merluccius merluccius*), tuna (*Thunnus thynnus*), albacore (*Thunus alalunga*), sardine (*Sardina pilchardus*), and sea bass (*Dicentrarchus labrax*) in the Mediterranean and Black Sea area. Multiple gear types are used by European fleets being adapted to the target species and fishing vessel. Gear types include demersal and pelagic trawl, gill net, purse seine, and dredges. The behaviour of marine fauna is not completely known and the reproductive habits are multiple and variable: some species spawn in spring, but others have been observed to spawn out of this period. While some species maintain similar patterns of distribution from one year to the next, other species show greater variability.

Since 1983 the Common Fisheries Policy (CFP) has been the EU instrument for the management of fisheries and aquaculture, determining the maximum quantities of fish to be safely caught, and distributing fishing quotas among the EU countries. The 2002 reform of the CFP aimed to protect fish resources, to organize the market, update the sector resources, and to establish international fishing agreements. Although EU fish stocks are under considerable pressure from fishing (Villasante et al., 2012) subsidies and a lack of compliance and enforcement of fishing regulations have led to a decline in commercial stocks. Among the assessed stocks, 39% in the Northeast Atlantic, 75% in the

Mediterranean Sea, and 88% in the Black Sea areas are overexploited (European Commission, 2013). One of the objectives proposed to reform the CFP is to reach fishing mortalities associated with the maximum sustainable yield by the year 2015. In areas where this criterion has already been adopted, several stocks have improved (Cardinale et al., 2013). As a whole, between 2000 and 2010 there was a significant reduction of 27% in total European catches (Eurostats, 2013) (Figure 2).

Figure 2: Total catches in all fishing regions of the EU-27 countries (black line) and of the five most productive EU countries plus Norway and Iceland.



Source: Eurostats 2013

Aquaculture is predominantly marine in the EU and its production has been stable for the last 20 years (STECF, 2012). Five countries (Spain, France, United Kingdom, Italy and Greece) generate 76% of the total aquaculture production. In 2010, this sector produced 1.36 million tonnes in the EU-27, whereas Norway's production was 1.0 million tonnes. The main aquaculture species by volume were mussels (37%), trout (15%), and Atlantic salmon (14%), while the highest revenue came from Atlantic salmon (19%), rainbow trout (17%), and mussels (13%).

1.2. Oil and Gas industry in European waters

In the early 1960s international agreements about the sovereignty over the continental shelves with respect to the exploration and production of subsea natural resources in the Northeast Atlantic were settled, and geological surveys in search of energy sources were initiated. Gas was first found and produced, before oil wells were drilled and started production in Norway (Ekofisk field in 1971) and in the UK (Forties field in 1975). The North Sea was divided into five sectors, corresponding to the UK, Norway, Denmark, Netherlands and Germany. The bathymetry of the North Sea makes most wells at depth of less than 100m.

At the beginning of production oil was loaded into tankers at the field and transported to onshore installations for further processing. The first pipes for transport were built soon after: in 1975 the Norpipe oil line was completed, leading from Ekofisk to the Teesside (UK) terminal, and in 1977 the Norpipe lean gas line from Ekofisk to Emden (Germany) terminal initiated Norwegian natural gas exports to continental Europe.

After 1980 licenses were awarded for production in the Norwegian Sea, north of the 62nd parallel, and in the Barents Sea. Wells are deeper in these areas and consequently sub-sea installations are more frequent. Pipelines were constructed in the 1990s. The Norwegian and Barents Seas are considered immature petroleum areas, but with high productive potential. There is still only one field (Snohvit) in production in the Barents Sea, from where gas is transported by pipe to Melkoya and processed into liquefied natural gas.

The O&G industry is not yet well established in the Mediterranean Sea, where deeper waters and seismic activity pose particular challenges. This area is also characterized by an important tourism industry. However, there are more than 400 wells in Spain and Italy, and intensive prospecting activities are carried out in the south-eastern Mediterranean. Exploration and production is ongoing in the Black Sea, with some promising fields in the European waters (Figure 1).

Table 1: Characteristics of European marine areas with O&G installations. Adapted from OSPAR (2013)

REGION	INDUSTRY	ENVIRONMENTAL IMPLICATIONS FOR O&G INDUSTRY
(I) Arctic Waters	Production of oil and gas Shallow waters (< 230m) Exploration in Faroe and Iceland	Extreme climatic conditions may increase risk of accident
(II) Greater North Sea	Exploration and production of oil and gas. Old exploitations (since 1960s) Very shallow waters (< 100m)	South: sandy sediments and strong currents. Adapted fauna North: less sandy and weaker current. Corals and sponges
(III) Celtic Seas	Exploration since 1969 Production since 1985 Shallow bays	Shore areas are seabird heavens in winter. Oil spill may have strong impact
(IV) Bay of Biscay and Iberian Coast	Production of gas in Gulf of Cadiz	Variable topography Rich ecosystems and fauna
(V) Wider Atlantic	Early exploration Deep waters (> 2000m)	Mud and clay Cold water coral
(VI) Baltic Sea	Exploration and production Shallow waters (~ 100m)	Shallow brackish water Semi-closed configuration Sensitive marine ecosystem
(VII) Mediterranean Sea	Exploration and early production	Semi-closed configuration Significant seismic activity Tourism industry
(VIII) Black Sea	Exploration and early production Variable water depth (50-2000m)	Closed configuration Limited knowledge of biological life in deep waters. Vulnerable to disturbance

Source: Adapted from OSPAR (2013)

Currently most of the oil (85%) and gas (65%) produced in Europe comes from offshore fields (JRC, 2013), helping to secure the supply of hydrocarbons to European countries. The offshore O&G industry is a major economic activity in the Northeast Atlantic and a developing industry in the Mediterranean Sea and Black Sea areas. Currently more than 1300 O&G installations, including above sea platforms and sub-sea units are spread over the North Sea, Norwegian Sea, and Barents Sea (OSPAR, 2013), mostly exploited by the UK and Norway (Figure 1).

1.3. Interaction between fishing and offshore oil & gas industries

Fishing and offshore O&G industries interact by sharing marine and ocean waters. Both industries are identified as human activities with an important impact on the marine environment, and are subject to intense regulations in order to ensure protection and a sustainable use of resources.

Offshore O&G exploration and production activities may eventually impact fish populations, mainly during the most vulnerable spawning season, through the presence of physical structures put in place or through the range of techniques used. Safety zones of 500m radius are established at all offshore surface installations and sub-sea structures, excluding pipelines, when they become operational. Safety areas are patrolled by support vessels, which are often fishing vessels contracted for the purpose (OGUK, 2009), and monitored by the installations themselves. Fishing is not permitted inside safety zones. Although the total area protected increases with the number of offshore installations, it is not considered to affect catching rates, as fishing effort can move to other areas.

Some types of fishing gear may interact with seabed installations and pipelines, compromising the security of both elements, and with risk to over-trawl piles of drilling residues. Pipelines are either trenched for self-protection or left unprotected on the seabed when they are of a large diameter. In new installations, advanced materials and technology provide enhanced protection to pipelines and wellheads from over-trawling, but old structures are still threatened by heavier fishing gear. In the UK continental shelf (UKCS) fishing vessels are engaged for conducting trawl sweeps at various locations and to verify that the area is clear of any residual oil-related material.

Fishing activities are managed and catches limited with recovery plans recommended by the International Council for Exploration of the Sea (ICES) and enforced by national and international legislation. Closures of spawning or nursery areas during certain periods are not rare and affect industries, forcing fishing efforts to move to alternative areas and banning O&G activities. Declining fish stocks and increased regulation could lead to increasing conflicts between the two industries competing for the same water space. To ensure successful development and interaction between fishing and O&G industries, joint forums of discussion have been created, like the Fisheries and Offshore Operators Consultative Group (FOOCG) in the UK, where representatives of all parties involved discuss concerns and advice on best practices. The Fisheries Legacy Trust Company (FLTC), established in 2007 to manage interactions between the offshore O&G and fishing industries, created the FishSAVE, a device providing fishers with updated locations of offshore installations to prevent conflict. In the UKCS O&G operators are required to appoint a Fisheries Liaison Officer to liaise with relevant Government departments and fishing organisations on issues relating to their exploration and production activities before getting a licence. Similarly, in Norway petroleum regulations require a fishery expert to be on board the vessel that is carrying out seismic surveys, out of consideration to the fishing operations in the area.

1.4. Scope and methodology

This document aims to briefly compile the current state of knowledge for the economic cost on fisheries that results from accidents occurring in the offshore O&G industry. Given their share of the marine environment, there is an intense interaction between the fishing and O&G industries during normal operations, from which both industries benefit. However, when activities deviate from normal functioning through an accident in O&G installations, there is a high likelihood that it will result in significant effects to fishing stocks and damage to fishing activities.

