



Development of Regional Joint Master Program in Maritime Environmental Protection and Management - MEP&M -

Introduction to the impacts of oil and gas activities on the marine environment

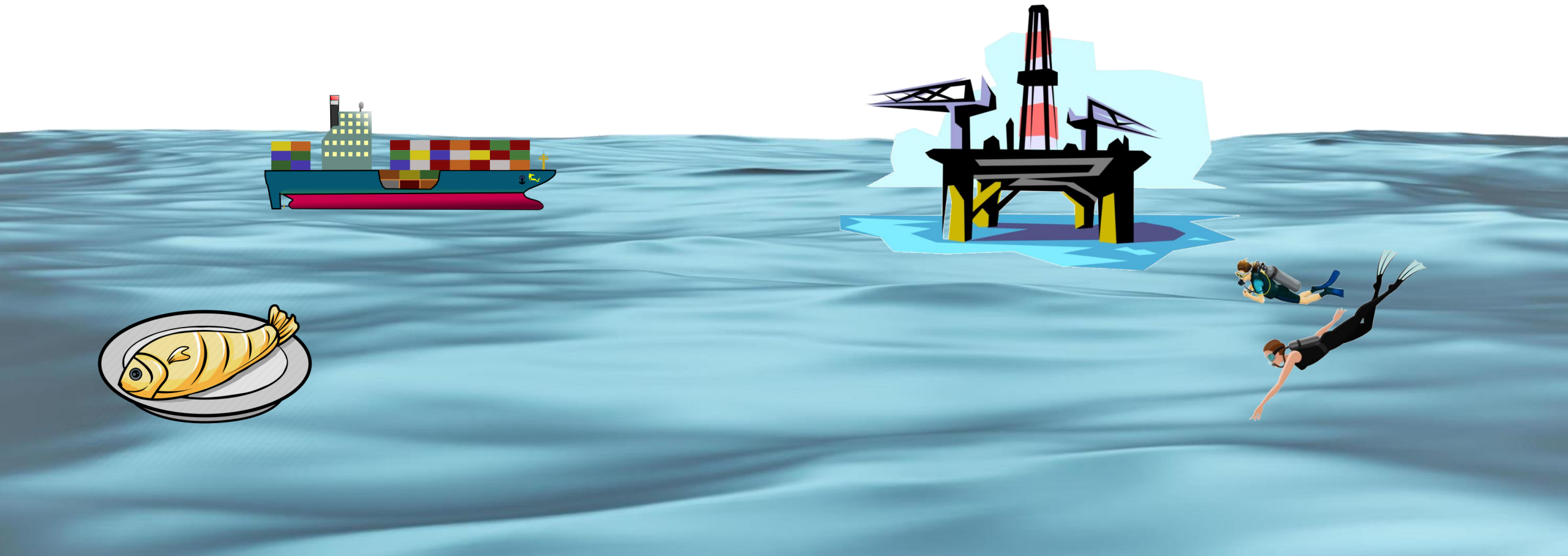
WP3 Capacity Building through staff training and equipment purchase-
Dev 3.4.1 KNOW HOW TO TRANSFER TO TEACHING STAFF RELATED TO THE
MEP&M

