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Emerging conservation challenges and prospects in an era of offshore oil and natural gas discoveries

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Abstract

Globally, extensive marine areas important for biodiversity conservation and ecosystem functioning are undergoing rapid exploitation of oil and natural gas resources, expanding to previously inaccessible deeper waters and other frontier regions. Marine fossil fuel operations hold massive economic value. Here, we outline conservation challenges and prospects resulting from the marine hydrocarbon industry, providing past and current examples from areas such as the Gulf of Mexico, the Mediterranean and elsewhere. We propose that the conservation science community should quickly respond to the surge in the offshore hydrocarbon industry. A prompt response may mitigate impacts of future decisions and actions of the industry and governments, potentially alleviating risks to marine biodiversity, including the understudied deep-sea. This response should consider how to leverage opportunities and reduce risks resulting from ongoing and planned hydrocarbon operations towards more effective biodiversity conservation, legislation and science. Recent environmental decision support tools can help explicitly incorporate threats to biodiversity, allowing better trade offs among multiple conservation objectives, risks and costs.

Emerging and current offshore hydrocarbon operations

The majority of undiscovered hydrocarbon reserves and unexploited fossil fuels outside the Middle East are located in deep sea offshore deposits in waters as far deep as 4,000 meters (Ahlbrandt et al. 2003). While the vast depths of many of these deposits have previously prevented commercial exploitation, recent technological advances now enable the oil and natural gas industry to venture into increasingly deeper waters and other new frontiers (IEA 2013; Pinder 2001; Merrie et al. 2014). Since 2009, a third of the global oil production and a fourth of natural gas production originated from offshore platforms (Maddahi & Mortazavi 2011). This proportion is expected to increase (IEA 2013). In fact, offshore areas provided nearly 70% of the major oil and gas discoveries worldwide in the first decade of the 21st century (Sandrea & Sandrea 2010). Deep-water capital expenditure is expected to grow by ~130% between 2014 and 2018 compared to the preceding five-year period, totaling $260 billion globally (Rangi 2014). While steps are being taken to encourage alternative renewable energy sources, there are strong financial incentives to search for marine oil and gas and to lease large marine regions.

The environmental threats posed by offshore oil and natural gas operations draw much public and media attention. This is especially evident following major oil spills, such as the 2009 Montara well blow-out in the Timor Sea off Australia and the 2010 BP Deepwater Horizon oil spill in the Gulf of Mexico (where over 150 million gallons spilled from a depth of ~1500 m over 87 days, polluting vast marine areas, including beaches and wetlands; Norse & Amos 2010; Montagna et al. 2013; Fisher et al. 2014). Earlier spills, such as the 1989 *Exxon Valdez* tanker accident in the Gulf of Alaska and the extensive oil spills during the 1990-1991 Persian Gulf War (~240 million gallons; Etkin 1999), also drew wide public attention (~11 million gallons spilled). These well-publicized spills, however, comprise just a portion of the environmental risks and impacts on marine and coastal ecosystems from oil and gas exploration, development, production, transport and abandonment (Fig. 1).

Nevertheless, the impacts of deep-sea offshore activities on biodiversity remain understudied and our knowledge is often based on relatively few locations (e.g., Smith et al. 2008). Research gaps in deep-sea ecosystems (below 500 m) are significant (Barbier et al. 2014, Danovaro et al. 2014, Jobstvogt et al. 2014, Levin et al. 2014, Mengerink et al. 2014), albeit with important exceptions, such as research on the hydrocarbon-seep chemosynthetic communities in the Gulf of Mexico (Cordes et al. 2009; Fisher et al. 2007; MacDonald et al. 1989). Major research and practice gaps also exist regarding the governance and management of the deep sea, as well as related socio-economic factors (van den Hove & Moreau 2007, Barbier et al. 2014). Ecological restoration in the deep sea remains understudied, and is expected to cost at least 2-3 orders of magnitude more than the restoration of shallow marine systems (Van Dover et al. 2014). While research in these realms is technically complex and costly, these knowledge gaps require attention if we are to understand the responses of deep-sea communities to oil and gas operations and plan accordingly (Barbier et al. 2014; Fisher et al. 2014; Mengerink et al. 2014).

Offshore hydrocarbon operations: challenges for conservation

The environmental impacts of routine offshore hydrocarbon exploitation activities include a wide range of potential risks and impacts on biodiversity and ecosystems in marine and coastal systems. These can occur at the exploration, development, production, transport or well-abandonment phases. Each threat must be explicitly accounted for in future marine conservation plans and decisions. We present the phases of marine hydrocarbon operations, with examples of associated conservation challenges.