This work investigates historical trends in the occurrence of accidents, and the most frequent types and causes of current accidents, as well as the effects and impacts on the marine environment and on fisheries and aquaculture. Impacts on fisheries have an economic cost, historically established by available, accepted or convenient methods. Through a series of examples this document describes the relevant and most frequent methods employed for the estimation of economic costs, and highlights the circumstances that make each one applicable and recommended. Existing efforts to prevent accidents and to alleviate and mitigate their effects on the environment, and in particular on fisheries and aquaculture are also described.

An extensive literature review of academic publications, research projects, websites and public databases is included. European, national, and international legislation that affects offshore activities in European waters is also explored. The significance and incidence of different types of accidents, and the characteristics of each type are understood through access to the databases held by authorities for investigation and safety purposes. These databases are explored and relevant information is highlighted. Interviews with O&G operators and other working personnel provide a contrasted and realistic perception of the current state of knowledge.

2. OIL AND GAS DRILLING ACCIDENTS

KEY FINDINGS

- Despite intense regulations and guidelines, incidents related with offshore O&G activities exist. Accidents are recorded and characterized in databases, for investigation and assessment of risks.
- Historically, the most environmentally damaging accidents in EU waters have occurred during transportation of products by ship.
- Currently, fixed production units suffer the highest number of accidents, while for floating installations those dedicated to drilling have the highest risk.
- Exceptional accidents have the largest short term impact on the environment and on fisheries and aquaculture, but small accidents have an unknown impact in the long-term.
- Explosion and/or structural collapse of structures are the most dangerous type of accident, frequently involving human casualties.

Every stage of the offshore O&G industry is in close interaction with the marine environment. All activities during exploration, drilling, production, maintenance, transport, and decommissioning of installations are advised by detailed guidelines and strict legislation for normal functioning. But there is always a risk of human error, exceptional weather conditions, and malfunction or failure of equipment. Any deviation from normal functioning is considered an incident or accident. Each accident occurs in a particular combination of natural and technical conditions, and its effect on the environment is variable as well.

2.1. Types and effects of accidents

An accidental episode frequently triggers further events that could be considered individual accidents in themselves. For instance, an unexpected oil blowout in a production well might be followed by an explosion, a fire, a spillage, and in the worst case scenario by the structural failure or collapse of the entire installation, if the response is not fast and adequate. The effects and consequences of individual accidents depend on a combination of circumstances and environmental factors. Nevertheless, typical offshore accidents and potential effects are individually outlined here.

2.1.1 Blowout

Blowout is an unexpected flow of oil and gas that occurs during drilling wells, when there is a zone of abnormally high pressure. Blowouts are more frequent during the initial phases of well construction, when preventative measures are not in place, but may also occur during production. Low-intensity episodes are controllable by blowout preventers (BOP) such as safety valves, or by changing the density of the drilling fluid, but intense and prolonged gushing may lead into catastrophic situations. Uncontrollable blowouts can develop into large oil or gas spills. Blowouts occur as consequence of equipment failure, personnel mistakes or extreme natural impacts like seismic activity or hurricanes.

2.1.2. Explosion

The explosion of an oil or gas well is the most dangerous accident, posing risk of catastrophe with human casualties. An explosion may occur directly linked to a blowout or spillage of oil. In the case of partial or complete destruction of the offshore installation, an additional risk exists of a high volume of hydrocarbon spill. In this case the volume of leakage is difficult to quantify, and the well could be spilling for a long period until depletion or until it is brought under control.

2.1.3. Structural failure or collapse

During construction of a platform, or more rarely during production, there is risk of structural failure associated with difficult working conditions. Most accidents are due to error in the design or fabrication because the undulating sea-beds where the structures are located make them susceptible to a lot of uncertainties. Failures can also result from material fatigue. If the failure is enough to make the entire structure collapse and sink, there is an obvious and important economic loss.
Transport pipelines may malfunction and even break during transport, as a consequence of corrosion or global buckling. When the rupture is localized, the pipeline can be repaired or replaced. If the rupture is small or occurs in a remote area it might go unnoticed for some time, leaking oil or gas.

2.1.4. Transportation

Tanker accidents are among the most harmful accidents in the marine industries, due to the nature of the materials being transported and the effects on the environment. The most frequent causes of tanker accidents are running aground and into shore reefs, collision with other vessels or installations, hull failure, and fires or explosion of the cargo (Musk, 2012). Accidents frequently occur in proximity to the coast and may lead to shores being affected by large amounts of spilled oil. The spillage might be slow or fast, sometimes lasting for months.

2.1.5. Spillage of oil products and chemicals

The discharge of oil or chemicals from offshore O&G installations or from transporting vessels is regulated by law, and can only take place under certain circumstances, normally in small quantities. Only substances of minor polluting power can be discharged legally. However, accidental discharges from offshore installations may occur, caused by human error or equipment failure, during operations of diesel transfer from supply vessels, overfilling of tanks, or during well operations. Even in these cases, spills associated with those operations rarely surpass one tonne and have little impact to the environment. Operators are required to have an oil spill contingency plan to respond effectively in such case.

The effect of an oil discharge or spillage on the environment depends on many factors (Table 2), including the size and nature of the spill, the season of year, weather conditions, the nearby physical environment and biological communities, and the effectiveness of the response. Light oil is easily dispersible and has a less harmful effect than dense products. Ritchie (1993) remarked that the low impact of the Braer spillage on the Shetland shores after grounding during the winter of 1993 was in part due to the light characteristics of the oil, and also to the persistence of extreme weather conditions, a source of huge waves and water currents that accelerated the breaking up and dispersion of the oil particles. Hydrocarbon spills leave dispersed and dissolved residues in the water column that may taint fish populations. Denser residues are deposited on the seabed, sometimes smothering habitats and affecting the spawning, nursing and feeding of some species (Hartog and

Jacobs, 1980). The impact a spill makes over a beach of sand that gets soaked with pollutants is presumably more durable and damaging than the same spill reaching hard rock cliffs, where the oil gets dispersed when in contact with the rock. Enclosed seas like the Mediterranean Sea, the Black Sea, or the Baltic Sea suffer more harmful impacts than an open ocean, as the water recycling rate is far lower.

Table 2: Factors determining the effect of oil spillage

Factor	Lower impact	Higher impact
Size of spill	Small	Large
Nature of spill	Light oil	Dense crude
Season of year	Non critical	Reproductive period Leisure time
Weather conditions	Storminess	Calm atmosphere
Physical environment	Open ocean Rocky cliff	Enclosed water Sand beach Sensitive ecosystem (coral, mangrove)
Response	Fast and adequate	Inadequate

Source: Authors

Oil slicks have a selective influence on animal groups. Short-term effects, which are visible and sometimes quantifiable, depend on the mobility of fish and the possibility of escaping toxicity (Cohen, 1995). For this reason, sedentary populations unable to escape the area directly affected by the oil slick might get tainted and possibly die rapidly by intoxication. Long-term effects on fish communities are more difficult to estimate, and depend on feeding habits, adaptation, and reproductive capacity. Long-term effects also rely on the capacity of the physical environment to return to normal levels of toxicity. Jézéquel and Poncet (2011) observed the long persistence of oil in some shore habitats ten years after the Erika spillage of 20,000 tonnes of heavy oil on the coast of Brittany. Similarly, Ecologistas en Acción (2013) has documented the persistent effect on the coast caused by the spillage of the Prestige in 2002. On the contrary, Payne et al. (2008) reported a stable and extremely low contaminated environment in Prince William Sound and the Northern Gulf of Alaska, strongly affected by the Exxon Valdez spillage twenty years before. The consequences of offshore accidents involving spillages are especially severe when they happen near the shore, in shallow waters or in areas with slow water circulation (Table 2).

2.1.6. Other circumstances:

There are harmful effects occurring in association with offshore O&G accidents but not limited to those events that impact the fauna and marine environment.

- *Noise*. Underwater sources of noise related with offshore O&G are various, including seismic surveys, drilling operations, and supporting vessels. Seismic surveys during exploration use high frequency noise that sometimes results in the temporary redistribution of fish. Some works have studied the impact of noise on fish and mammals (McCauley, 2003; Gordon et al., 2004) but the impact of this activity is still not clear (NRCD, 2010). Seismic activity could have an adverse impact on the spawning success of fish, but there is a lack of supporting evidence. Strong noise produced with explosions during decommissioning of installations is of relatively short duration and charges are shaped to direct noise and energy into a narrow band, minimizing the effect on the environment. The level of noise produced by platforms depends on the type of installation: fixed platforms make less noise when drilling than semi-submersible platforms, which emit noise with thrusters to maintain position.

- *Cuttings piles*. When drilling the substrate to access the oil or gas reservoir, small pieces of rocks known as cuttings are originated. Cuttings need to be removed to avoid clogging the well, and are carried to the surface combined with the fluids used for extraction and lubrication. The cuttings are discharged to the seabed, re-injected into a well or taken ashore for treatment and disposal. Oil based drilling fluids, although effective, are considered harmful for the environment, as they do not disperse easily. Water-based drilling fluids are considered more environmentally friendly. The constituents of mud must be identified in the Offshore Chemical Notification Scheme which categorizes chemicals according to their toxicity, persistence and bioaccumulation potential. Oil-based mud is transported ashore for treatment and recycling and only water-based mud can remain to disperse in the sea.