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15 July 2021

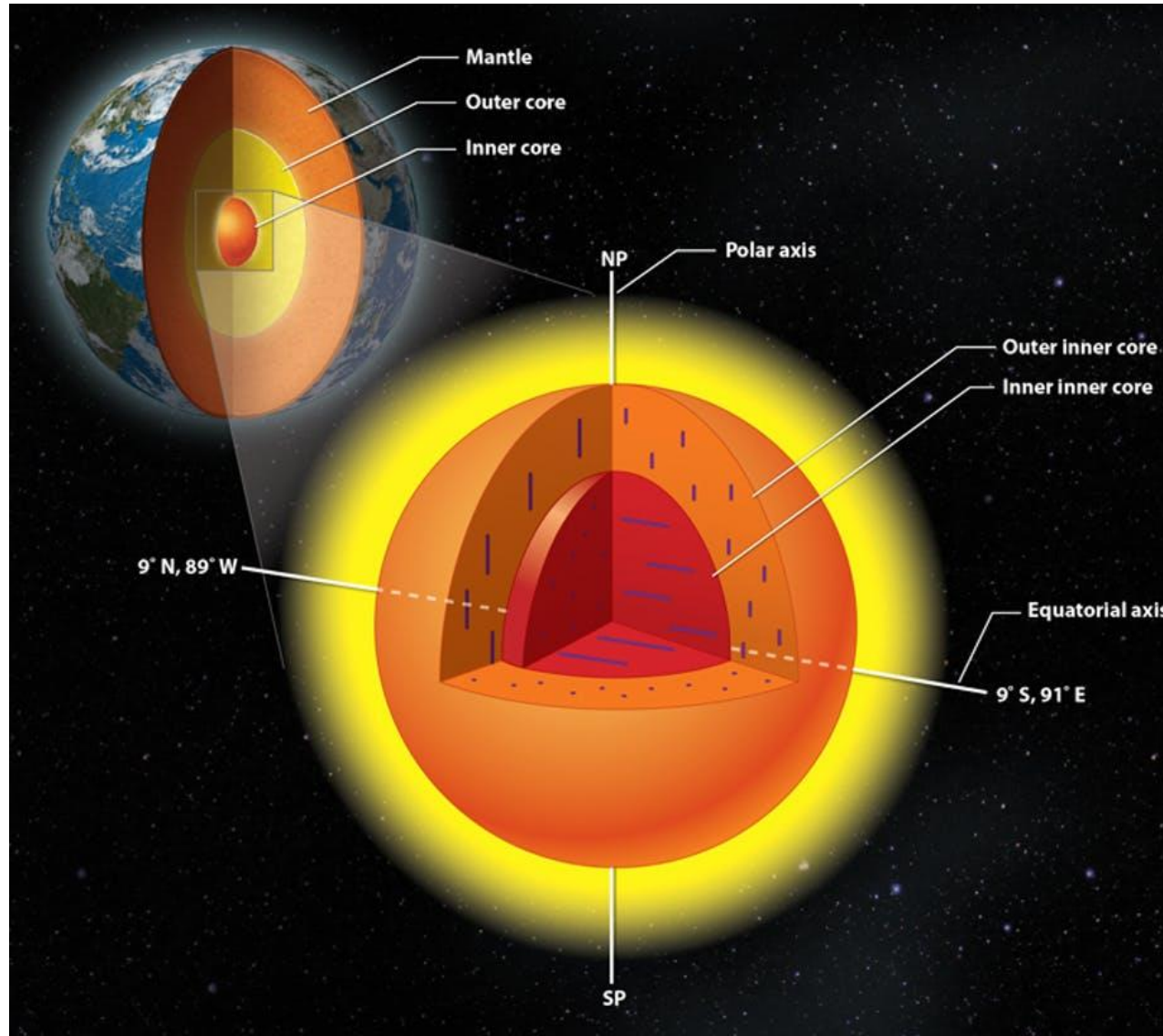


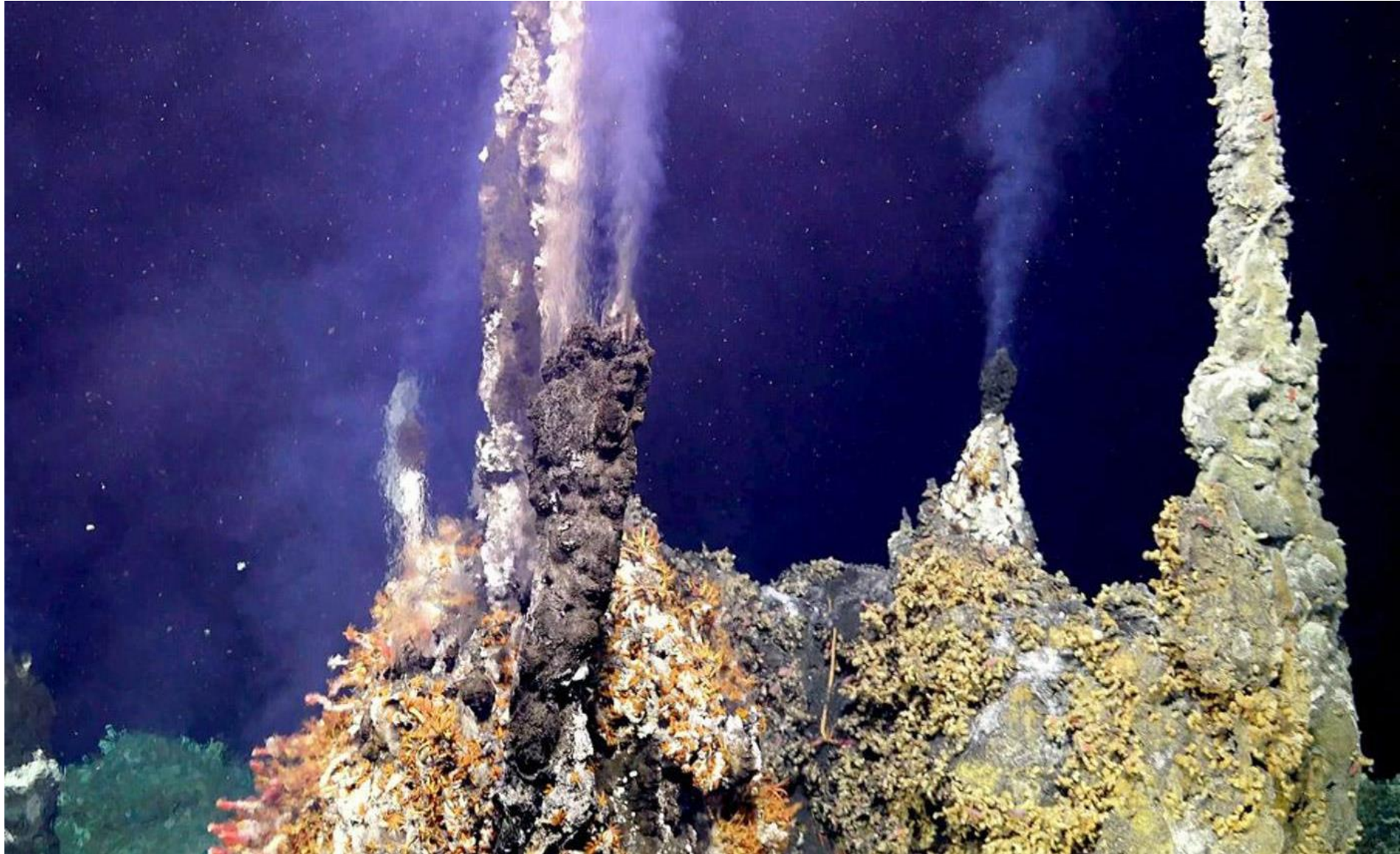


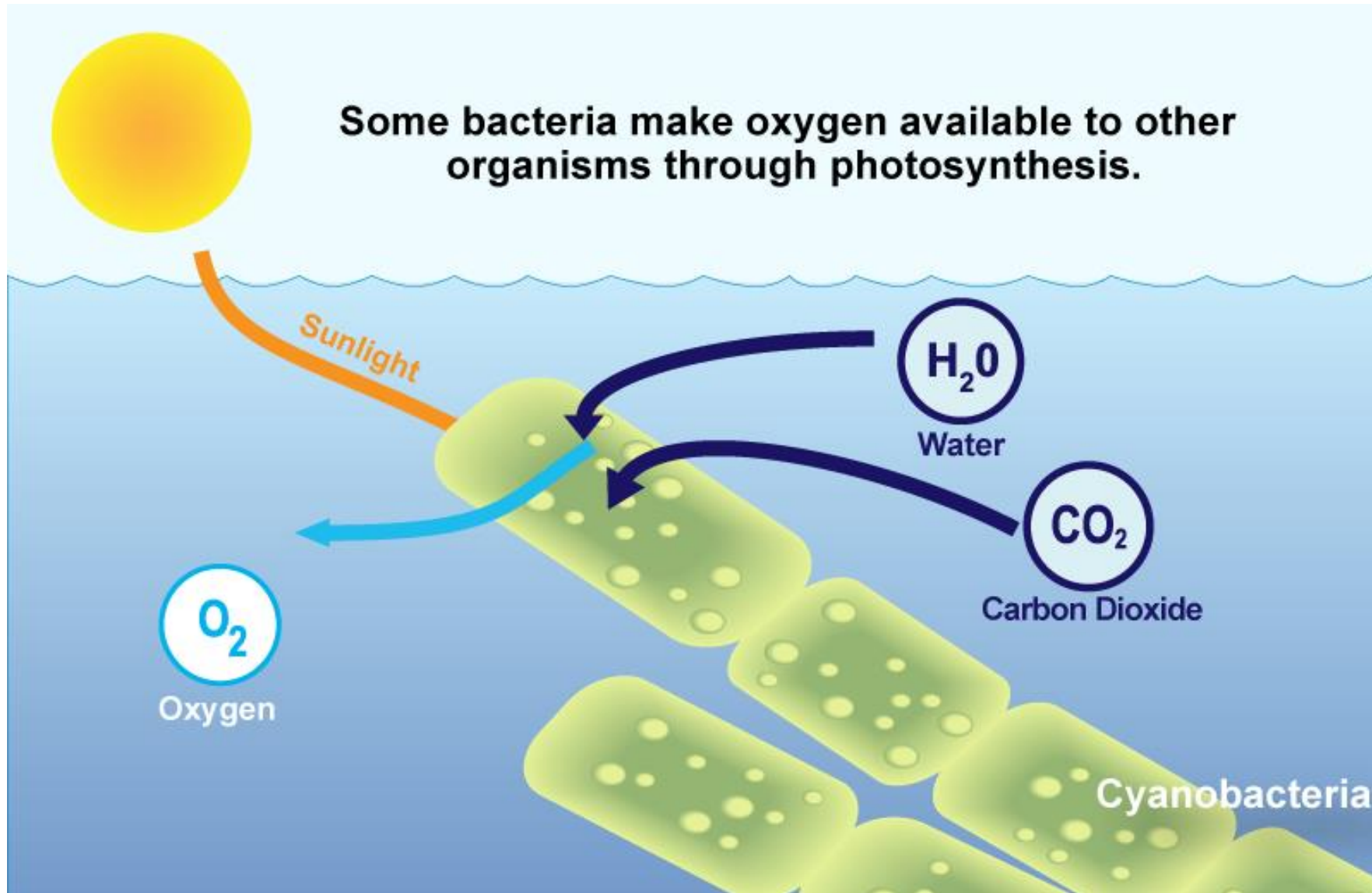
Introduction

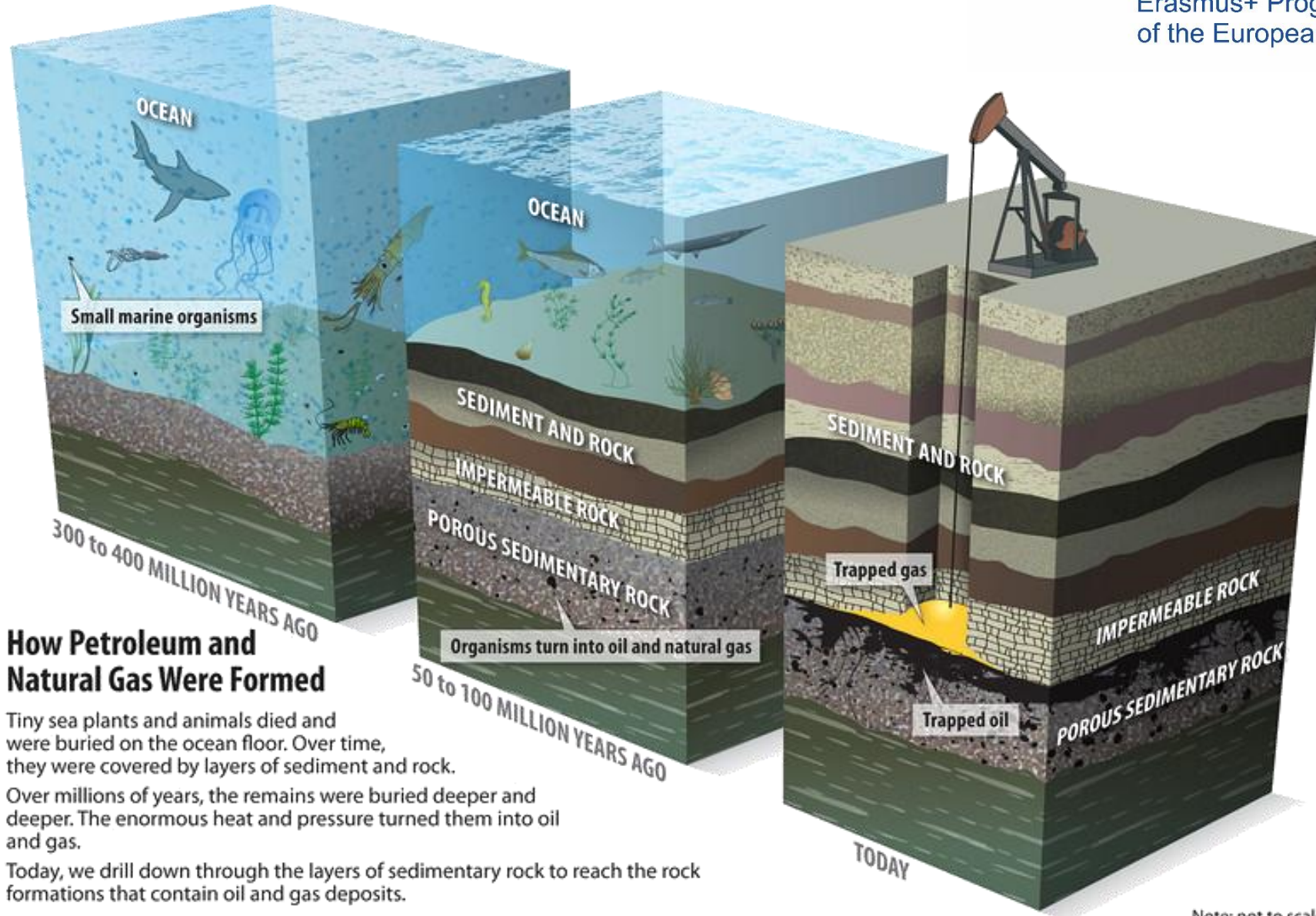












How Petroleum and Natural Gas Were Formed

Tiny sea plants and animals died and were buried on the ocean floor. Over time, they were covered by layers of sediment and rock.

Over millions of years, the remains were buried deeper and deeper. The enormous heat and pressure turned them into oil and gas.

Today, we drill down through the layers of sedimentary rock to reach the rock formations that contain oil and gas deposits.

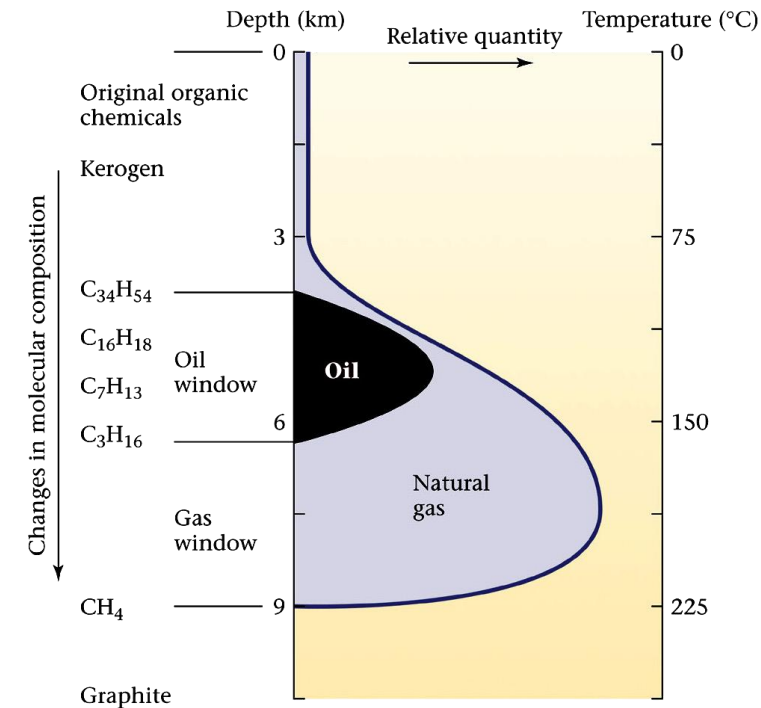
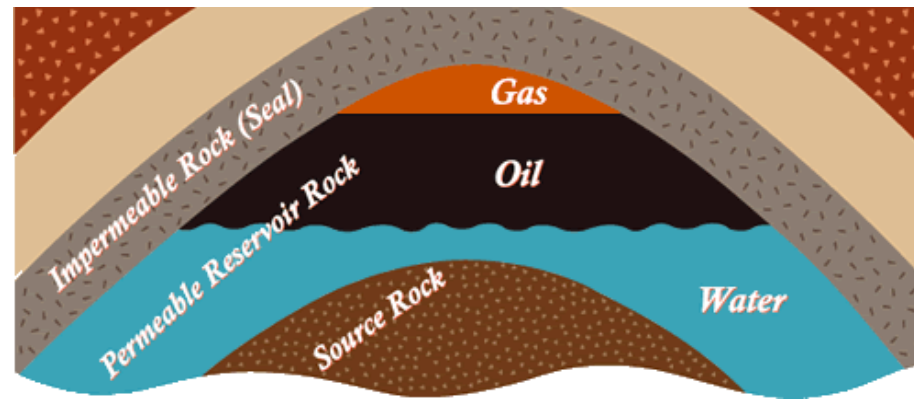
Note: not to scale





Hydrocarbons genesis

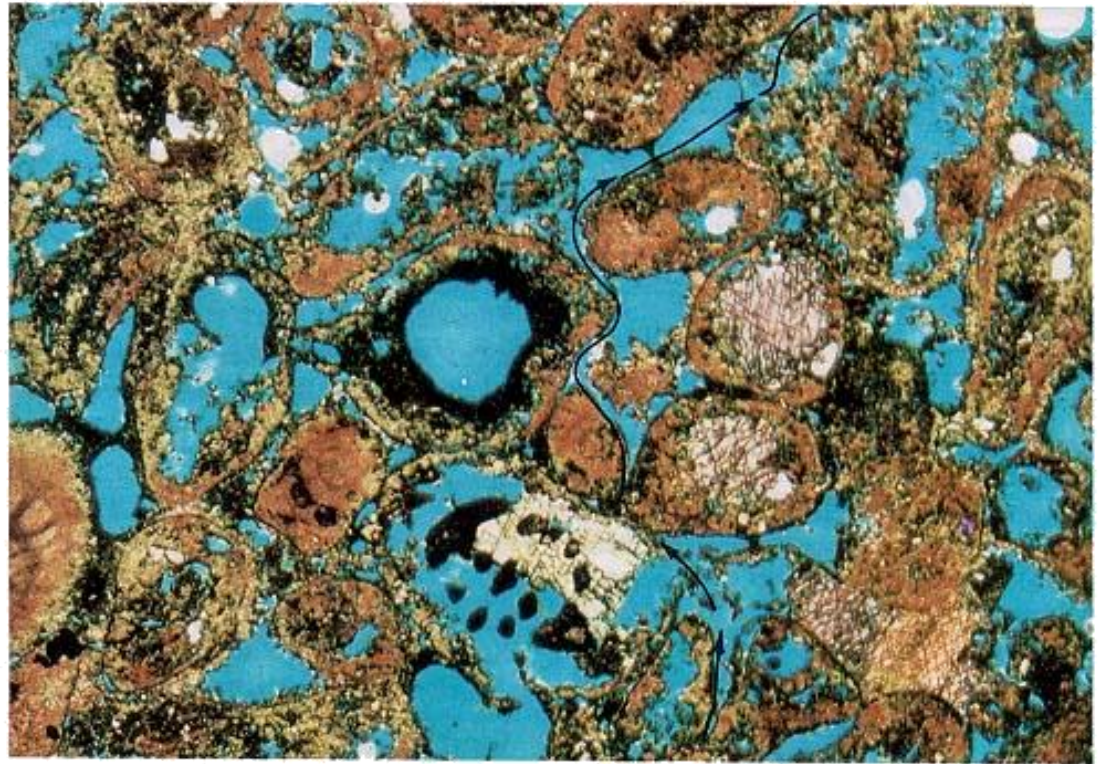
- **60 million years: the average time for the formation of hydrocarbons**
- **Crude oil, the liquid remains of ancient plants and animals, is a fossil fuel that is used to make a wide range of fuels and products (NOAA, 2020).**
- **Oil window**
- **Gas window**





Oil

- **Reservoirs: pores of rocks**
- **Transport**
- **Different petroleum products**



D

1 mm

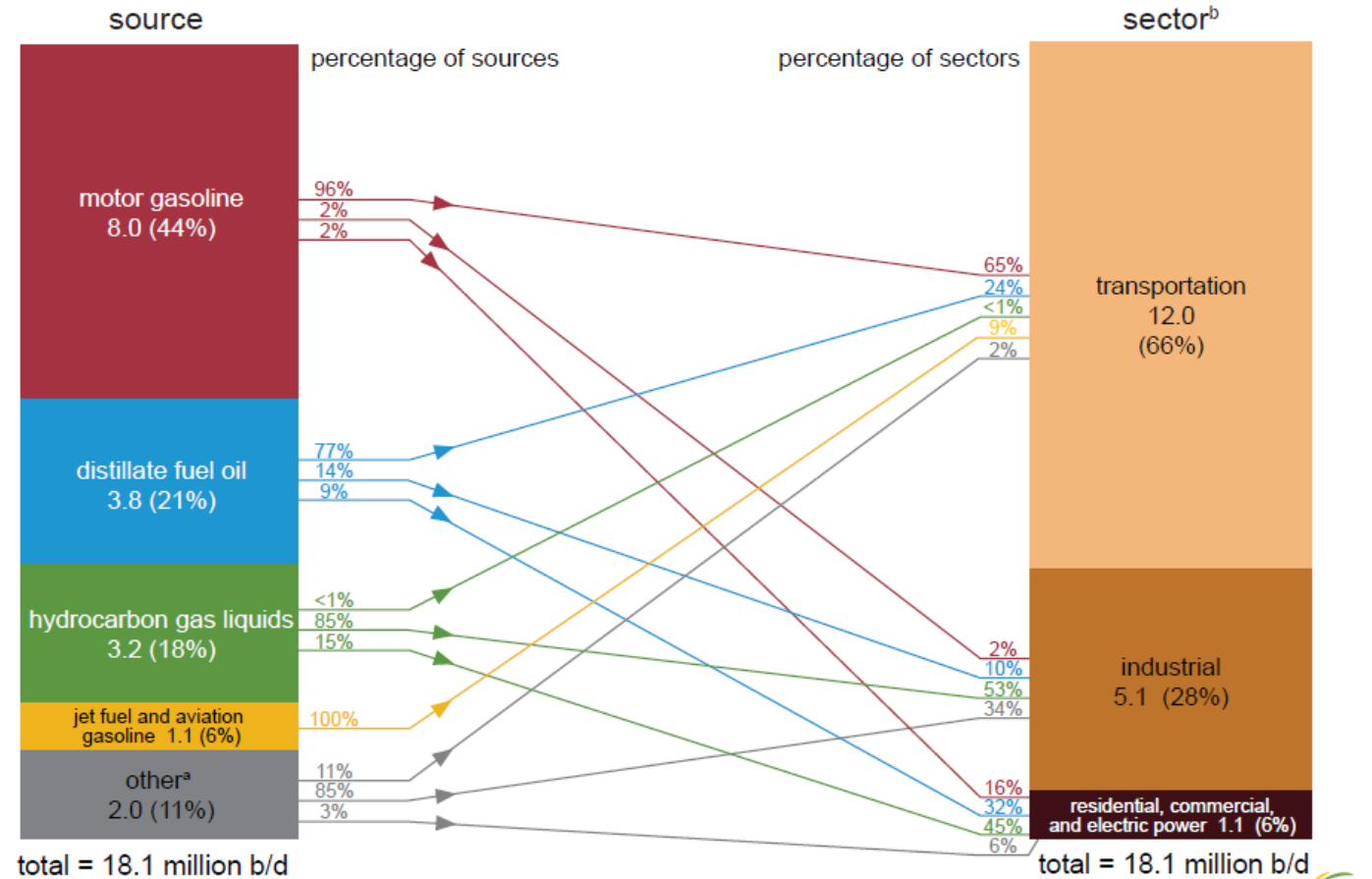


Oil

• U.S. petroleum consumption by end-use sectors' percentage share of total in 2020