Exploration

During exploration, marine environments that previously had minimal human impact become exposed to a range of activities, such as seismic surveys (Gordon et al. 2003; Richardson & Würsig 1997), exploration drilling and associated cutting piles (Benn et al. 2010). Exploration drillings are a risky part of the operations and major accidents, such as the 2010 BP Gulf of Mexico disaster (see below), have occurred during this phase. Noise caused by seismic operations can lead to stress, evasive and stranding behavior in marine mammals, turtles, fish and cephalopods (Fewtrell & McCauley 2012; McCauley et al. 2000; McCauley et al. 2003). Various technological advances aim to address these threats, such as the use of bubble curtains for noise reduction (Kuo & Fulton 2013). The UK's Joint Nature Conservation Committee (JNCC) guidelines for minimizing acoustic disturbance of marine mammals by the oil and gas industry's seismic surveys provide a basis for other international noise pollution mitigation measures during seismic surveys (http://jncc.defra.gov.uk/pdf/JNCC_Guidelines_Seismic%20Guidelines_Aug%202010.pdf).

Construction, extraction and transport: Oil spills and gas leaks

Oil spills and natural gas leaks occur at various stages of the operations. Chemicals and oil are routinely discharged during the drilling and production stages from drilling muds and produced water and can be collocated with oil and, to a lesser extent, with gas. Produced formation water (water associated with oil in the reservoir) is considered the largest pollution source after accidents, and the total volume discharged annually has been estimated at 7500–11,500 tons (Holdway 2002). Cuttings released during drilling operations are normally considered a local effect, restricted to a zone within 100 m of the discharge (Neff 2010), yet can contaminate sediments and surface waters and their spatial impact can increase with water depth. This may, in turn, lead to biological effects, such as smothering and mortality of epibenthic species and ecological changes to the benthos (Ellis et al. 2012). Oil sheens from currently admissible concentrations of hydrocarbons on the water surface have been shown to damage seabird feathers (O'Hara & Morandin 2010), leading to mortality and reduction in breeding success (Wiese et al. 2001).

Large oil spills are a major threat to biodiversity and a range of studies have examined their impacts (e.g., Kingston 2002; Mendelssohn et al. 2012; White et al. 2012; Barron 2012). Spills affect many marine species and can have long-term consequences for coastal habitats (Peterson et al., 2003), impacting areas far from the spill source, with oil being carried by winds and sea currents (e.g., Goldman et al. 2014). In 2000, oil released from the sinking tanker *MV Treasure* near Robben and Dassen Islands of the South African Cape affected >17,000 endemic and endangered African penguins (*Spheniscus demersus*), leading to a costly international rescue effort estimated at US$100 for each successfully treated released bird (Whittington, 2003; BirdLife International 2013). Biodiversity impacts include mortality following an oil spill event (e.g., ~250,000 seabird deaths from the 1989 Exxon Valdex oil spill) and chronic exposure to sediment pollution can also impact natural populations for years following the event (Peterson et al. 2003). Current oil-spill models are insufficient and too little is known about the ecological and socioeconomic impacts of spills to fully support accurate risk assessments for many marine habitats and species (Peterson et al. 2012).

The 2010 BP/Deepwater Horizon Oil and Gas Disaster

The 2010 BP/Deepwater Horizon oil spill and gas disaster in the Gulf of Mexico persisted for months and affected biodiversity throughout the water column. It negatively impacted marine animals, plants (Barron 2012), deep-water coral assemblages (Fisher et al. 2014), deep-water ecosystems, and coastal habitats (beaches, marshes, wetlands, estuaries; Mendelssohn et al. 2012; White et al. 2012; Montagna et al. 2013). Since knowledge of deep-ocean ecosystems in the Gulf was limited at the time of the spill, there was limited baseline information for measuring impacts and building real time restoration plans (Norse & Amos 2010). Indeed, company-reported incidents (such as blowouts, fires, injuries, pollution) tend to increase with offshore platform water depth (Muehlenbachs et al. 2013). Deep-water drilling is technological challenging and associated failures can be complex to fix (National Commission 2011). The well drilled at the time of the BP/Deepwater Horizon disaster began at 1,600 m depth. One of the deepest offshore well operations currently in progress starts at ca 2,900 m (Shell Oil's Gulf of Mexico Stones), and drilling operations are reaching for greater depths, requiring the development of additional safety indicators for all operation phases (Skogdalen et al. 2011).

The recovery of degraded marine ecosystems from vast oil spills may occur naturally over time or may require active restoration efforts. While parts of the system may recover within years (Kingston 2002), more complete recovery may take decades (Borja et al. 2010) or longer. Subsurface oil from the *Exxon Valdez* tanker spill, for example, persisted for at least 16 years (Peterson et al. 2003; Short et al. 2007). Recovery rates in the deep sea may be on the scale of centuries based on the slow rates of metabolic activity, growth and reproduction found there (Montagna et al. 2013).