  Sediments deposited on the seabed can smother fauna that require particular sediments to feed and spawn on, as well as even resilient corals (Larsson and Purser, 2011) and phytoplankton (Pabortsova et al., 2011). In deep waters the oil might disperse and dissolve before depositing on the seabed, but in shallow waters sediments deposit faster and may harm living species.

- *Atmospheric emissions*. Activities producing gaseous emissions due to flaring at the well site are assumed to have no impact on fish populations (OGUK, 2009).

- *Radioactive materials*. "Produced water" (the compound of water and waste materials that result from drilling) contains soluble components, including Barium and radioactive intermediates of Uranium and Thorium that can precipitate forming an insoluble NORM (naturally occurring radioactive material) scale. Extreme measures are taken to clean equipment and dispose these materials in authorized locations. Some studies (Olsgard and Gray, 1995) have corroborated the existence of radioactive contamination sourced from production platforms (on the Norwegian shelf) after a period of 6-9 years and evidence of contamination was found 2-6 km away from the platforms. However, the radioactivity discharged from offshore oil and gas operations is not considered to have a significant environmental impact (OGUK, 2009).

2.2. Recent history of offshore oil and gas accidents

2.2.1. Accounts of accidents

Offshore incidents and accidents are recorded in databases for health and security purposes as well as for research and risk assessment (Box 1). O&G industry operators are committed to report incidents to the pertinent authorities, according to the type and dimension of the event. A usual mechanism for reporting is the questionnaire, pre-designed to compile relevant information for assessment of causality and for research of injury alleviating measures.

Box 1: Records of offshore incidents and accidents

BLOWOUT is a database compiled by SINTEF for assessment of offshore blowout risk. The database includes information of blowouts and well releases occurred worldwide since 1955, categorized by location, well type, operation in course, blowout cause and characteristics. This database is sponsored by oil companies.

WOAD (Worldwide Offshore Accident Databank), operated by Det Norske Veritas, is one of the main sources of offshore accident information for public use, and compiles data from public domain sources.

ITOPF (International Tanker Owners Pollution Federation limited) maintains a database of oil spills from tankers, carriers and barges. This database contains information on more than 10,000 accidental spillages occurred worldwide since 1970, (excluding those resulting from acts of war) that are categorized according to the amount of spilt substance.

REMPEC (Regional Marine Pollution Emergency Response Centre for Mediterranean Sea) maintains an online database and GIS of alerts and accidents since 1977 in Mediterranean Sea, related with oil and other hazardous substances spillage. The database records accidents to any type of ship and accidents on land that result in spillage to the Sea.

ACOPS (Advisory Committee on Protection of the Sea) provides annual reports of the oil and chemical spills that are reported from vessels and offshore O&G installations operating in UK waters in the UK Pollution Control Zone (UKPCZ).

HSE (Health and Safety Executive) bodies in Norway and UK implement a system for compilation of incidents' data collected directly by companies. Operators fill in a standard questionnaire to inform of incidents occurred offshore.

MAIB (Marine Accident Investigation Branch) of the Department for Transport examines and investigates all types of marine accidents to or on board UK ships and on other ships within UK territorial waters.

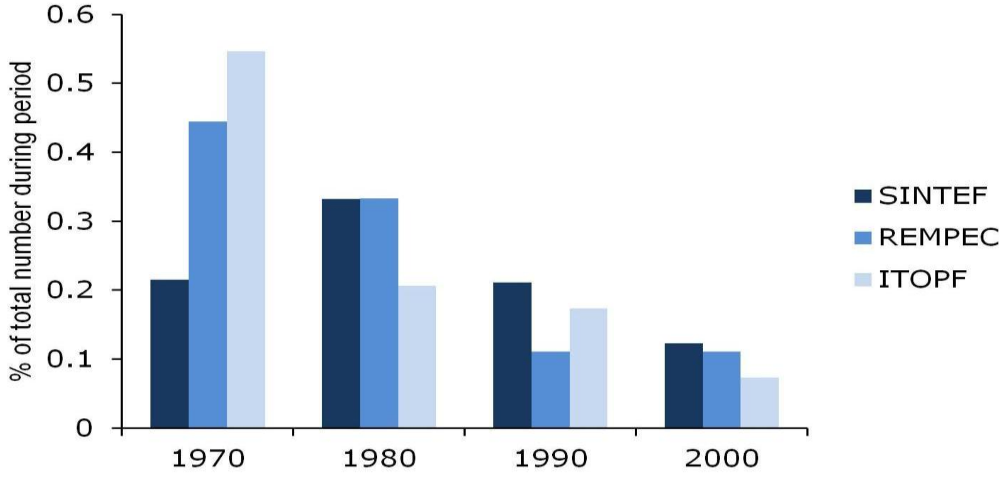
Source: Authors

2.2.2. Trends in offshore accidents

Historically almost a third (31%) of major accidents recorded by the ITOPF database have occurred in the European coasts, with many incidents in the Atlantic area, one of the main routes of oil tankers. But despite the offshore O&G industry intensification and increased seaborne trade during the last decades, there has been a reduction in the number of accidents, with a clear and drastic trend captured in databases (Figure 3). According to ITOPF, the amount of oil spilt between 2000 and 2012 in relation with tanker accidents is about 19% the quantity spilt in decades 1990 and 1980 and about 7% of the spilt in the 1970s (ITOPF website).

According to SINTEF records, the number of offshore blowouts was highest in the 1980s and it has reduced ever since. Accidents occurred in the Mediterranean Sea that resulted in the spillage of more than 5000 tonnes of oil has had a decreasing trend too, according to REMPEC (Figure 3).

Figure 3: Trends in the number of accidents recorded in various databases. ITOPF records tanker accidents, SINTEF offshore blowouts, REMPEC accidents with spillage to the Mediterranean Sea.

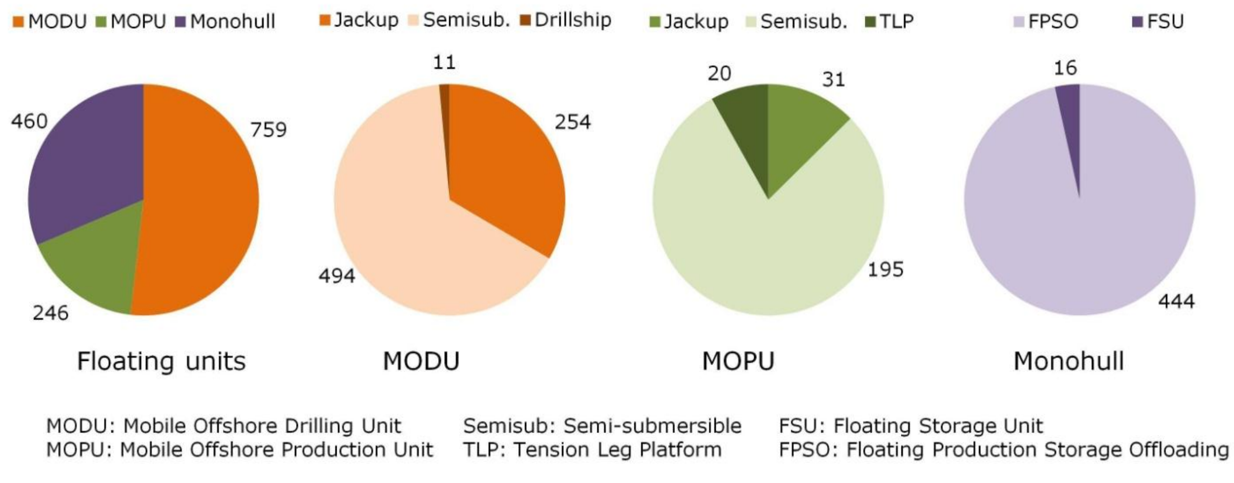


Source: Adapted from SINTEF, REMPEC, ITOPF

Oil and Gas UK (OGUK) analyzed the statistics of accidents occurring in all types of offshore units on the UK continental shelf during the period 1990-2007, with data compiled from relevant UK and Norwegian databases (COIN/ORION, MAIB, WOAD and BLOWOUT). This analysis enabled identification of the type of installation with higher risk of accidents. A total of 6269 accidents occurred in fixed units and 3436 in floating units during period 1990-2007. These values represent a reduction in the number of accidents examined for the prior period 1980-2007 (7312 and 4112).

During the recent period 2000-2007, more than half (51%) of the accidents occurred in floating installations were suffered by Mobile Offshore Drilling Units (MODU), while monohull and Mobile Offshore Production Units (MOPU) suffered 31% and 16% of a total of 1465 incidents. In floating units the most frequent type of accident is "falling object", with "spillage" and "crane" related in second and third places. The distribution of accidents in types and subtypes of floating units during period 2000-2007 is shown in Figure 4.