- Transportation 66%
- Industrial 28%
- Residential 3%
- Commercial 2%
- Electric power <1%

U.S. petroleum products consumption by source and sector, 2020
million barrels per day (b/d)



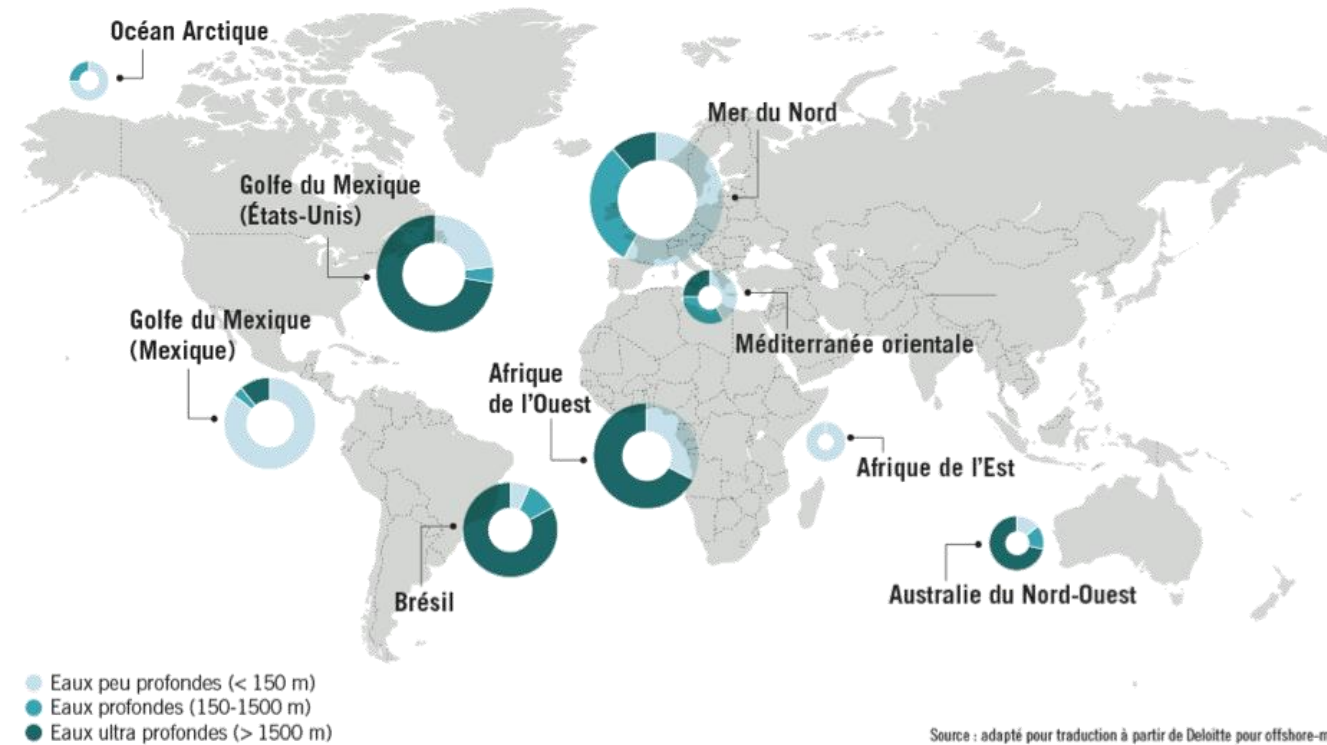
Sources: U.S. Energy Information Administration (EIA), *Monthly Energy Review* (April 2021), Tables 3.5, 3.7a, 3.7b, and 3.7c.
Note: Sum of components may not equal total due to independent rounding. See "Extended Chart Notes" on next page.

^a Includes asphalt and road oil, aviation gasoline blending components, lubricants, kerosene, petrochemical feedstocks, petroleum coke, residual fuel oil, still gas (refinery gas), special naphthas, waxes, unfinished oils, and miscellaneous products.
^b Industrial, commercial, and electric power sectors include primary energy consumption by combined-heat-and-power (CHP) and electricity-only plants in the sector.



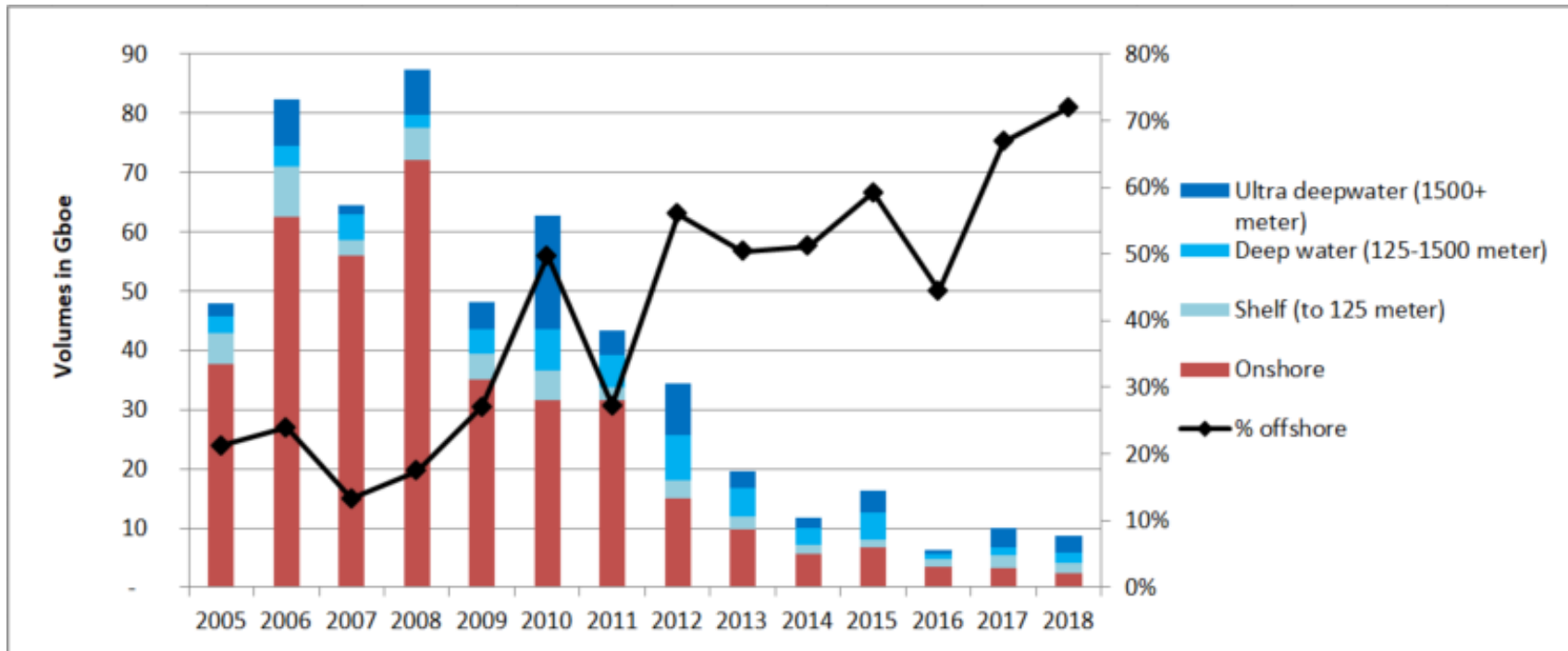
Offshore oil and activities

Figure 1. Régions pétrolières et gazières offshore et profondeurs des puits forés





Offshore oil and activities





Accidents

- **Public and media attention**

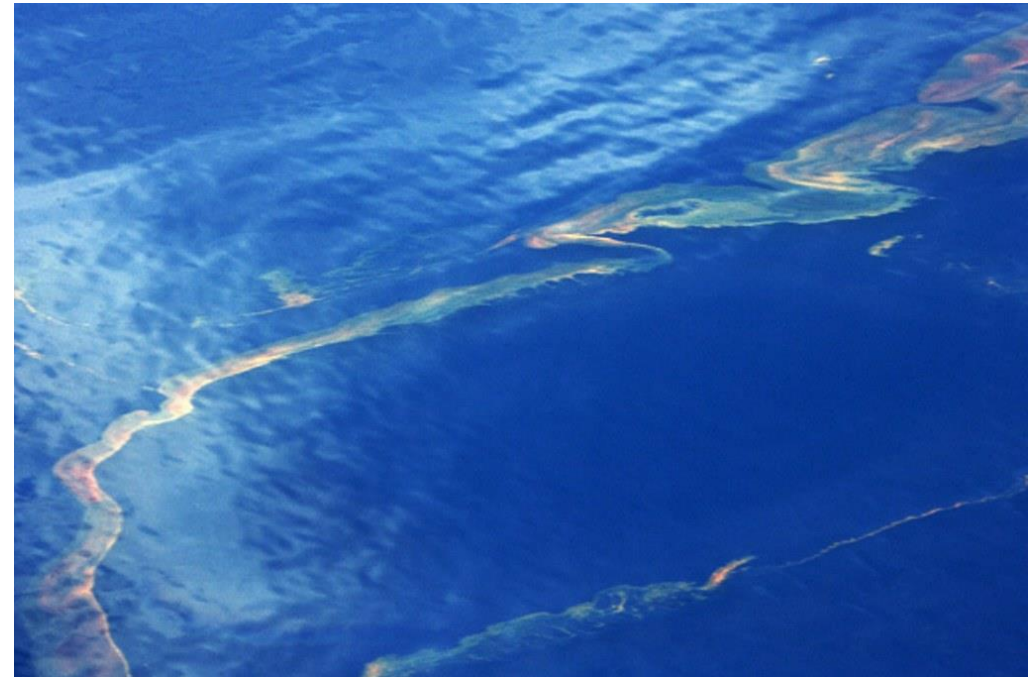


The
Guardian



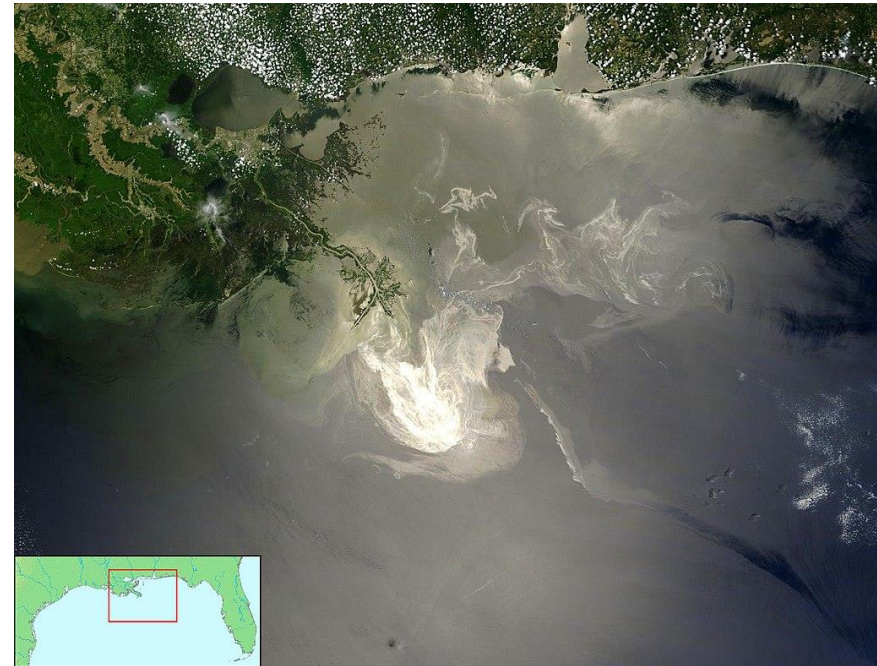
Accidents

- **Public and media attention**
 - Montara well blowout in 2009 in the Timor Sea off Australia



Accidents

- **Public and media attention**
 - BP Deepwater Horizon oil spill in 2010 in the Gulf of Mexico



The oil seen from space by NASA's
Terra satellite on 24 May 2010





Properties and weathering of spilled oil

- **Oil contains thousands of hydrocarbon molecules**
 - chemical structure, molecular weight, density, and ability to associate with either water or sediment.
- **Oil is composed of compounds of carbon and hydrogen atoms**
 - some arranged in long chains or rings, known as aromatic compounds
- **The mixture of hydrocarbons in oil range from smaller, volatile compounds monocyclic aromatic hydrocarbons [MAH] to very large, non-volatile compounds polycyclic aromatic hydrocarbons [PAH] (Fingas 2013).**
- **Both refined and unrefined oils contain a high proportion of highly toxic and carcinogenic compounds that include alkanes (paraffins), naphthenes (cycloalkanes), alkenes (olefins), dienes, alkynes, and benzenes**



Properties and weathering of spilled oil

- **Petroleum refers to a wide range of hydrocarbon-based materials and can vary intensely depending on the reservoir source**
- **All types of oil are distinct in varying degrees of chemical composition, corresponding weight and, prior to refining, concentration of heavy metals, sulfur and other volatile substances.**

The basic composition of petroleum

Carbon	84 to 87%
Hydrogen	11 to 14%
Sulfur	0.06 to 2%
Nitrogen	0.1 to 2%
Oxygen	0.1 to 0.2%
Metals	0 to 0.14%