Figure 4: Number of accidents in offshore floating units during period 2000-2007



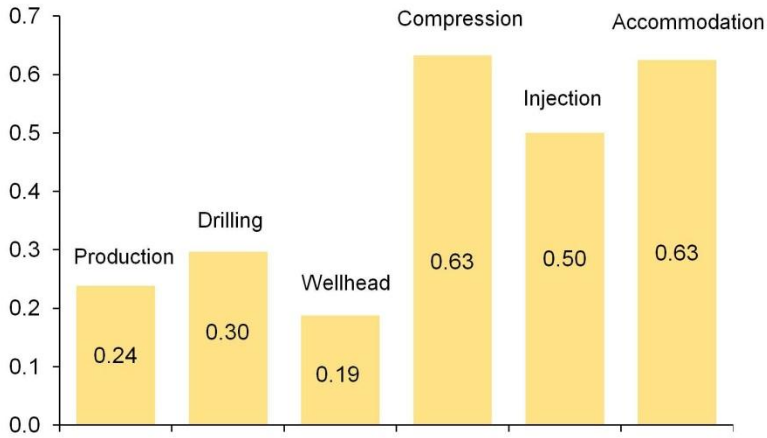
Source: Adapted from Oil and Gas UK (2009)

Most accidents occurred in fixed installations during the period 2000-2007 happened in production units (92%), while 6% were in wellheads and less than 1% in drilling, compression, injection or accommodation units. Injection units did not registered any accidents. Comparing the accident data with the previous period (1990-1999) a reduction in all types of fixed units is observed, particularly relevant in accommodation and compression installations. The most frequent type of incident in fixed units is by far "spillage", followed by "falling object" and "crane" related accidents.

In the Mediterranean Sea, the number of recorded incidents resulting in spillage of oil increased from 1977 to 2010 (REMPEC, 2011), but no major spillage has occurred offshore during this period. An increasing activity and better detection mechanisms are thought to be the reasons for the increased number of spill records.

Figure 5: Accidents in offshore fixed units during period 2000-2007. Percentage reduction in the number of accidents in fixed installations between periods 1990-1999 and 2000-2007.

Installation	Accidents 2000-2007
Production	2538
Drilling	19
Wellhead	169
Compression	18
Pumping	0
Injection	3
Accommodation	3
Total	**2750**



Source: Adapted from Oil and Gas UK (2009)

2.2.3. Examples of recent accidents in Europe

- ***Land-base facilities***

Accidents in land base facilities are not frequent. One of the major accidents affecting European waters was the 2006 spill at the Jiyeh power station in Lebanon, on the Mediterranean coast. The release of heavy fuel oil into the eastern Mediterranean occurred when the storage tanks were bombed in July 2006 provoking a large spill and an environmental disaster. The plant's damaged tanks leaked between 20,000 and 30,000 tonnes of oil, and a 10 km wide oil slick covered 170 km of coastline, killing fish and threatening the habitat of endangered species.

At Donges Refinery, located in Loire-Atlantique (France), there was a pipe leak on March 16, 2008. An estimated 400 tonnes of heavy fuel oil escaped during the loading of a vessel. The following day a ban was introduced on sea fishing and marine culture activities, as well as on the sale of aquaculture produce. The French health authorities sampled shellfish regularly to monitor any possible contamination, and the ban was completely lifted on 18 April 2008, being the river banks the last area permitted. The agricultural ground bordering the Loire River, normally used as pasturing grounds from April onwards, were affected by oil deposits, affecting the regular pasture season of animals.

The Loire River Estuary had also been affected in January 2006 by 60 tonnes of heavy oil spilt after two LPG tankers collided at the oil terminal in Donges, on the boundary of the independent port of Nantes Saint-Nazaire. Cleaning operations began a few days later on the rocks of the north bank of the estuary and on the rough grasslands in the south bank, once the area affected was identified by aerial, river and land observation missions.

- ***Transport accidents***

Although historically a big proportion of the worldwide transport accidents occurred in European waters (Table 3) causing major environmental damage, the majority of recent accidents have had only moderate or minor environmental effects, except for the case of Prestige in 2002.

Table 3: Tanker accidents occurred in European waters since 2000. Nine of the twenty major worldwide historical tanker accidents occurred in Europe are included for comparison.

Date	Name	Country	Spillage	Spill (t)
1967	Torrey Canyon	Scilly Islands, UK	Crude oil	119,000
1975	Jakob Maersk	Portugal	Crude oil	88,000
1976	Urquiola	Spain	Crude oil	100,000
1978	Amocco Cadiz	France	Crude oil	223,000
1980	Irene Serenade	Portugal	Crude oil	100,000
1991	Haven	Italy	Crude oil	144,000
1992	Aegean	Spain	Light crude oil	74,000
1993	Braer	United Kingdom	Light crude oil	85,000
1996	Sea Empress	United Kingdom	Light crude oil	72,000
1999	Erika	France	Heavy fuel oil	20,000
2000	Eurobulker	Greece	Bunker fuel oil	700
2000	Alhambra	Estonia	Heavy fuel oil	250
2001	Baltic Carrier	Denmark	Heavy fuel oil	2,700
2002	Prestige	Spain (Garcia)	Heavy fuel oil	77,000
2003	Fu Shan Hai	Baltic-3 countries	Heavy fuel oil and other pollutants	1,200
2012	Alfa I	Greece	Oil	330

Source: Authors compilation from multiple sources

In November 2002 a single hull Liberian oil tanker operated by a Greek captain suffered an accident off the coast of Galicia (Spain). The tanker carried 77,000 tonnes of heavy bunker oil, and leaked 19,000 tonnes in the erratic path followed during six days, until it finally sank in a water depth of 3500m. Oil spilled from the sunk tanker during several months, with three main "black waves" arriving to the coast in the first month, and polluted more than 1300 km of coast. In 2004, 11,000 oil tonnes were recovered from the tanker. Although by summer 2003 most of the affected shores were officially clean, the impact of the spill on some beaches is still visible ten years after the accident (Ecologistas en Acción, 2013). Galician littoral was closed to fishing when the oil arrived to the coast, for periods between two to eleven months.

On 5 March 2012, the single hull tanker Alfa I hit a submerged object near Piraeus (Greece) and sank into a water depth of ~20m soon after. It had been loaded with 2000 tonnes of fuel and gas oil, but the exact amount of spilled materials is unknown. The spillage affected 13 km along the shoreline, contaminating sand beaches and rocky areas.

- ***Offshore blowouts***

In August 2004, while the rig Adriatic IV was drilling a natural gas well over the Temsah gas production platform in the Mediterranean Sea, off Port Said (Egypt), a gas blowout took place. An initial explosion was followed by a fire that spread from the jack-up to the platform. It took a week to control the fire and the Adriatic IV was damaged beyond possible repair. Production had previously ceased and workers were evacuated.

In March 2012, a gas and condensate leak started from a production well at the Elgin wellhead platform in the North Sea, 240 km east of Aberdeen (Scotland). Elgin is a high pressure and temperature field in production since 2001. When the leak was detected, all workers were evacuated due to the risk of fire and explosion, and an exclusion zone was set up. Nearby installations were also evacuated. All power was shut down, but the flare continued for almost a week. The amount of gas leaked is difficult to estimate, as gases are quickly assimilated by the marine environment or lost to the atmosphere, and releases of gas and condensate are rare. Mud was injected into the well and the leak stopped on May 15, 2012. The well was then permanently plugged with five cement plugs creating a thick barrier (http://www.elgin.total.com/elgin/home.aspx?lg=en). Investigations revealed the cause of the leak was a type of stress corrosion unique to the well that was fed from a so far non-producing chalk layer located approximately 1000 meters above the original reservoir.

In November 2004, an incident occurred in a sub-sea installation in the Snorre A facility. According to the accident report prepared for the Norwegian Petroleum Safety Authority (PSA), there were a number of deviations from rules and guidelines in planning, implementation and follow-up of the work being done in the well. Uncontrolled gas blowouts from an underwater source and from the topside installation flew to the surface and engulfed the platform in a cloud of natural gas. Only a small group of the crew remained on board, and they succeeded in regaining control over the well by the injection of drilling mud. However, this is considered as one of the most serious incidents to occur on the Norwegian shelf, for the potential consequences had the gas ignited and burned.

- ***Minor incidents***

Although a few large spills account for most of the oil spilled in the last decades (Musk 2012) the effect of small and middle size oil spills have an important role in pollution, and their effect may be important in the long run (Redondo and Platonov, 2009). Small spills are recorded in HSE databases and detected and monitored by satellite. Only in the Mediterranean Sea, Ferraro et al. (2009) have reported more than 9000 oil slicks for the period 1999-2004. The vast majority of these incidents are small and difficult to count. In addition to this, there are also natural seepages (Kvenvolden and Cooper, 2003) among detected events.

In August 2011, around 200 tonnes of oil were spilt during three days leaking from a flow line near the Gannet Alpha platform, which was located 180 km off Aberdeen (Scotland).

The oil was dissolved naturally, but despite the moderate volume leaked, it was considered very significant in the context of annual amounts of oil spilled in the North Sea.

Fishing vessels have eventually their fishing gear equipment snagged with debris resulting from offshore O&G activities (e.g. wires, fasteners). In addition to the damage caused to fishing equipment or the vessel itself, fishers' activities are affected by the time lost. A database maintained by OGUK records around 1500 of these incidents since 1989, with 30% occurred since 2000.

3. IMPACTS ON FISHERIES

KEY FINDINGS

- Accidents may have direct impacts on fisheries and aquaculture, which can be reliably quantified in the short-term, and other long-term impacts more difficult to quantify.
- For estimation of the economic cost of the impact on fisheries of an offshore O&G major accident, the *Social Cost* is the method most frequently applied. The economic cost of minor incidents is evaluated by the *Compensation* method, by assessment of settled claims.
- Valuation methods requiring assumptions and modelling are not acceptable by compensation mechanisms, and they are therefore seldom used.
- Figures of landing losses after an accident are used as market value for appraisal of costs, although these data are recognized to reflect only part of the impact on fisheries.
- Estimation of costs may vary conditioned by the consistency of data, the period of reference, the area considered affected, and the fishing species accounted.
- Different figures of the global cost arise from expert estimations, estimation by claimants, and compensation paid to claimants.

3.1. Impacts of drilling accidents on fisheries

Offshore O&G accidents may have serious impacts on fisheries and on the entire seafood industry. Due to uncertainties related with the resilience of the environment, the adaptation of species, and the reaction of the market, only short term impacts can be reliably assessed.

3.1.1. Direct impacts on fisheries

- *Closure of fisheries*. Following any kind of accident offshore, an exclusion safety area is established to limit and control potential effects. If there is a spill of oil or other substances, local authorities usually close fisheries immediately, as precautionary measure to preserve public health. The ban to fishing in the usual areas constitutes a direct impact on the fishing industry, which sometimes has no alternative for fishing elsewhere. The duration of the closure is variable, dependent on the species affected and on the impact of the accident. Shellfish, relatively immobile and sometimes filter feeders are more likely to get contaminated, and therefore shellfish exclusion zones remain longer in place, until the authorities confirm there is no health risk. Reopening occurs when waters are free from oil, and might be considered on a species by species basis, after passing sensory and chemical analysis to ensure there are no harmful oil residues.
- *Change in demand due to public perception*. Public perception may change the demand for products if the consumer feels there might be a health risk or an increased environmental impact. After the Braer accident in 1993, enormous worldwide publicity surrounding the oil spill resulted in serious damage to the reputation of Shetland’s seafood and a temporary reduction in consumption. Through shifts in market demand due to broader consumer concerns,, the spatial

effects of pollution can extend beyond the area of physical impact (Lipton and Strand, 1997). The adjustment of markets and fishers to a new situation is usually fast.

3.1.2. Indirect impacts on fisheries

- *Reduction in harvesting rates.* Even if the fishing exclusion zone is not very extensive, the mortality of some fish and the running out of others, leads to reduction of stock availability. The fishing effort has to intensify to obtain a similar return.
- *Mortality of organisms.* In addition to fish unable to escape the accident, which die by direct impact, a number of fish might be affected by intoxication in the following days or months. Immobile organisms such as corals are likely to be affected by smothering when toxic substances are deposited over them.
- *Behaviour and reproductive capacity.* If the seabed is affected by deposition of oil or other substances, sensitive species might be prevented from spawning in their usual areas, affecting present and future spawning levels. A report in Shetland after the Braer spill (NRC, 1994) concluded that the effects on shellfish reproduction and behaviour change could last for eight years.

3.1.3. Indirect impacts on ecosystems

Little is known about the long-term effects of a spill on ecosystems, about the resilience of different environments, and the reaction of complex feeding webs. But the intermediate and long-term harm to ecosystems is of great concern, especially where food production is dependent for spawning, nurseries and growth. Sub-lethal effects reduce fish health, resulting in decreased growth and reproductive capacity.

3.2. Economic cost of impacts

A number of factors influence the economic cost of the impact on the fishing industry resulting from an offshore accident. The intensity of effects, associated with the type of accident and environmental characteristics (Table 2) is crucial, the resilience and response of fish to pollutants, and also the responsiveness of consumers to price changes. Furthermore, the mechanism of valuation is critical in determination of costs, with diverse mechanisms yielding very different results.

3.2.1. Direct economic cost

Immediate economic costs are linked to the loss or damage of equipment and overall, to the closure of fisheries as precautionary measure to ensure safety of fish for consumption. Lower production during the closure and after, increased effort (crew numbers, time and fuel) to maintain production, and consumer perception of reduced fish quality affect the economic revenue of the fishers' community. The duration of the fisheries closure (Fisheries Exclusion Zone) goes from a few days to several months, being tradeoffs between ensuring public safety and providing fishing opportunities to commercial fishermen. During this time fishers' income is reduced and might be inexistent if there is no alternative activity.

Box 2: Example of the result of the closure of fisheries

IMPACT ON FISHERIES PRODUCTION IN SHETLAND

As a result of the Braer grounding in the southern coast of Shetland in 1993 and the spillage of 85,000 tonnes of oil affecting the environment:

10% of the demersal fisheries were adversely affected during four months.

40% of all shellfish grounds were excluded for two years.

25% of total production of farmed salmon was severely tainted.

These impacts on fisheries represented an important and direct loss of income for the industry.

Note: Farmed salmon is in cages and could not swim to escape the oil slick

Source: Goodlad, 1996

In addition to fishermen, other industrial sectors directly affected by the closure of fisheries are the processing (canning, freezing), marketing, and distribution industries. Although sometimes these sectors find substitute stocks from other fishing areas, seasonality of captures, adaptation of machinery, or consumer preferences pose difficulties to maintain economic revenue. Affected sectors which are physically far from the accident are normally not eligible for economic compensation. For instance, claims to the IOPC Compensation Fund for economic loss may be accepted only if there is a 'reasonable proximity' between the contamination and the prejudice for which compensation is being claimed. After the Sea Empress spill (1996), claims for shellfish dealers that were based hundreds of kilometres from the area were rejected through application of this principle (Thebaud et al., 2004).

3.2.2. Indirect economic cost

As the public loses confidence in the quality of fish as a food source, prices go down. The magnitude of the perceived change in quality of the fish products depends to a great extent on how the media treat the case. The publicity surrounding a spill can result in serious damage to the reputation of seafood (Goodlad, 1996): orders for food are cancelled and buyers stop buying, local plants of fish processing cannot sell. In addition to the natural recovery of fish, a media counter-campaign might be necessary to recover public confidence. Even after recovery of safety and quality of fish, consumers still use the spill as an excuse to try to lower prices and negotiate discounts.

Markets generally adapt to what is available. When the supply from an area affected by an offshore accident is reduced or inexistent, merchants go somewhere else to get the necessary produce. Therefore, by the time the environment and fisheries are recovered, an effort to recuperate market quota requires economic sacrifice in the form of lower prices. Sometimes search of other selling markets, which might be less convenient or profitable. While direct economic cost is appreciated on the short term, indirect impacts mostly run in the medium- to long-term, and consequences and implications are more difficult to estimate.

3.2.3. Methods for estimation of economic cost

In the assessment of economic costs there are always some uncertainties associated to the complexity of the fisheries and the ecosystem affected by the accident. Usually only short-term economic costs are valuated, because for medium- to long-term assessment the biology and recovery of species, and the adaptation of the market to new circumstances are complex factors that require modelling.

Table 4: Methods for evaluation of economic cost of an offshore O&G accident

METHOD	DESCRIPTION	Reference
Social cost	Assessment of the loss of benefit or revenue from fishing activities; it is frequently evaluated as economic value of the difference in landings before and after the accident.	Garza-Gil et al. (2006b)
Compensation	The monetary value accepted to be rewarded by compensation mechanisms is assumed to be the cost on fisheries.	Moore (1998)
Evaluation of affected productive sectors	Economic losses of all sectors associated with fishing activities are assessed with existing base data.	Loureiro et al. (2006)
Habitat Equivalency Analysis	Compares resources lost as a result of an incident with benefits that can be gained from a habitat or wildlife restoration project. Requires modelling.	Zafonte and Hampton (2007)
Resource Equivalence Analysis	Monetary cost of funding the reestablishment of a comparable amount of resources lost or injured. Requires modelling.	McCay et al. (2004)
Restoration Based Analysis	Estimation of costs needed to restore resources equivalent to those existing prior to the accident. Requires modelling.	Mazzotta et al. (1994)

A range of methods for appraisal of environmental services exist, that can be grouped in three categories: market-based, revealed preference, and stated preference (UNEP-WCMC, 2011). Some of these methods evaluate the monetary cost of services (Table 4) and can be applied to evaluate the impact an offshore O&G accident makes on local fisheries. The social cost analysis is by far the method most frequently applied for assessment of costs after major accidents, and has been used in estimation of damages by the Prestige (Garza-Gil et al., 2006b), the Amoco Cadiz (Grigalunas et al., 1986), the Sea Empress (Moore et al., 1998) and the Exxon Valdez (Preston et al., 1990) accidents. The social cost analysis has been preferred over any other method for two reasons. First, its application for estimation of damage to fisheries is feasible, as market values are normally available: data of fisheries revenues before and after the accident are recorded in public statistics. The second reason is linked to the conditions of the damage compensation mechanisms: claims based on non-market valuation methods are not accepted in the current international liability framework (Garza-Gil et al., 2006b).