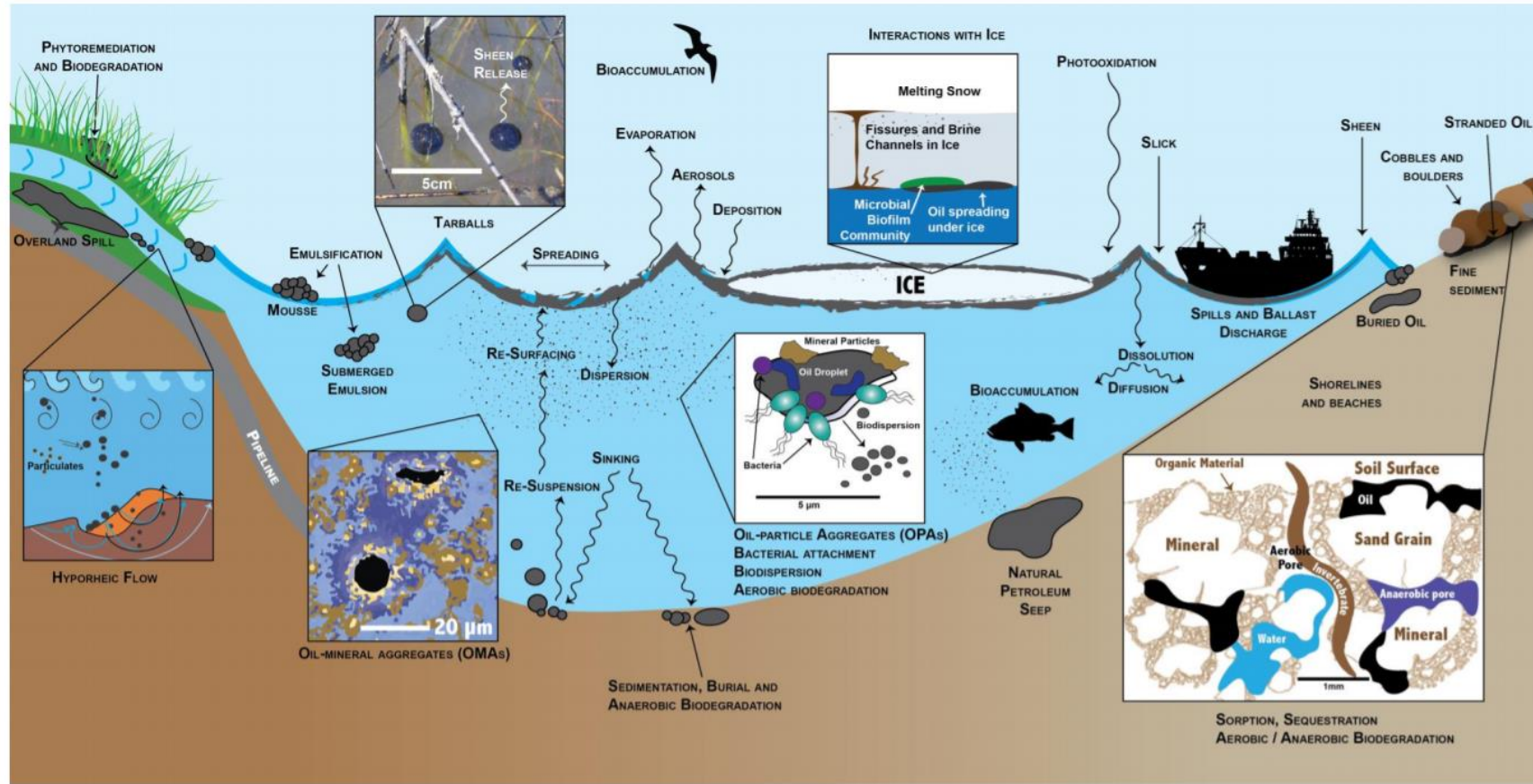


Properties and weathering of spilled oil

- **Different forms of oil**
 - Light crude
 - Heavy crude
- **Chemical composition of the oil reservoir dictate the effect that that the spilled oil will have on the environment (Gong et al., 2014).**
- **Chemical signature**
 - because understanding the chemical properties of petroleum materials released during an offshore oil spill is critical.
- **Chemistry of the material dictates the physical properties of that material**



Properties and weathering of spilled oil



Weathering



Oil pollution

- **Fate**

- When oil is spilled on sea it spreads over the surface to form a thin film – called oil slick
- Light oil spreads faster than heavy wax oil
- Low molecular weight fractions evaporate
- Water soluble components dissolve

Oil pollution

- **Fate**

- Non-water soluble components emulsify and forms a viscous mass – “chocolate mousse”
- Heavy residues form tar balls





Persistence and Bioavailability of Spilled Oil

- **Persistence of oil in the environment is strongly affected by habitat.**
- **Rocky shores exposed to wave action and other physical disturbances are generally less sensitive to oil**
- **Rocky shores**



Persistence and Bioavailability of Spilled Oil

- **Gravel dominated and sheltered beaches**
- **Small benthic organisms**

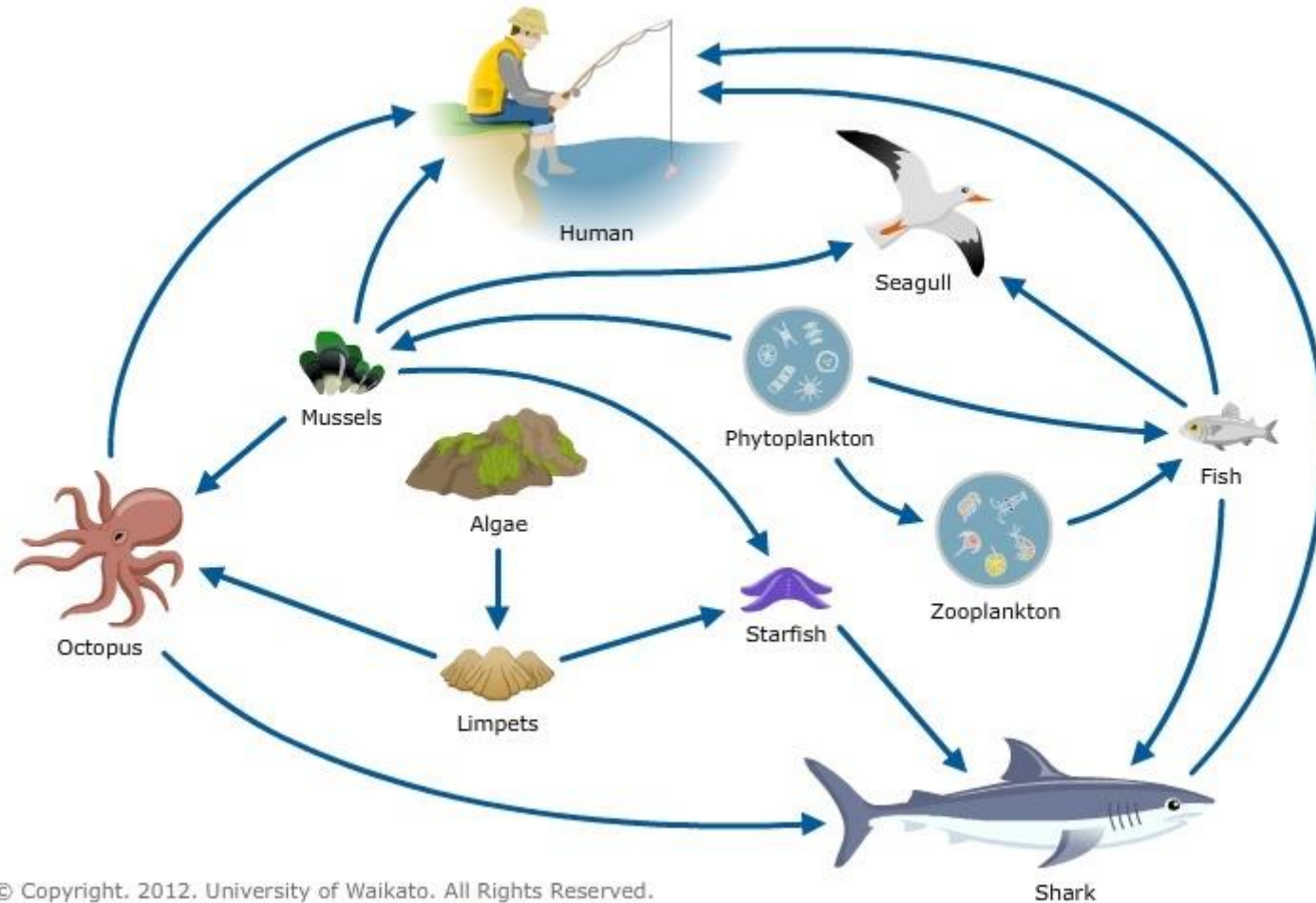


Persistence and Bioavailability of Spilled Oil

- **Bioaccumulation and biodegradation of oil in living organisms**
- **Generating different compounds**
- **Bioaccumulation occurs when fat-soluble hydrocarbons move directly across cell membranes**
- **Bioaccumulation in marine invertebrates depends on the type of oil released**



Persistence and Bioavailability of Spilled Oil





Oil pollution in exploration and production

- **Potential impacts on the environment depending on:**
 - the stage of the process,
 - the nature and sensitivity of the surrounding environment,
 - pollution prevention,
 - mitigation and control techniques (Trabbucco, 2012)
- **Two main categories of impacts on ecosystems:**
 - those resulting from the drilling and production infrastructures and associated waste;
 - those resulting from accidental or operational oil spills (Plan Bleu, 2014).

Environmental impacts of routine offshore hydrocarbon operations

• Exploration

- Seismic surveys
- Exploration drilling
- Pile cutting

➔ Noise



Noise abatement ...

... for sea creatures: Air bubble curtains with hoses from Continental reduce noise during the construction of offshore wind farms

Noise reduction: **up to 18 decibels**

Interior diameter of hose: **100 millimeters**

Hose weight for a length of 1,000 meters: **20 tonnes**

© Continental

Environmental impacts of routine offshore hydrocarbon operations

- **Construction and Extraction**
 - Oil spills and natural gas leaks can occur at various stages of hydrocarbon operations
 - Chemicals and oil and gas are released from the drilling muds and produced water.
 - Produced formation water is considered the largest source of pollution after spills.



More than 18 billion barrels of waste fluids are generated annually from oil and gas production in the United States (Oceana).



Environmental impacts of routine offshore hydrocarbon operations

• Construction and Extraction

- Drill cuttings discharged from drilling operations can contaminate sediments and surface waters, and their spatial impact can increase with water depth.
- Lead to biological effects, such as smothering and mortality of epibenthic species and ecological changes to the benthos. Damage to seabird feathers and result in mortality and reduced reproductive success..





Oil pollution in exploration and production

• Impacts

- Main problems are linked to the presence of the offshore structures and to waste streams

Table: Main pressures and impacts induced by offshore oil and gas extraction. Source: Plan Bleu 2014.

- ECOLOGICAL OBJECTIVES	PRESSURES / IMPACTS
	<i>Description</i>
Non - indigenous species	Associated shipping operations can cause biological disturbance due to potential introduction of non-indigenous species and translocation.
Contaminants 9.3 Acute pollution	Accidental oil spills impacts could be local in case of small or medium oil spill or relatively large in case of large accidental oil spill. Impacted ecosystem components are mainly seabirds, fishes (including exploited) shellfishes (including exploited), marine mammals and benthic species
Contaminants 9.1 Concentration of priority contaminants	Concentration of priority contaminants, especially due to release of polluted produced waters, inducing local impacts.
Noise	Offshore operations generates vibrations and noises especially during the seismic surveys required by the exploration phase



Secondary Effects

- **Regarding marine pollution, it should be noted that globally, only 9% of marine pollution from oil is attributable to offshore production (Lentz and Felleman, 2003).**
- **Will be discussed in the Mediterranean focus**

Impacts of Oil Spills on marine fauna

- **Fish**
- **Tetrapods vertebrates**
- **Crustaceans**
- **Mollusks**
- **Echinoderms**
- **Cnidarians**
- **Zooplanktons**

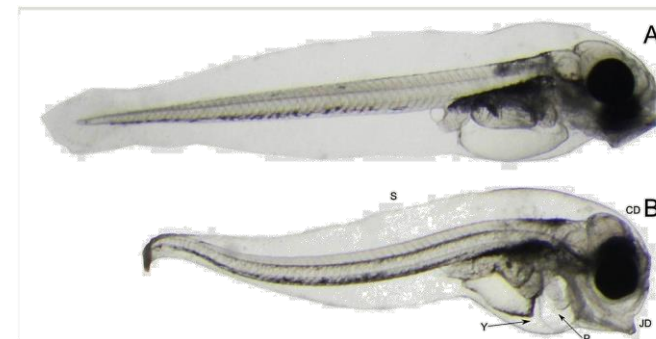




Impacts of Oil Spills on Vertebrates

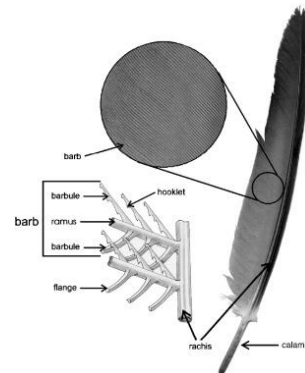
• Fish

- Increased mortality
- Damage to fish eggs and larvae
 - e.g., morphological deformities, reduced feeding and growth rates, increase vulnerability to predators and starvation
- This susceptibility is mainly manifested in the early stages
- Habitat degradation, loss of hatching ability of eggs, fouling of gill structures, impaired reproduction, growth, development, feeding, respiration...



Impacts of Oil Spills on Vertebrates

- **Tetrapod vertebrates (birds, mammals, turtles)**
 - Birds
 - Harm to the lungs, liver and kidney
 - Feather microstructure
 - Hypothermia
 - Death
 - Ulcerations,, hemolytic anemia, and aspergillosis.