In application of the social cost method, there is no conceptual difficulty in defining commercial losses due to the effects of accidents involving pollution after an offshore O&G accident. However, difficulties may arise from the lack or reduced quality of baseline data and from the need to develop a reasonable scenario of what would have happened had the pollution not occurred (Lipton and Strand, 1997).

In the assessment of the economic cost that minor offshore O&G incidents produce on fisheries, the compensation mechanism is preferred for its simplicity. Claims made by fishermen to O&G operators are normally accepted and compensated if the cause of the incident is clear. When the incident's responsibility cannot be stated, fishermen claim to a compensation fund (OGUK, 2009).

Box 3: Examples of the economic cost of offshore O&G accidents in European waters

ECONOMIC COST OF MINOR IMPACT INCIDENTS

Fisheries affected in the North Sea by incidents in relation with the offshore O&G industry

Since year 2000 there have been almost 500 claims to the Fishermen's Compensation Fund (UK) for damages to fishing vessels in relation with incidents of O&G activities in the North Sea. These claims are made for three concepts: **loss of gear**, **loss of fishing time**, and **damage to vessel**. The amount claimed and settled in individual cases ranged between **£100** and **£50,000** with a mean value of **£3900**. On average, the most costly component of the total amount claimed and settled is the damage produced to fishing gear (63%), followed by the loss of fishing time (31%). Damages to the fishing vessel make up, on average, 6% of the amount claimed and settled in individual cases. The total amount claimed and settled between 2000 and May 2013 was **£1.8 million**.

Source: OGUK claims database

ECONOMIC COST OF MAJOR IMPACT ACCIDENT

Fisheries affected in the Galician coast after the Prestige accident in 2002

Almost five thousand fishing vessels are registered in Galicia (MAGRAMA, 2013), representing 6% in number and power of the entire European fleet. This proportion was even more important in 2001 (Garza-Gil et al., 2006a). **Coastal communities** in Galicia are strongly **dedicated to fishing** and related industries like **canning** and **freezing**. After the Prestige accident various efforts have been dedicated to estimate the economic impact on the fishing industry.

Garza-Gil et al. (2006b) evaluated the **short-term cost** of the accident impact analysing fish **landings** and aquaculture (mussel and turbot) **production** and income. Reference data were averaged for five years prior to the accident. The economic loss suffered in 2003 (the year after the accident) was estimated to be **€56 million** in relation with fishing and **€9 million** for the aquaculture activities. The reduction of production was calculated to be 10% while income decreased more than 17%. This difference was attributed to the loss of consumer confidence on the quality of the produce.

Loureiro et al. (2006) quantified **short-term economic losses** on the most productive sectors affected in Galicia and other regions affected by the Prestige spill. The sectors accounted are commercial fisheries and shellfish, mussel production, and canning and processing industries. The **difference in landings** of 36 species in the periods prior to the accident and after the accident showed a **loss of 50% in quantity** and **60% in revenue** value. The accumulated economic loss associated with loss of landings in the two years following the accident was **€124 million.** Although mussel production was not directly affected by the spill, since farming occurs in rivers and estuaries, this sector economic loss was estimated as **€12.8 million**, affected by market fluctuations and loss of perceived quality and reputation. Losses by the canning industry were **€26.8 million** in two years following the accident.

García Negro et al. (2009) performed an exhaustive analysis of landing losses with data broken down for the individual markets and species during period 1998-2005. They found **total landings decreased by 17%** after the accident, but more importantly highlighted a complex pattern of landings by species, probably explained by exploitation of new species or increased fishing effort.

An apparent variability of results in the estimation of costs after the Prestige accident reflects significant difficulties encountered to produce accurate and reliable estimation of the economic costs. The consistency of the base data, the period of reference, the affected area considered and the species accounted in the analysis are some of the factors that may influence the appraisal results. As posed by Thebaud et al. (2004), establishing a single global estimate of the social cost of an oil spill is extremely difficult, since three types of figures may be considered: estimates by experts, compensation claims, and compensation eventually paid to claimants.

As an additional limitation, calculation of the economic cost based on fishing landings does not reflect the real impact on the fishing industry, as fishing effort is redistributed to other areas (Abad et al., 2010) implying derived costs, and new species become marketable and exploited with unpredictable consequences. Stocks and catching efforts would be more reliable information, but these data are seldom available (Loureiro et al., 2006).

4. CURRENT EFFORTS TO MITIGATE ACCIDENT IMPACTS

KEY FINDINGS

- Among historical efforts to reduce the frequency of accidents offshore, an international framework of liability, including the Civil Liability Convention and MARPOL convention, have had important positive effects.
- Recent European legislation dealing with all the industry activities aims to minimize the risks associated with offshore O&G activities.
- International mechanisms for compensation of damages caused by offshore activities exist. Some of these mechanisms are specific to O&G industry accidents.
- Intense research supported by O&G operators and promoted by governments searches technological improvements to assure a safe development of the industry offshore.

The 2010 Deep Horizon environmental disaster in the Gulf of Mexico raised awareness of the risks involved in O&G offshore activities and evidenced the lack of adequate regulations for a case of accident, triggering the development of new legislation that ensured maximum safety. Currently the O&G industry in European waters operates under the most safety conditions worldwide.

4.1. Efforts to prevent accidents

4.1.1. Legislation and conventions

National legislation is diverse between EU states and the offshore industry operates to different environmental, health and safety standards in different EU state members. EU legislation did not use to cover all aspects of the offshore O&G industry. Recently ratified European legislation aims to ensure that offshore O&G production respects the world's highest safety, health and environmental standards everywhere in the EU (Europa, 2011a); it also aims to promote the same standards across the world.

Box 4: European legislation for safety of offshore O&G operations

DIRECTIVE 2013/30

Safety of offshore oil and gas operations

In July 2013, Directive 2013/30 about safety of offshore oil and gas operations came into force, amending prior Directive 2004/35. This regulation is addressed to all member states but its affection and requirement of transposition to national legislation differs for countries with offshore waters or landlocked.

Establishing minimum requirements and conditions for safe offshore exploration and exploitation (Europa, 2013) the Directive aims at reducing the occurrence of major accidents related to offshore O&G operations and to limit their consequences.

It establishes rules covering the entire lifecycle of exploration and production activities, from design to final removal of installations. Additionally, it aims to improve the response in the event of an incident and where prevention is not achieved, to assure clean up and mitigation is carried out minimising consequences.

The risk management principles include the requirement for operators to take all suitable measures to prevent major accidents in offshore oil and gas operations and to limit consequences for human health and the environment in the event of a major accident. The Directive provides that operators would not be relieved of their duties if an accident occurred as consequence of action or omission of their contractors.

The Directive provides rules for transparency and sharing of information, cooperation between member states, emergency response plans, and trans-boundary emergency preparedness and response.

As surrounded by EU and non-EU countries, the Mediterranean Sea is not entirely ruled by EU legislation. A key measure to protect the marine and coastal environment of the Mediterranean Sea from the possible negative consequences of offshore exploration and exploitation activities, complementary to Directive 2013/30/EU is the ratification by the EU of the **Offshore Protocol of Barcelona Convention for the Mediterranean Sea**, encouraging others to do the same (Europa, 2011b). The Protocol allows to work together with non-EU Mediterranean countries to ensuring better protection of the sea and for all its users. The Protocol requires systems to be put in place for monitoring and compensating damage caused by offshore activities. In addition, under the planned legislation, the responsibility for environmental cleanup following any offshore incident would fall wholly upon the operator, extending liability from 22 km (under current legislation) to 370 km.

Concerning the Black Sea, the Convention on the Protection of the Black Sea Against Pollution (**Bucharest Convention**) was signed in 1992 and ratified by all six countries with coastal areas in the Black Sea. The Bucharest Convention main objective is to oblige contracting parties to prevent, reduce and control the pollution in the Black Sea in order to protect and preserve the marine environment. It is the basic framework of agreement and has three specific Protocols for control of land-based sources of pollution, dumping of waste and joint action in the case of accidents such as oil spills.

The **International Convention for the Prevention of Pollution from Ships**, known as **MARPOL** has been amended and updated by the Protocols of 1978 and 1997. MARPOL Convention addresses pollution from ships by oil and other substances, applies to 99% of the world's merchant tonnage and has contributed to significant decrease in pollution from international shipping.

4.1.2. Liability

Guided by the International Maritime Organization (IMO), the international community has created mechanisms to compensate victims of oil pollution. The International Convention on Civil Liability for Oil Pollution Damage 1992 (1992 Civil Liability Convention) updates the former 1969 Civil Liability Convention, and establishes that the ship-owner has strict liability for pollution damage when a spill of persistent oil occurs from his ship. This liability excludes exceptional circumstances like an act of war or the negligence of a superior authority. The amount of liability is determined according to the size of the ship. Furthermore, for ships carrying more than 2000 tonnes of oil as cargo in bulk, the ship-owner is obliged to maintain insurance to cover liability.