Impacts of Oil Spills on Vertebrates

- **Tetrapod vertebrates (birds, mammals, turtles)**
 - Mammals and turtles
 - Mostly exposed to oil on the sea surface and shoreline causing eyes and adenoidal tissue damage low immunity, lung and adrenal diseases.
 - Sea otters, dolphins, whales and sea turtles are also tly affected by oil spills.
 - Deepwater horizon oil spill
 - Dolphins, sea turtles and whales with respiratory irritation, inflammation, pneumonia, gastrointestinal inflammation, ulcers, bleeding, diarrhea, and may cause damage to organs.
 - Furred mammals
 - Sea turtles



Impacts of Oil Spills on Vertebrates

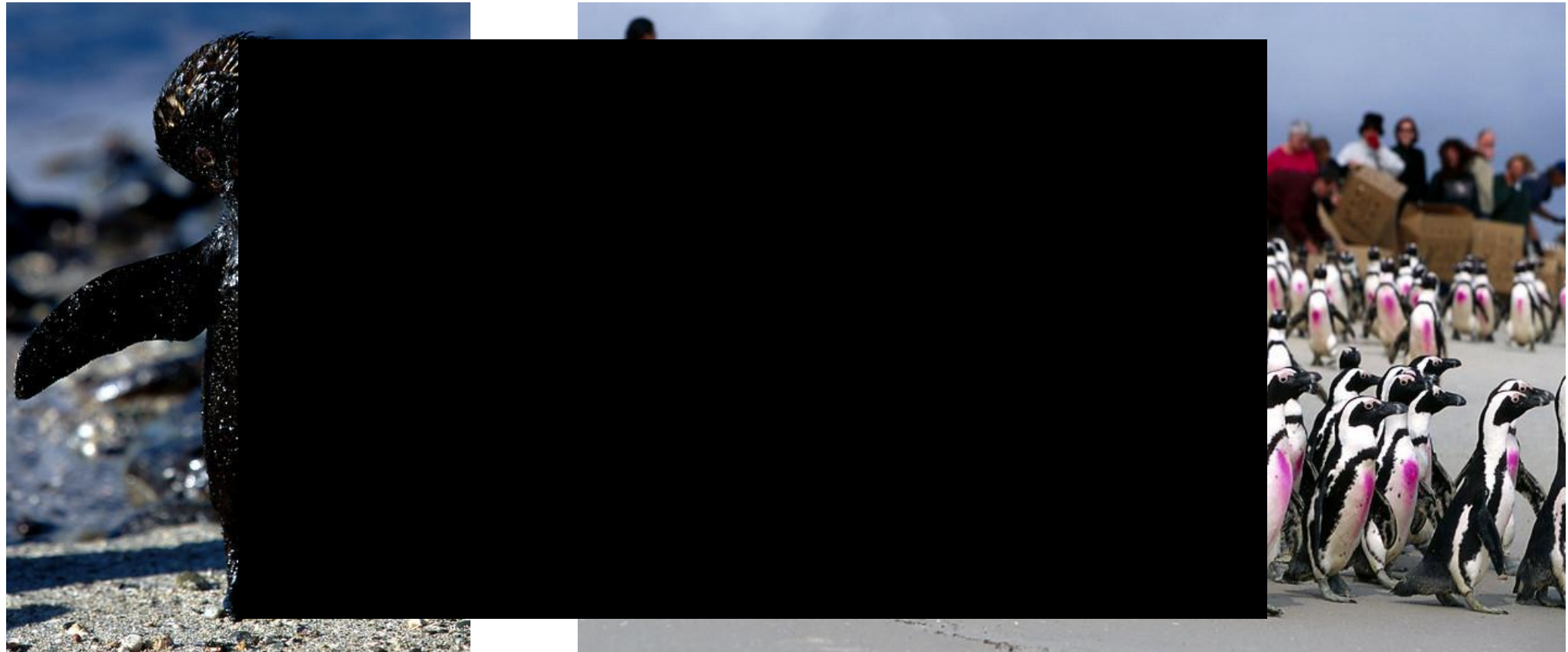
- **Case study**





Impacts of Oil Spills on Vertebrates

- **Case study**



Impacts of Oil Spills on Invertebrates

• Crustaceans

- Planktonic and benthic
- Crabs : coating on surfaces and body suffocating, feeding on oil polluted sediments
 - ensnaring and blockage of the gills, and low feeding
 - impaired physiology and behavior, interfering ecosystem roles
- Very sensitive, high mortality after oil spills



One of many contaminated crabs at the Deepwater Horizon site. (LUMCON)

Impacts of Oil Spills on Invertebrates

- **Crustaceans**

- Amphipods

- Mostly die off and exhibit a drastic change in population number when exposed to oil
 - Oil exposure impacts negatively on reproduction

High vulnerability due to their inability to move and distribute in their environment and their lack of planktonic larval stage.



Amoco Cadiz and coast of Brittany in 1978

Impacts of Oil Spills on Invertebrates

• Mollusks

- Most research has focused on bivalves and gastropods
- Gastropods on exposure to less toxic concentration of oil are known to experience impaired physiological function, behavior and ultimately death after long exposure



Amoco Cadiz and
coast of Brittany in
1978

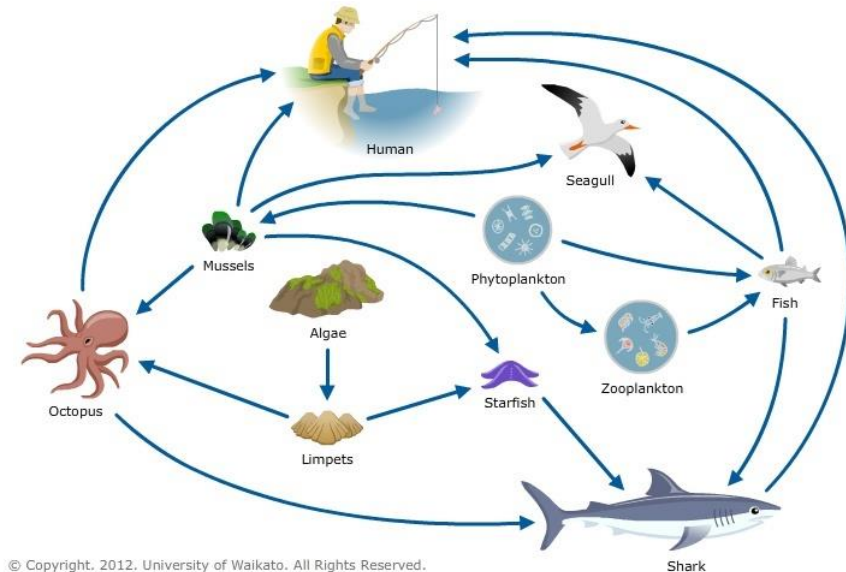


Impacts of Oil Spills on Invertebrates

• Mollusks

• Mussels

- Filter feeding accumulating oil through their gills
- Reduced cell and overall immunity, reduced development and nutrition, reduction in inhabitant groups, interference with their tolerance of air and DNA destruction.
- Affect also marine food webs



Impacts of Oil Spills on Invertebrates

- **Mollusks**

- *Mytilus trossulus* may have impacted sea otter



- **Oysters**

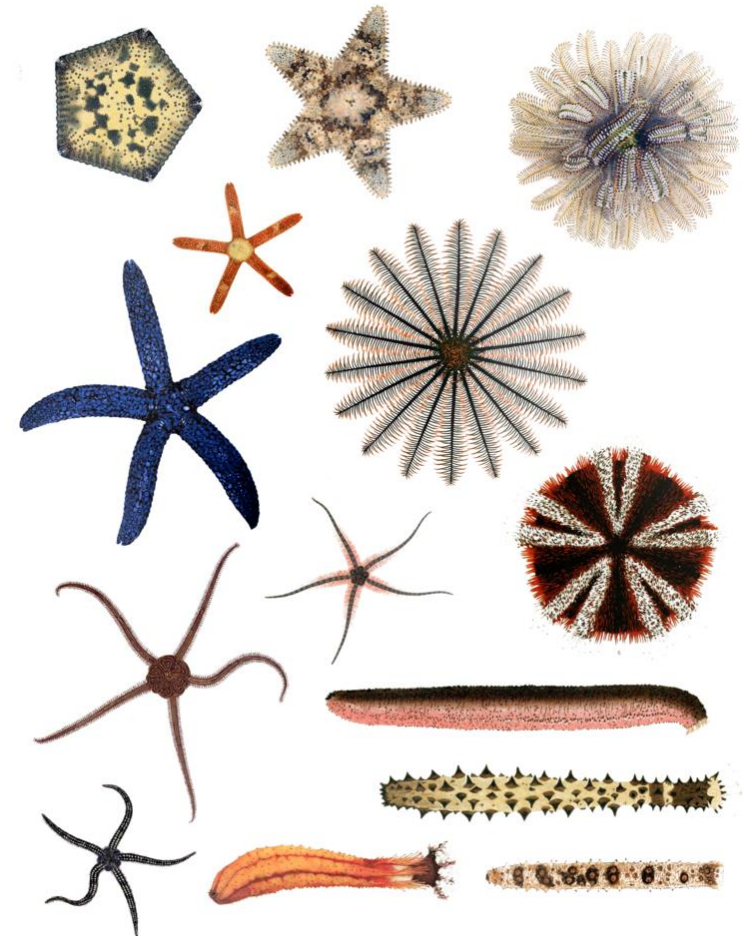
- Also accumulate oil constituent for long periods of time
- Impact on physiological functions (development, nutrition and reproduction).



Impacts of Oil Spills on Invertebrates

• Echinoderms

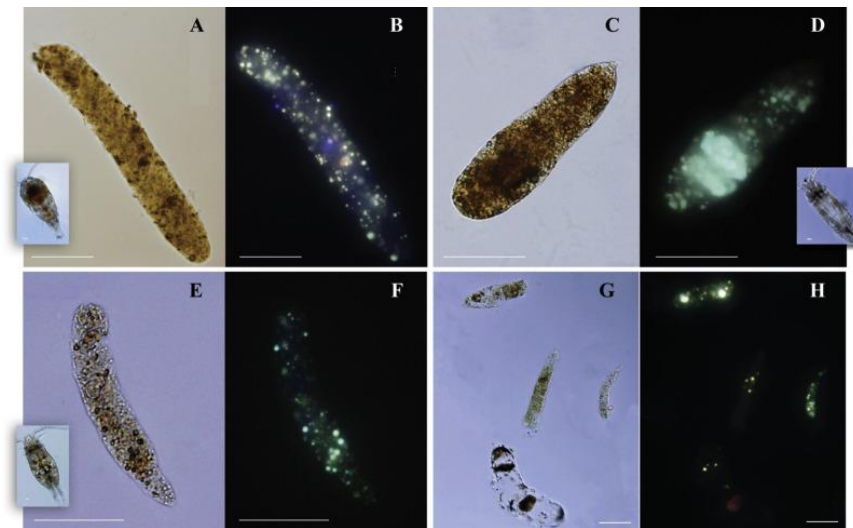
- 7000 species
- Sea urchin research discovered a constant reduction in population when exposed to oil
- Other impacts include interference with their physiological functions such as impaired movement, feeding, reproduction and behavior
- Sea stars also experience mortality and damaging effects on physiological functions



Impacts of Oil Spills on Invertebrates

• Zooplankton

- Subjected to liquefied droplets and floating oil
- Tend to be stranded in oil polluted waters
- Reduced physiological functions and mortality
- Planktonic larvae of invertebrate communities are more prone to oil spill impacts than their adult communities
 - Reduced physiological functions such as growth, egg production, nutrition





Impacts of Oil Spills on Invertebrates

- **Cnidarian**
 - Corals
 - chronic oil pollution on coral communities including impaired reproduction, larval development, and juvenile recruitment
 - Also negative impacts on coral regeneration, growth, and juvenile recruitment.



Oil slicks moving onto coral reefs at Galeta at low tide after the Bahia las Minas refinery spill, Panama, in April 1986. (NOAA)

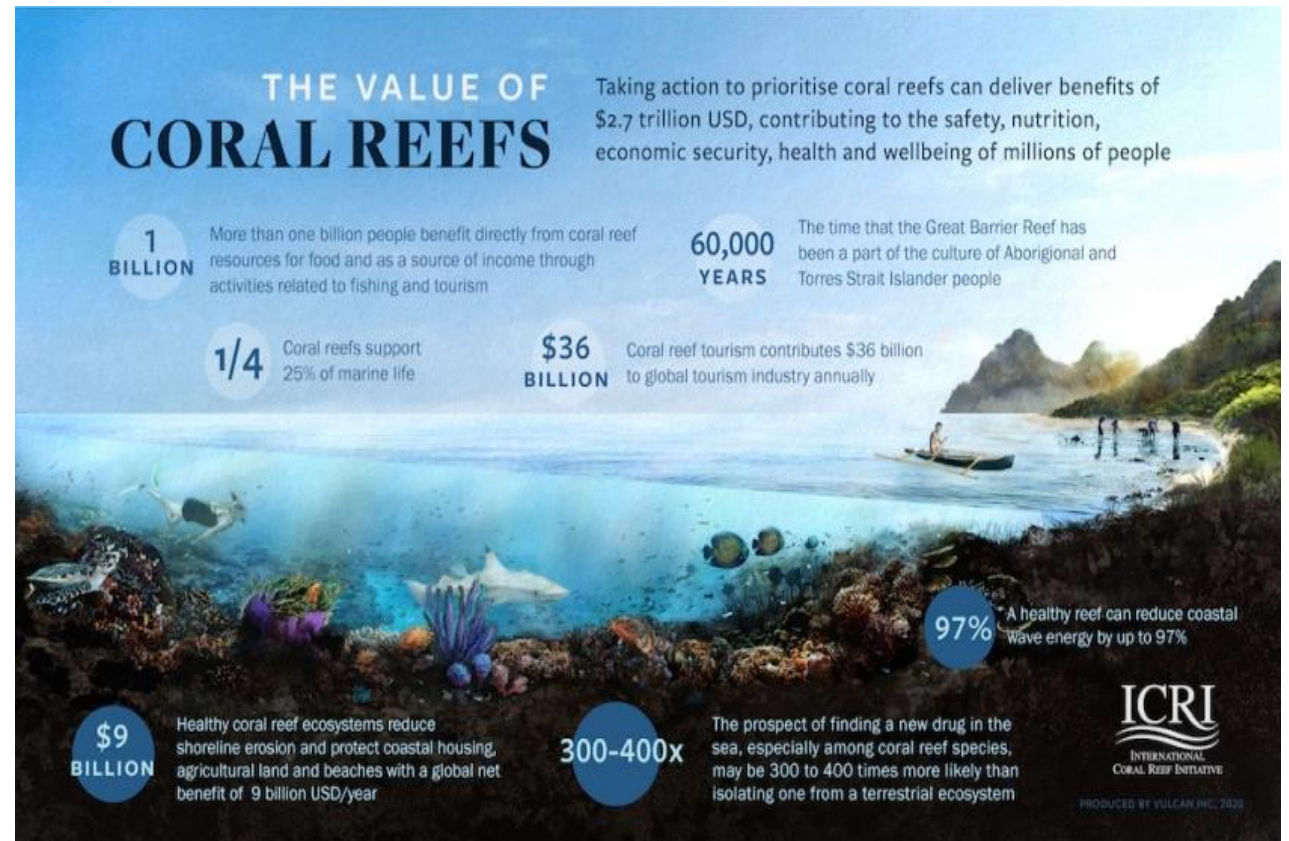


Impacts of Oil Spills on Invertebrates

- **Cnidarian**

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- chronic oil pollution on coral communities including impaired reproduction, larval development, and juvenile recruitment
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**What about human?
How are we impacted by oil spills?
What activities or sectors of the human communities
do you think are impacted by the release of oil into the
marine environment?**

Wooclap



Impacts of Oil Spills on Human communities

- **Impacts on Fisheries**
- **Impacts on Tourism**
- **Impacts on Policy and Regulations**
- **Human Health and Other Social Impacts**
- ...



Impacts of Oil Spills on Human communities

- **Impacts on Tourism**



The Exxon Valdez oil spill occurred in Prince William Sound, Alaska, on March 24, 1989,

Impacts of Oil Spills on Human communities

- **Impacts on Human Health**



2007 South Korea oil spill





Impacts of oil and gas activities on the marine environment (Part 2)

A Mediterranean focus

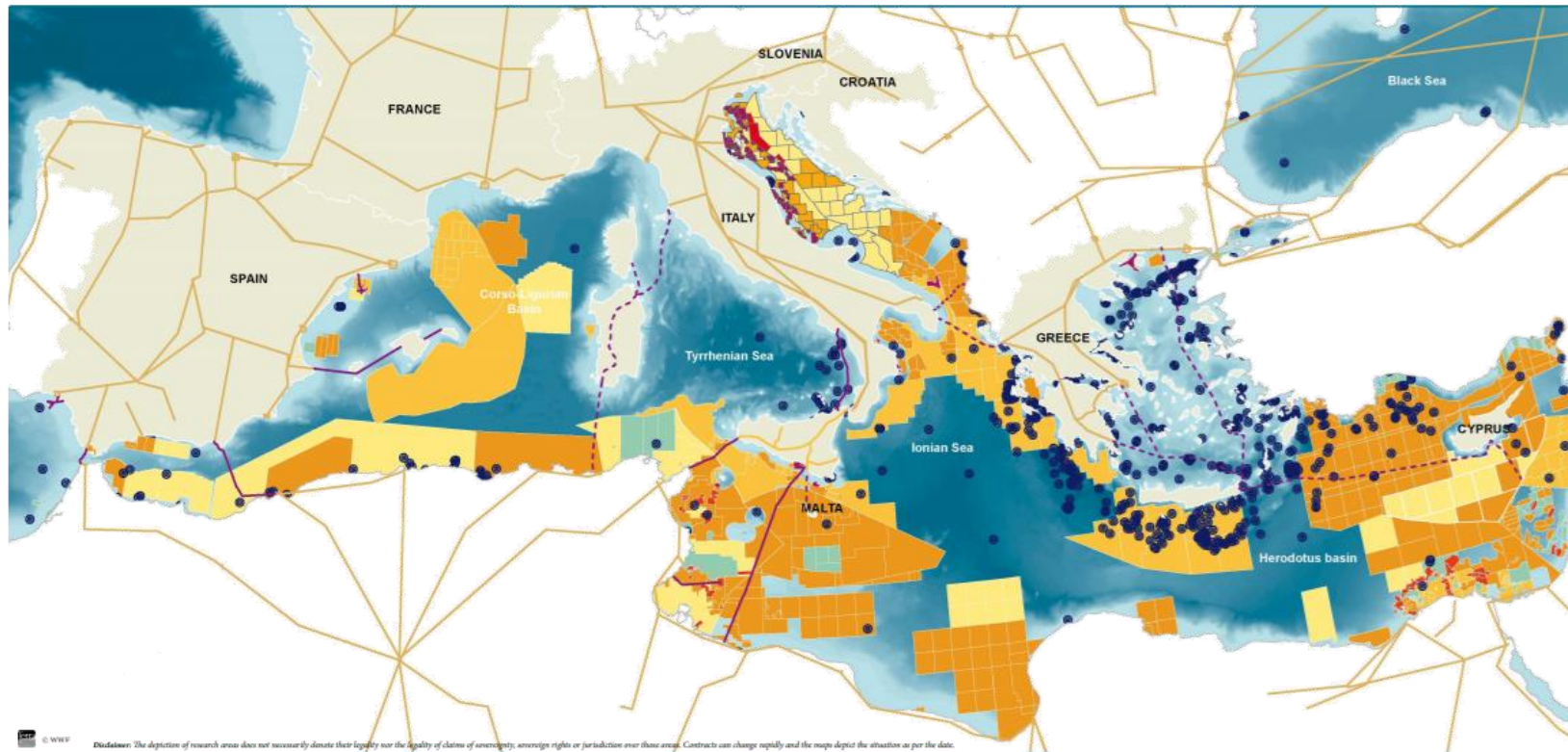


Oil and Gas Exploration and Production in the Mediterranean Sea

- **The Mediterranean, a centre of European civilization**
- **Hydrocarbon exploration activities started in Greece**



Oil and Gas Exploration and Production in the Mediterranean Sea



© WWF
 Disclaimer: The depiction of research areas does not necessarily denote their legality nor the validity of claims of sovereignty, sovereign rights or jurisdiction over those areas. Contracts can change rapidly and the maps depict the situation as per the date.

Figure 7. Map of seismic events of magnitude > 4 overlapped with oil and gas contracts map

Scale: 0 200 400 km

OIL AND GAS CONTRACTS

- OPEN AREA
- EXPLORATION AREA
- PRODUCTION AREA
- BIDBLOCK AREA
- DEVELOPMENT AREA
- RELINQUISHED AREA

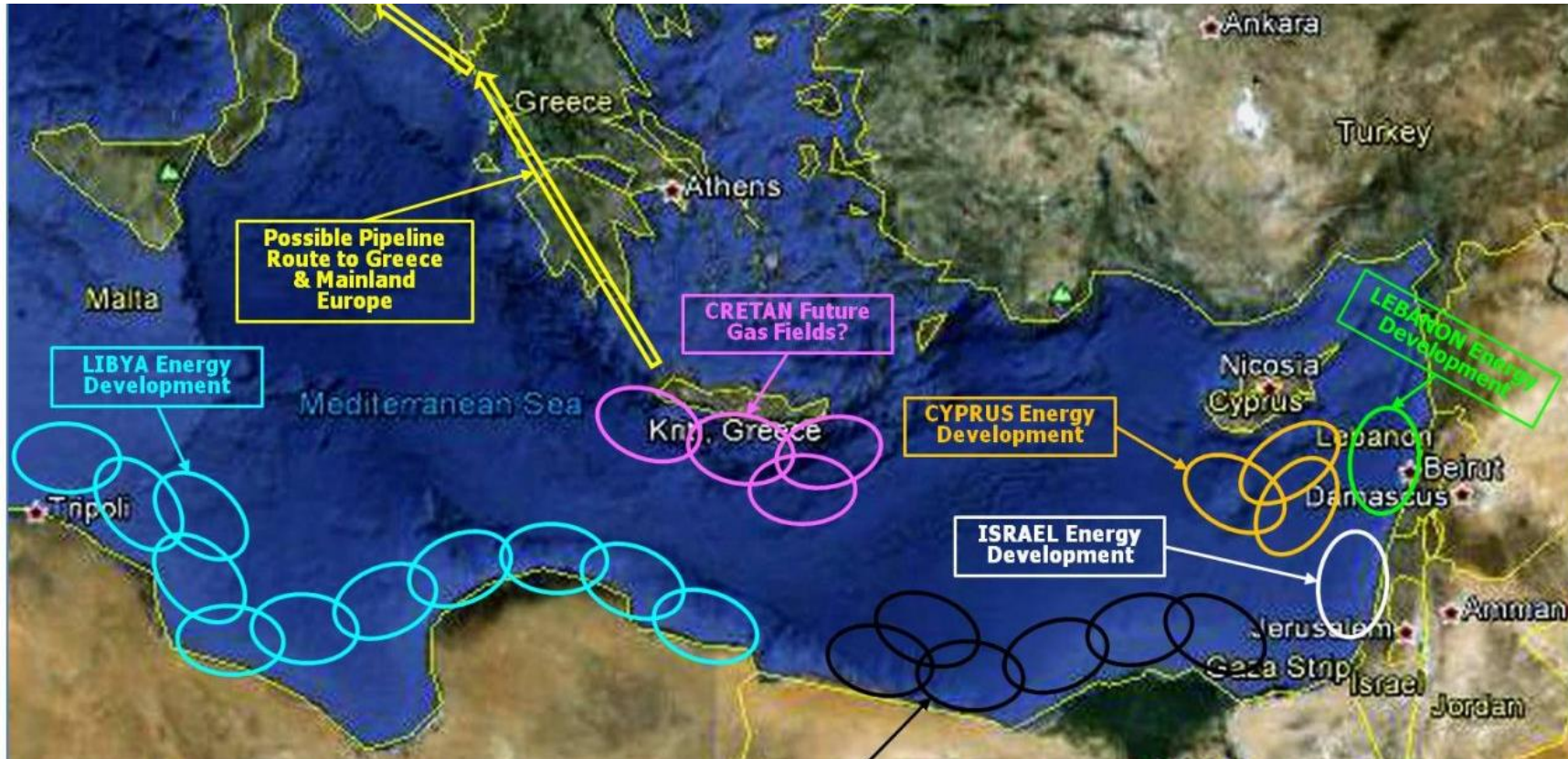
NATURAL GAS INFRASTRUCTURES

- MARINE GAS PIPELINE - ACTIVE
- MARINE GAS PIPELINE - PROJECT
- TERRESTRIAL GAS PIPELINE

● SEISMIC EVENT SINCE 2006 (MAGNITUDE > 4)
 Source: Orfeus (2014)

Sources: DrillingInfo (April 2015)
 National sources collected by WWF (2015) | drillinginfo.com
 Source: WorldMap (2014)

Oil and Gas Exploration and Production in the Mediterranean Sea



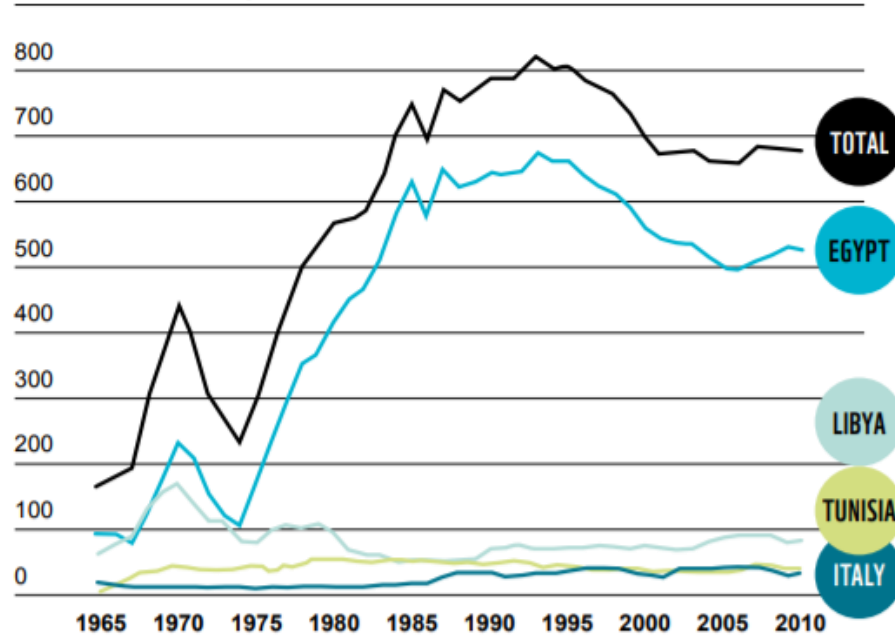
Oil and gas exploration and exploitation activities in the Eastern Mediterranean.