In 2007 the International Convention on Civil Liability for Bunker Oil Pollution Damage (Bunker Convention) entered into force, extending the liability and compensation regimes to damage caused by spills of oil when carried as fuel in bunkers of any kind of ship.

4.1.3. Research and Technology

Offshore O&G operators use the state of the art technology in their daily activities and invest big amounts of money for research. Governments and international organizations are also involved in research projects aiming to improve safety during offshore operations and to manage accidents and reduce their impacts on the environment.

Monitoring the effects of each particular accident is important for research, but also for future prevention and better preparedness for an incident. Fundamental research in relation with oil spill modelling, biodegradation of oil, and the metabolism of oil in different species are relevant topics, particularly as new areas are explored for production. For instance, the unique conditions of the Arctic region, characterized by extreme temperatures and regime of light, require investigation to avoid uncertainties and to prepare the best possible response in case of accident.

Box 5: Examples of research for prevention of accident impacts

RESEARCH FOR PREVENTION OF ACCIDENT IMPACTS

PROOFNY (2002-2015) is a research programme coordinated by the Research Council of Norway, dedicated to acquire knowledge on possible **long-term effects of discharges from petroleum activities**. Sixty-five projects have been carried in relation with **biological effects of produced water**, effects of **discharges in the northern waters**, and effects of **drilling discharges**.

Joint industry program on oil spill contingency for Arctic and ice covered waters (2006-2009) is an R+D project by research organizations on behalf of a group of oil companies aiming:

"To improve our ability to protect the Arctic environment against oil spills"

"To provide improved basis for oil spill related decision-making"

"To advance the state-of-the-art in Arctic oil spill response"

CEDRE conducts a series of projects in relation with **Research and Experimentation on Accidental Water Pollution** to get better knowledge of the effects of polluting substances on the marine environment.

SINTEF Chemistry and Materials has established a research project to learn more about the effects and hazards of **underwater gas blowouts and gas leaks** with support from industry actors. This project is established as a Joint Industry Program and is developing **SURE**, an advanced modelling tool for Subsea Gas Release.

In 2003 the Mediterranean Operational Oceanography Network (MOON) established the Operational Oceanography in the Mediterranean Sea, a computer-aided support system based on real-time ocean forecasts systems coupled with satellite images and oil-spill models **to prevent the impact of accidental spills**. The satellite component integrates data received from spectroradiometric and radar-satellite sensors such as MODIS (on board AQUA since 2002 and TERRA since 2000) and ASAR (on board ENVISAT since 2002), making it possible to monitor the evolution of the oil pollution on a daily basis if needed. The capacity of **satellite remote sensing** to capture data over extensive and inaccessible areas makes it suitable to provide substantial support to routine surveillance in open-ocean and coastal areas. Software for modelling the fate and transport (MEDSLIK[1]) or biological

[1] MEDSLIK (Mediterranean Slick)

effects (SIMPAC[1]) of the oil spillage provide valuable assistance for decision making and management of the response in the case of an offshore O&G accident.

Research provides the sound and necessary knowledge to develop justified rules and legislation. For instance, there had been a long-term concern about over-trawling piles of drilling residues after decommissioning extractive installations and removing of the safety zone. After a period of research on the subject, current legislation makes removal of cuttings compulsory.

4.2. Efforts to alleviate accident effects

4.2.1. Action Plans—Contingency plan

Countries under the **International Convention on Oil Pollution Preparedness, Response and Co-operation** (OPRC) signed in 1990 and which entered in force in 1995, are required to establish measures for dealing with pollution incidents, nationally or in co-operation with others. In this context, cooperation programs of regional character (e.g. Bonn Agreement, Barcelona Convention, European Community Task Force, Arctic Council, and Copenhagen Agreement) or bilateral agreements (e.g. Norbrit Plan between Norway and the UK) have been developed. Furthermore, a Protocol to the OPRC relating to hazardous and noxious substances (OPRC-HNS Protocol) was adopted in 2000.

Offshore installations and ships are required to report incidents of pollution to coastal authorities and to have an emergency plan to respond promptly and effectively to oil pollution incidents. Parties to the convention are required to provide assistance to others in the event of a pollution emergency and provision is made for the reimbursement of any assistance provided.

The Mediterranean Action Plan (1975) is supported by seven Protocols addressing specific aspects of environmental conservation. One of them is the Protocol for the Protection of the Mediterranean Sea Against Pollution Resulting from Exploration and Exploitation of the Continental Shelf and the Seabed and its Subsoil (The Offshore Protocol, 1994).

4.2.2. Remediation

Remediation is the process of removing pollution or contaminants from the environment affected, to minimize the impact of the incident. There are a range of methods for removal of contaminants, and choosing the most appropriate for a particular situation requires thorough consideration. In some cases there is no cleaning action required; monitoring the fate of the spill is the best action until natural dissipation of the contaminant into the water occurs. Remediation techniques include the following:

- *Physical removal*. The use of booms to contain dispersion of heavy fuels until recovery by skimmers is a preferred method in contingency plans. It assures the removal of the pollution from the environment. Unfortunately it is seldom possible to remove but a small fraction of the oil, as it tends to disperse quickly into the water.
- *Chemical dispersant.* Dispersant substances work enhancing the natural dispersion of oil in water, by breaking the oil into droplets that are dispersed into the water column and eventually dispersed by water currents. When applying chemical dispersants from boats or helicopters, there is tradeoffs as the pollution risk is transferred from the sea surface to the water column.

[1] SIMAP (Spill Impact Model Application Package)

- *Bioremediation agents*. This is the application of oil-degrading bacteria and nutrients to enhance the natural process. Bioremediation has so far not been demonstrated technologically feasible or beneficial for large-scale restoration areas (ITOPF, 2013).
- *Shoreline cleaning.* When the oil reaches the coast, a combination of techniques can be used to clean the coast: manual and mechanical removal, flushing or washing with water at high pressure and temperature, and wiping with rags and adsorbent materials are frequently applied.

4.2.3. Compensation mechanisms

International and national mechanisms exist to provide financial compensation for damages to property and to the environment caused by marine accidents. Some mechanisms are specific to O&G industry accidents and others would cover damages caused by non-specific circumstances.

After the Torrey Canyon incident in 1967 a liability-based compensation regime was set up in two international Conventions. The Convention on Civil Liability (CLC) was set up in 1969 and amended in 1992, and establishes the strict liability of ship-owners in case of incident. The amount of liability is limited, linked to the tonnage of the vessel, and associated to compulsory insurance. The second convention is the Fund Convention of 1971 (1971 Fund) which established a supplementary fund financed by the oil industry for compensation of damages not covered by CLC. The Fund Convention set up an international organization (International Oil Pollution Compensation Fund: IOPC Fund) to administer the unique international regime for compensation. Under these conventions the damages that can be claimed are grouped into four categories: cleanup, preventive measures, fishery-related, and tourism-related (Kontovas et al., 2010).

Box 6: IOPC compensation mechanisms

INTERNATIONAL OIL POLLUTION COMPENSATION

The International Oil Pollution Compensation Funds (IOPC Funds) are three intergovernmental organizations:

The 1971 Fund

The 1992 Fund

The Supplementary Fund

These organizations provide **compensation for oil pollution damage** resulting from spills of **persistent oil from tankers** that occur in its **Member States**.

The IOPC Funds are **financed by contributions** of entities that receive certain types of oil by sea transport. Contributions are based on the **amount of oil received**. Contributions to the Supplementary Fund are based on a higher amount of oil received (1 million tonnes instead of 150,000 tonnes) and entitles to higher compensation.

The 1992 Fund compensates victims when the 1992 CLC is not adequate or sufficient. The maximum compensation is **203 million SDR for incidents occurring after November 2003**, irrespective of the size of the ship.

Separately from the compensation funds, two voluntary agreements in relation with tanker pollution were set up to indemnify the 1992 Fund: STOPIA 2006 (Small Tanker Oil Pollution Indemnification Agreement) and TOPIA 2006 (Tanker Oil Pollution Indemnification Agreement).

Table 5: Current compensation mechanisms and maximum amount payable for damages caused by offshore pollution

NAME	DATE OF CREATION AND (ENFORCEMENT)	TOTAL PAYABLE	MEMBERS
1992 Convention on Civil Liability	1992	Depends on tanker size	124
IOPC Supplementary Fund Protocol	2003 (2005)	750 million SDR[1]	29
IOPC 1992 Fund	1992 (1996)	203 million SDR	111
Bunker Convention	2001 (2008)	Depends on bunker size	54
Offshore Pollution Liability Agreement	1974	$250 million	9

Source: Authors compilation from multiple documents

In 2007 the International Convention on Civil Liability for Bunker Oil Pollution Damage (**Bunker Convention**) entered into force, extending the liability and compensation regimes to damage caused by spills of oil when carried as fuel in bunkers of **any kind of ship**.