Source: 2012 Pytheas Limited

Oil and Gas Exploration and Production in the Mediterranean Sea

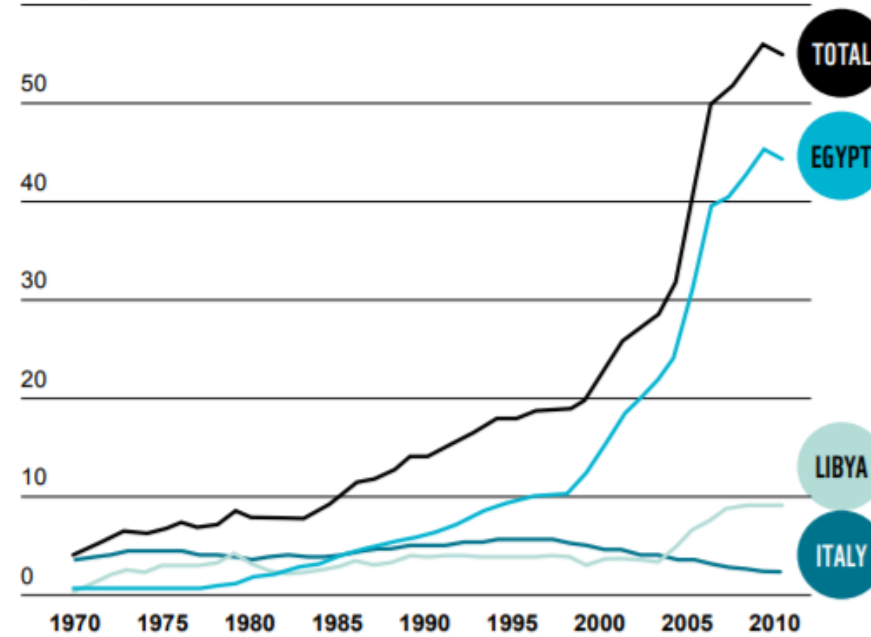
OFFSHORE OIL PRODUCTION

thousand of barrels/day

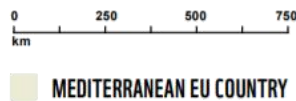
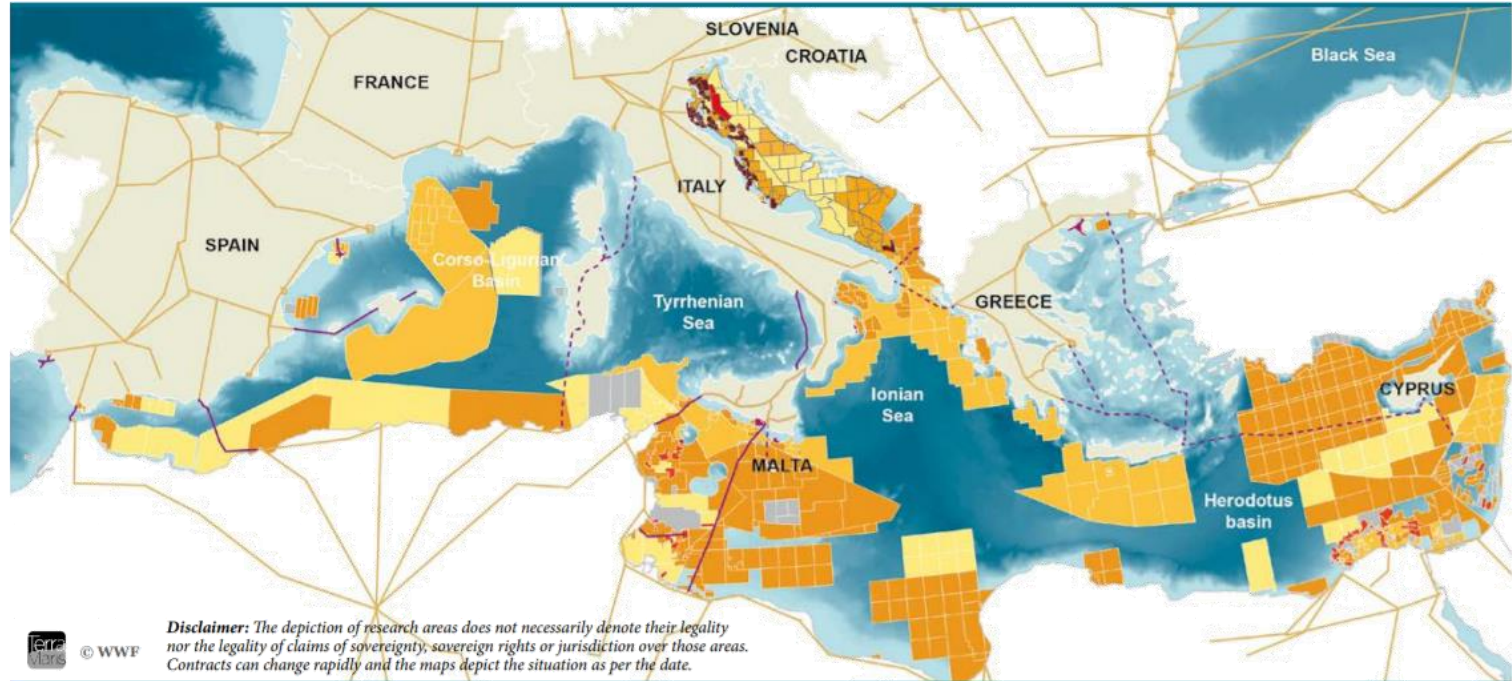


GAS PRODUCTION

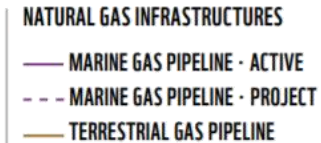
Mtoe/year



Future trends



Sources: DrillingInfo (april 2015)
National sources collected by WWF (2015)



Source: WorldMap (2014)

Focus on Montenegro

- **Oil and gas exploration activity in Montenegro took place from 1949 to 1966, when the state-owned company Nafta Crne Gored drilled 16 onshore exploration wells.**
- **In March 2017, Energean signed a concession agreement with the State of Montenegro for the exploration and exploitation of hydrocarbons in offshore blocks 4219-26 and 4218-30**



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



Oil pollution sources in the Med

- **Overall oil pollution in the Mediterranean comes from 5 sources:**
 - Accidental spills on the land, from storage tanks, road/rail/pipeline accidents, acts of war or vandalism, where oil is carried to the sea by rivers.
 - Oil spills from pipelines around the Mediterranean do occur
 - Ships and coastal storage accidents or acts of war, releasing a large quantity of oil in a particular place.
 - Operational spills from shipping: take place weekly as an overall average (up to daily on some heavily concentrated traffic routes)
 - Natural seeps on the sea bed: there is some evidence of natural spills occurring in some places, with oil and gas seeping from underground reservoirs.



**Match the sources with their estimated total input of
oils to the world ocean**

Wooclap



Sources of Oil Pollution in the Mediterranean Sea

- **The Global Marine Oil Pollution Information Gateway shows shares of oil pollution from another two reports.**
- **The Australian Petroleum Production and Exploration Association (APPEA) claims the following distribution of the inputs from different sources:**
 - Land-based sources (urban runoff and discharges from industry): 37%
 - Natural seeps: 7%
 - The oil industry–tanker accidents and offshore oil extraction: 14%
 - Operational discharges from ships not within the oil industry: 33%
 - Airborne hydrocarbons: 9%



Oil pollution

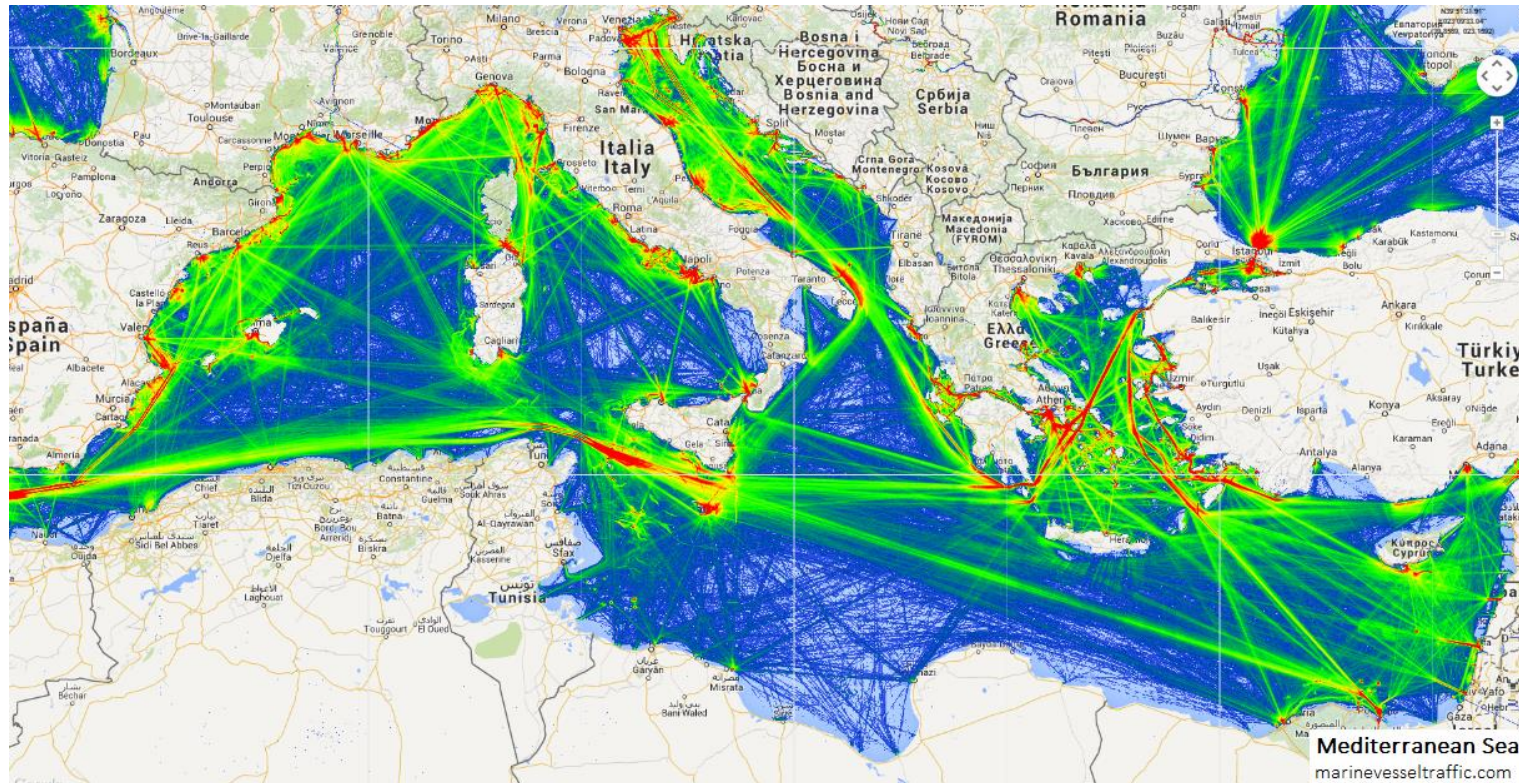
- **Shipping**

- The diversity of shipping in the region includes fishing fleets, ro-ro ferries, pleasure boats, military vessels, large container ships, bulk carriers and tankers, as well as fixed "ships" including offshore oil exploration and exploitation vessels.
- REMPEC (The Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea) report
 - 325,000 voyages in the Mediterranean Sea in 2007 and 2013 (two thirds of them were internal to the Mediterranean).



Oil pollution

- Shipping



Density map of ship traffic in the Mediterranean Sea
(<http://www.marinevesseltraffic.com/MEDITERRANEAN-SEA/ship-traffic-tracker>)



Oil pollution

- **Shipping**
 - Operation of motorboat generates oil
 - Special tanks
 - Pumped to a storage tank harbour
 - Released at sea
 - Lack of adequate reception facilities
 - Pollution perception by sailors



Oil pollution

• Shipping

- Operational oil spills can be voluntary or not, resulting from a human decision, a human error or a technical failure.
- Legal in high seas
- Collisions
- Natural factors such as storms
- Oceano report (2000s): the total amount of crude oil passing through EU waters could be over one billion tonnes.
- Accidental spills
- The Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (AGESAMP): 200 accidental spills from ships annually in the region.



Oil pollution

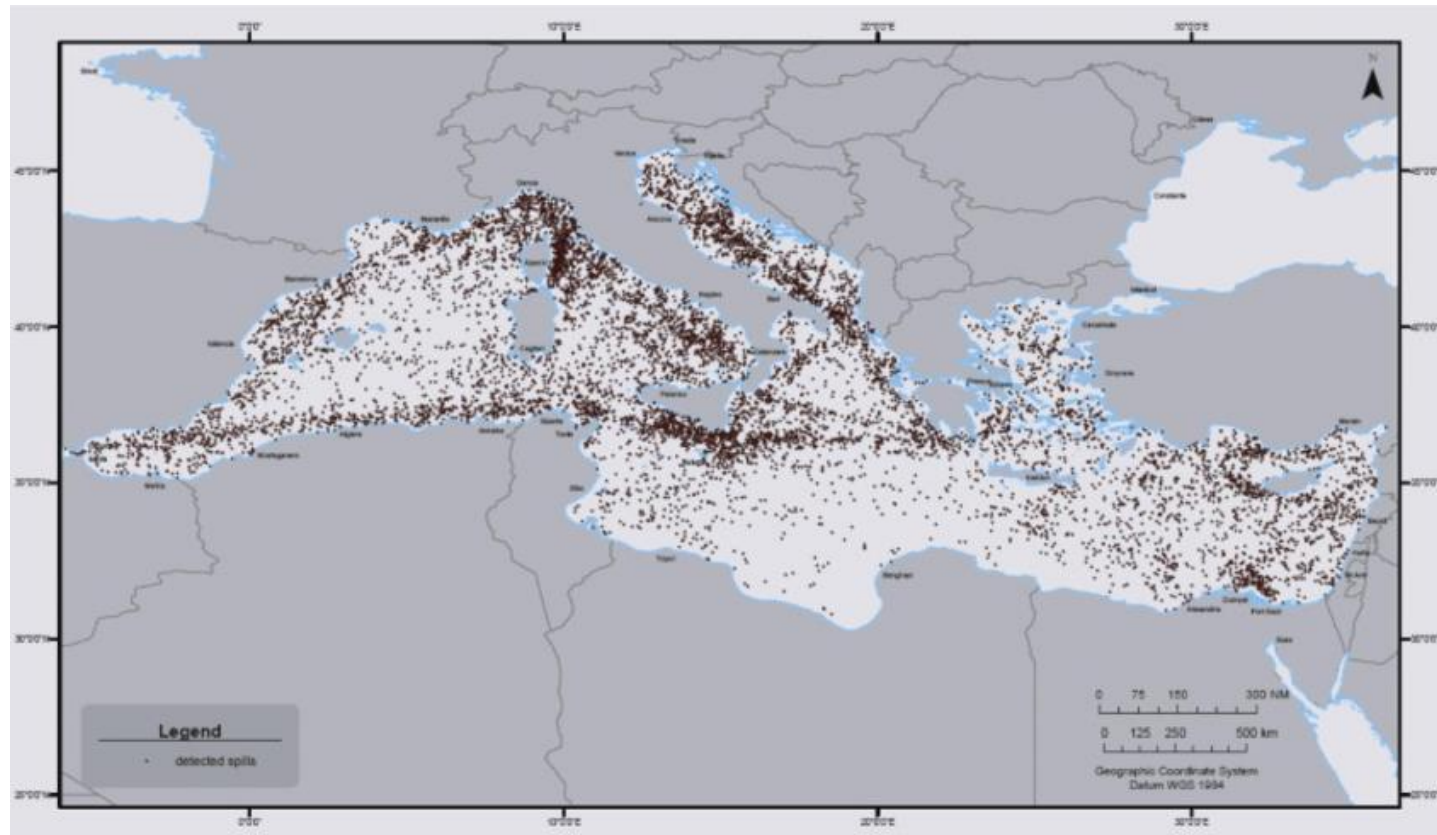
- **Shipping**

- EMSA's reports on pollution preparedness and response for the years 2011-2013 mention that between February and December 2011, some 2,143 satellite SAR images were acquired, showing 2,048 possible oil spills detected.
- These numbers can not be totally representatives since the temporal and spatial coverage of the Mediterranean incomplete.



Oil pollution

- **Shipping**



Oil spill in the Mediterranean sea. Possible oil spills detected in the Mediterranean sea between the 1999 and the 2004. (Courtesy of European Commission, Joint Research Centre).



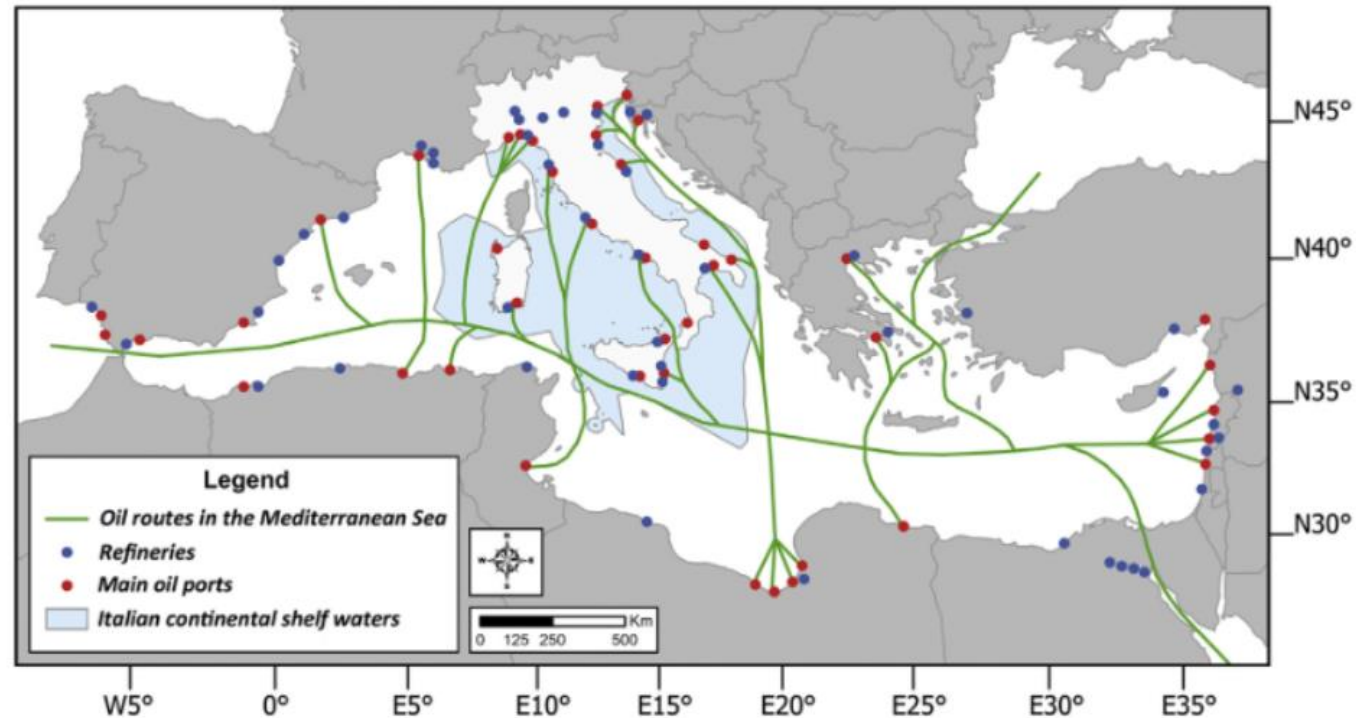
Oil pollution

• Ports and Oil terminals

- The Mediterranean has about 150 coastal cities and ports of various sizes.
- In 2006, crude oil loaded in Mediterranean ports amounted to 220 million tons. The top 20 Mediterranean crude oil loading ports, as measured by number of calls, accounted for 99% of all crude oil loaded in the Mediterranean.
- The top 5 crude oil loading ports are Sidi Kerir in Egypt (74,339,769 tons), Arzew in Algeria (40,240,000 tons), Ras Lanuf in Libya (14,065,500 tons), Es Sider Term in Libya (14,640,000 tons), Marsa el Brega in Libya (6,136,000 tons).
- The total volume of crude oil unloaded in Mediterranean ports in 2006 amounted to 255 million tons.

Oil pollution

- **Ports and Oil terminals**
 - All ports and oil terminals present a potential danger of oil pollution.



Map of the handling of oil in the Mediterranean Sea (main routes, refineries and main oil ports)



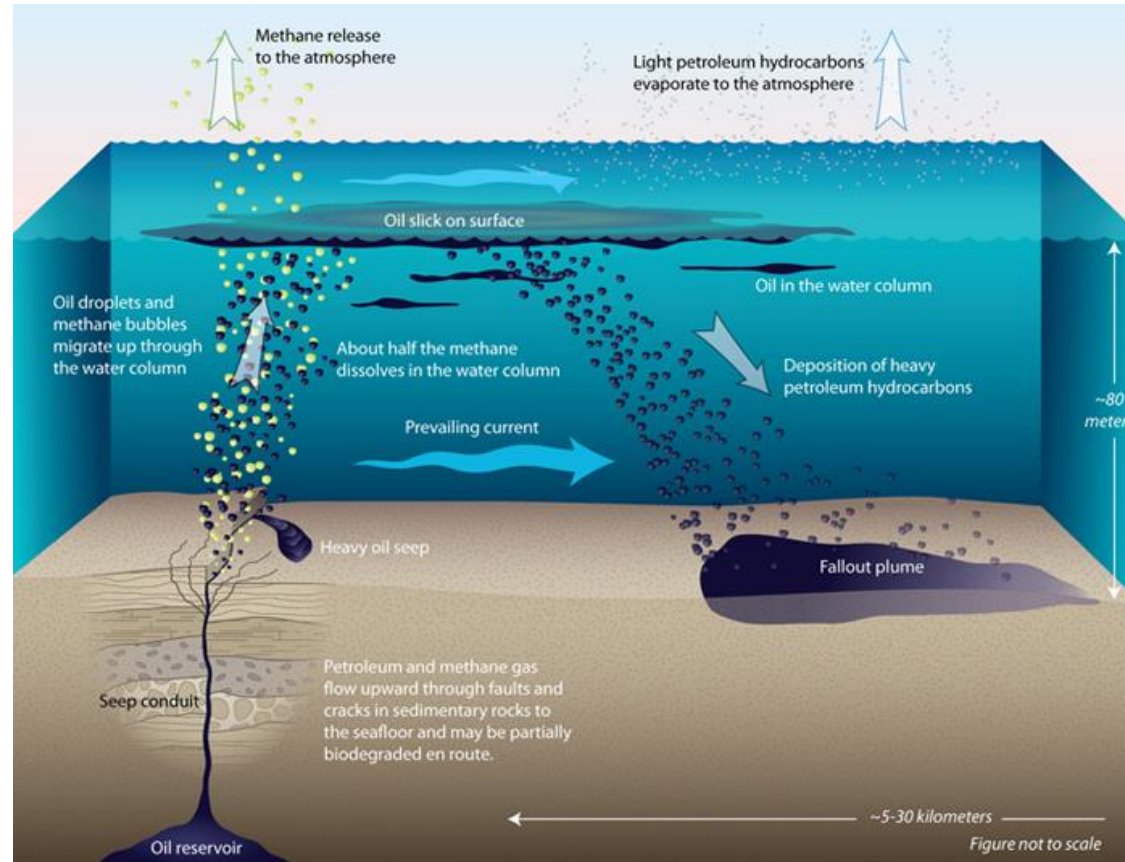
Oil pollution

- **Land-based sources**
 - Land-based sources include
 - discharges of oil with rivers and floods
 - discharges of untreated or insufficiently treated municipal sewage and storm water
 - discharges of untreated or insufficiently treated wastewater from coastal industries
 - accidental or operational discharges of oil from coastal refineries, oil storage facilities, oil terminals and reception facilities
 - emissions of gaseous hydrocarbons from oil-handling onshore facilities and from vehicles exhausts



Oil pollution

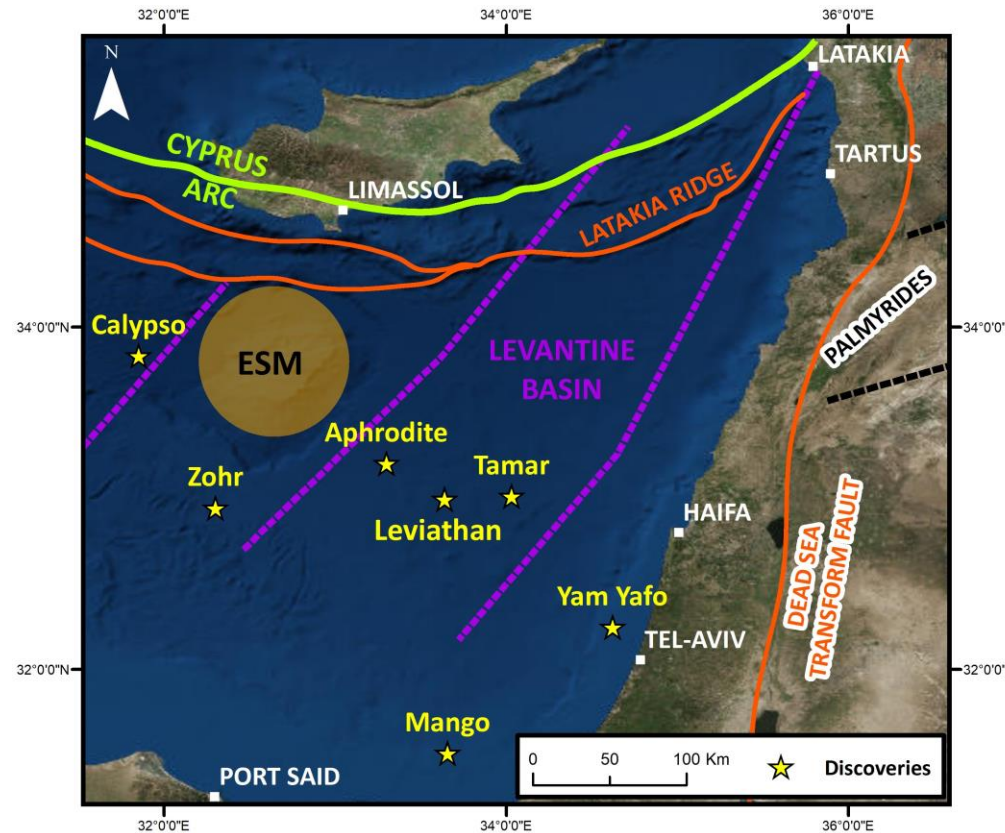
- **Natural Oil Seeps**





Oil pollution

- Natural Oil Seeps



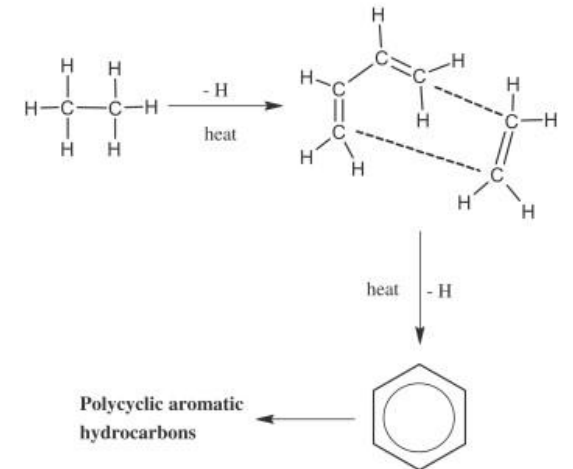
Levantine Basin, Eratosthenes Seamount (ESM) and discoveries.



Oil pollution

• Atmosphere

- Hydrocarbons enter the ocean not merely as "wet" oil products but also as gaseous air pollutants.
- Hydrocarbons from vapours deriving from the loading and unloading of oil at different stages from extraction to consumption
- Polycyclic aromatic hydrocarbons (PAHs) from incomplete combustion





How much oil?

- **Estimated volumes of oil vary widely. For example:**

- The Barcelona Convention – Mediterranean 2017 Quality Status Report indicates that between 1 Jan. 1994 and 31 Jan. 2013, approx. 32,000 tonnes of oil entered the Mediterranean Sea as a result of accidents (UNEP-MAP 2017 a, b).
- A much higher estimate by UNESCO estimates that oil pollution in the Mediterranean Sea is as much as 400,000–1,000,000 tonnes a year. Of this about 50% comes from routine ship operations and the remaining 50% comes from land-based sources via surface runoff (UNESCO, 2013).
- BUT other estimates suggest volumes around 15,000 tonnes/year (Cucco and Daniel, 2018) or perhaps 63,360 tonnes/year (Girin and Daniel, 2018).
- The actual volume of oil entering the Mediterranean Sea annually is unknown, particularly when also taking into account land-based, atmospheric and natural seep sources.



How many spills?

- **EMSA Pollution Preparedness and Response Reports for 2011 to 2013 identify that, between Feb. and Dec. 2011, 2,143 satellite SAR images were acquired showing 2,048 possible oil spills detected (EMSA 2012, 2013).**
 - 749 were identified as Class A – most probably oil (mineral or vegetable/fish oil); 1,299 as Class B – less probably oil.
 - BUT these numbers do not fully represent the real state of oil pollution in the Mediterranean Sea because the number of processed satellite images varied from 3 to 454 per year per country in 2007-2010



Oil pollution in the Med – Main impacts

- **Impacts**

- Enclosed nature
- Direct impacts could include:
 - Death of a wide variety of marine species;
 - Behavioural disturbances, including changes in feeding, reproduction and migration;
 - Airborne emissions of chemicals from controlled burns;
 - Microbial blooms;
 - Hypoxia – lowering of oxygen concentrations in water;
 - Toxic effects of chemicals used to disperse oil.



Conclusion

- **Effects depend on parameters governing the oil and the oil itself**
- **Effects – Impairment of marine life**
 - Loss of sensitive marine habitats – loss of flora and fauna
 - Death of fish eggs and larvae
 - Mortality of fish, reduction in catch
 - Plankton, esp. neuston at highest risk – exposed to water soluble components leaching from oil
 - Sea birds –buoyancy and thermal insulation lost
- **Commercial damage**
- **Tourism – becomes nuisance – loss of revenue**
- **The social and economic impacts of offshore oil spills require further study to develop a more complete picture of how affected communities suffer from spills**



Open Questions:

What are the most important oil pollution in your country/region?

What about national plans and legal instruments ?



THANK YOU