Offshore Pollution Liability Agreement (OPOL)[2] is a **European compensation system**. Membership is compulsory for those operators wishing to drill in the territorial waters of the UK, Denmark, Ireland, Norway, France, Germany, the Netherlands, Faroe Islands and Greenland. Operators of offshore facilities (wells, drilling units, platforms, offshore storage/loading systems and pipelines) have to maintain financial responsibility of at least $250 million for any incident and $500 million annually. The $250 million is to cover pollution damage and remedial measures. The responsibility for meeting claims under OPOL rests solely with the operator.

In 1975 the UKOOA (now Oil and Gas UK) created the Fishermen's Compensation Fund to compensate fishers who have suffered loss or damage to fishing gear caused by oil-related debris in the UK continental shelf when the operator responsible cannot be established. This Fund is financed by OGUK and managed by a committee with representatives from the O&G and fishing industries. Over 1500 claims have been filed since 1989, totalling £11.5 million claimed and circa £5 million settled.

4.2.4. International actions

International organizations like HELCOM (Helsinki Commission) in the Baltic and REMPEC in the Mediterranean have as main goal to maintain the ability to respond to pollution incidents. These organizations arrange resources with specialized equipment to respond efficiently to pollution events. Training and testing of each country response capacity is performed with programmed exercises (HELCOM, 2009). In addition, bilateral and multilateral agreements for rapid response exist and are encouraged by international organizations. For detection of illicit polluting activities, regular surveillance flights in the Baltic carry side looking radar (SLAR), infrared (IR), and visible sensors. Similar labour of surveillance is carried out in the Mediterranean Sea by the Operational Oceanography in

[1] SDR: Special Drawing Rights

[2] http://www.opol.org.uk/

the Mediterranean Sea established by the MOON (Coppini et al., 2011). Since 2007 the European Maritime Safety Agency (EMSA) provides a near real time satellite surveillance service (CleanSeaNet) for detection of oil spills and identification of culprits. These daily surveillance activities for detection of illegal pollution are also available to assist in case of an accident. Refuge places for ships in distress are determined by party countries, where issues of liability and compensation can be investigated.

5. CONCLUSIONS AND RECOMMENDATIONS

The offshore O&G industry in European waters, necessary to secure wealthy economies of EU countries, suffers eventual accidents during routine activities. Historically, the most harmful accidents have occurred during transportation, leading to significant damage to the environment, and in particular to fisheries and aquaculture. Valuation of the cost that the impact of major accidents has on fisheries and aquaculture is most frequently performed with the *Social Cost* method, a technique accepted by the current international compensation mechanisms. This appraisal technique is normally applied with fishing landings as the market value, comparing figures before and after the incident. However, this method is not free of uncertainty, mainly in relation with the base data available, which aims to create a reasonable scenario. Minor incidents are appraised with the *Compensation* method, evaluating the amount of settled claims.

As the offshore O&G industry matures in European waters, increasing knowledge and experience is enabling continuous technological improvements that aim to minimize the risk in all operations and to assure the maximum safety. Furthermore, legislation also evolves, being updated to meet the new industry requirements. Recently, Directive 2013/30 about safety of offshore O&G operations came into force, establishing minimum requirements and conditions for safe offshore exploration and exploitation. This Directive aims at reducing the occurrence of major accidents related to offshore O&G operations and to limit their consequences. It establishes rules covering the entire lifecycle of exploration and production activities, from design to final removal of installations, and it intends to improve the response in the event of an incident and where prevention is not achieved, to assure that clean up and mitigation is carried out minimising consequences.

5.1. Recommendations

Fishing and O&G industries have a relatively long history of co-existence in the marine environment and will continue sharing this space in the future. Prior interactive experiences, and the errors, mistakes or failures during O&G working activities that directly or indirectly originated accidents with damaging impacts to fisheries, are valuable sources of knowledge to build upon. Lessons should be learnt from the past to ensure increased security in present and future activities. The following suggestions are intended to help minimize negative impacts on fisheries of the offshore O&G accidents in European waters.

5.1.1. Regulatory measures and activity guidelines

European legislation aiming to ensure the highest level of safety in offshore O&G activities is already approved. This new legislation, covering all stages of the offshore O&G industry, and aiming to minimize the risk of accidents, and their impact in case of occurrence, is a promising instrument. For successful implementation of regulations and to succeed ensuring maximum safety, state members should:

- Transfer the Directive 2013/30/EU into national legislation in a timely manner and implement the new legislative framework at all levels, with national and non-national operators.
- Provide mechanisms for effective enforcement of the new regulations, assuring an adequate implementation of the novel rules in all activities of the industry.

- Encourage the government of countries out of the EU to produce regulatory frameworks of similar high safety standards to that existing in EU countries.
- Consider fishers' activities and areas of best interest at the time of enforcing rules, and inform the fishing industry of changes of regulations affecting the O&G industry.

All O&G operators working in EU waters should:

- Follow current rules in their daily development of activities, ensuring the highest possible level of safety at all times and minimizing human error and equipment failures.
- Report potential conflicts of the novel rules with the current technology, to achieve implementation of the most safety actions in realistic scenarios.
- In particular those operators involved in transportation should make every effort to ensure oil and gas from offshore sources is transported under the strictest conditions of safety, avoiding as much as possible those routes that might involve risk when conditions are unfavourable.
- Operate in the same safety manner when developing activities in non-EU waters, promoting a high standard level of safety in all offshore O&G exploration and exploitation activities.

Joint consortiums of operators, legislative bodies, and science advisers may produce and distribute updated activity guidelines, advising individual parties on how to operate under new regulations. These guidelines should cover day-to-day code of action, as well as guidance on how to react in case of an emergency, including self behaviour and information of contacts for assistance and response.

5.1.2. Influence on international environment

Marine ecosystems of EU states include waters and shores in the Northeast Atlantic, the Baltic Sea, the Mediterranean Sea, and the Black Sea. Offshore O&G activities by operators in these waters cannot completely be regulated by EU legislation, because other countries have jurisdiction over shared waters. However, accidents occurred in non-EU waters and to non-EU operators might affect the marine environment in EU countries. For this reason it is of paramount importance:

- To promote high safety standards and adequate regulations in neighbour countries with which EU states share the marine environment.
- To support the emerging offshore O&G industries in countries which are commencing these activities in their jurisdictional waters, by assisting and providing advice on methods for best development (e.g. licensing requirements and conditions for exploration and exploitation).
- To encourage countries on the Southern and Eastern shores of the Mediterranean Sea to adopt a regulatory framework similar to that being implemented in European countries. This goal to achieve a similar level of effort from all countries concerned in the Mediterranean Sea, will assure the highest safety for the environment.
- To encourage European and non-European countries in the Black Sea to develop compatible and inter-calibrated national rules to assure all countries make the same high effort to maintain clean and safe waters.
- To promote the ratification and recognition of jurisdictional water borders in the Black Sea.

5.1.3. Research and Technology

The most updated equipments of the offshore O&G industry are designed to assure maximum safety in all operations. These equipments aim to operate producing the least damaging affection to the marine environment during offshore activities. Continuity of research and improved technology is desirable and might be enabled by:

- Improving the knowledge of environmental conditions and biological response in areas where knowledge is currently scarce. For instance, there is a recognized lack of knowledge of biological conditions in the Black Sea, particularly in deep waters. Efforts might be addressed to improve the science in this Sea.
- The Artic waters are also of particular relevance as a potential source of oil and gas, and are currently deemed menaced by exploitation without enough understanding of risks and potential remediation and response in case of emergency. Incremental research and development of adequate technology for the extreme conditions existing in the Artic is necessary.
- Producing and maintaining accessible databases of small and medium incidents in relation with the O&G activities that affect fisheries and related industries are necessary to obtain a complete understanding of the economic cost of these impacts.
- Maintaining and increasing or improving the research effort to go one step ahead of what is immediately needed in the industry is desirable.
- Old installations might require more frequent inspections in order to ensure they are still able to perform safe activities. Some components may need replacement if they pose a risk of accident.
- Updated records of fish stocks are necessary to enable a sustainable management of natural resources. The distribution of the fishing effort and O&G activities should be made spatially and timely compatible, and this would be possible with enough knowledge of available resources.

5.1.4. Compensation

Compensation mechanisms for damages to fisheries after offshore O&G accidents have historically shown imperfections, leaving damaged sectors without deserved recompense. Enhancement of the compensation framework, aiming to assure that all affected parts are indemnified for direct or indirect losses of income would be benefited by:

- Improvement of the methods for assessment of economic cost, to provide estimations reliable enough to be accepted by the compensation framework. Methods relying on models for assessment of economic values require good data for calibration and validation of their estimates.
- Development and implementation of mechanisms specific for compensation of offshore O&G related incidents and accidents. With specific mechanisms, claims would be simpler and compensation more straight forward and with reduced delays.
- Guarantee that all sectors impacted and damaged receive compensation regardless the location and distance to the original focus (accident). For instance, cases when an event affects activities located in remote locations like canning or freezing fish food.

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