Secondary effects

Gas and oil operations also have multiple secondary effects. Gas leaks from drilling operations over the lifecycle of a well have been estimated to account for 1.7–7.9% (Howarth et al. 2011) of greenhouse gas methane (CH_4) emissions to the atmosphere globally (Alvarez et al. 2012; Tollefson 2012). They can potentially create anoxic zones in the ocean (Alvarez et al. 2012; EPA 2010). Installation structures and seabed pipelines, shipping traffic and transportation associated with the hydrocarbon industry present pathways for invasive species by ballast water, biofouling organisms, sediment transfer and the creation of stepping stones for alien species along linear infrastructure developments (Rivas et al. 2010). Some of these pathways are being dealt with in international treaties and regulations (e.g., the Ballast Water Management Convention, adopted by the International Maritime Organization in 2004).

New infrastructure within the marine environment also poses challenges for marine conservation planning. Linear features that run perpendicular to the shore into deep waters (e.g., pipelines), can be difficult to plan and zone around. The risks that these pipelines (buried or unburied) pose to biodiversity are largely understudied and deserve further attention. Offshore operations are also associated with new infrastructure on land (e.g., transportation, storage and refinement; O'Rourke & Connolly 2003), potentially impacting to coastal and terrestrial ecosystems. The risks of deserted wells to marine and coastal ecosystems and their implications for conservation are another relatively understudied topic (Jackson, 2014). These indirect impacts require further specialized conservation research.

Gas hydrates as a future issue

In addition to oil and gas, natural gas hydrates represent a hydrocarbon that will likely be further exploited in the near future. Methane hydrate is a highly concentrated, naturally-occurring frozen compound, which is formed when water and methane combine at moderate pressure and relatively low temperature conditions (Ruppel, 2011). It is estimated that gas hydrates (onshore and offshore) comprise about half of the world's organic carbon sources (Collet et al., 2009). Present mapping of gas hydrates reveals that they exist along the ocean margins worldwide, and projects are being led by the hydrocarbon industry to develop new technologies that will allow economical production in the future (Collet et al., 2009; Ruppel, 2011; Ruppel et al., 2011). While such production of gas hydrates has not yet begun, it represents a challenge and a potential threat that is yet to be understood (Sloan, 2003). Indeed, concern about the destabilization of methane hydrates due to increases in the temperature of bottom waters can also enhance global warming and cause widespread regional ocean deoxygenation (Sutherland et al., 2012).

Hydrocarbons, international conflict potential and conservation

Oil and gas discoveries motivate countries to focus attention on frontier areas. Operations are expanding rapidly into sensitive and unique marine habitats, such as the Arctic, West Africa, and the enclosed Mediterranean Sea (Fig. 2; SI 1, 2). Discoveries of exploitable hydrocarbon reservoirs have motivated some nations to declare their exclusive economic zones and extend their continental shelf claims (see Table 1 for definitions). This recent momentum can be observed, for example, in South Africa (Sink and Attwood, 2008) and the Eastern Mediterranean (see SI 1). However, in spite of the fact that fossil fuel operations are already underway, most Mediterranean countries have not yet declared their EEZ (Fig. 2a, SI 1; see also Katsanevakis et al. 2015).

Hydrocarbon discoveries in deep waters can be a catalyst for international conflicts and boundary disputes (Naylor 2011; Khadduri 2012). Cross-boundary coordination (Kark et al. 2009, 2015) is required in order to help develop joint conservation and/or management plans aiming to minimize large-scale negative impacts of hydrocarbon operations on biodiversity (Mazor et al. 2013, 2014) in deep waters, particularly in areas beyond national jurisdiction (Mengerink et al., 2014). This is particularly challenging where long-lasting economic and/or political disputes occur (Levin et al. 2013). Interestingly, maritime jurisdiction interests can also incentivize countries to establish large marine protected areas so as to assert their ownership of the area, as in the case of the Chagos (De Santo et al. 2011).

Legal and political framework

Countries experienced with the offshore hydrocarbon industry (e.g., OSPAR Convention members in Europe, USA, Australia) have put in place laws and regulations aimed at reducing the industry's likelihood of harming ecosystems and susceptible biodiversity (OSPAR 2009). However, even in these nations, the regulations, technology and practices related to containing and cleaning up spills are lagging behind the risks associated with deep-water drilling (National Commission, 2011). Deep sea enforcement and monitoring are often inadequate (UNEP 2007) and a significant number of environmental statements fall short of "satisfactory quality" (Barker and Jones, 2013). In many cases, specific hydrocarbon operation legalisation is absent, particularly in areas such as High Seas (Table 1), where governance and regulations are lacking (Van Dover 2011). According to the World Bank, the majority of developing countries have limited environmental regulations and where they exist, they are often not effectively enforced (Alba 2010). This is especially relevant in regions where political strife and security threats focus attention. Ecological concerns are too rarely the top priority of governments, including some OECD (Organization for Economic Cooperation and Development) countries, where one could expect rigorous standards to be enforced.

Politics continue playing a major role in the future of marine conservation in areas beyond territorial waters. The key players that have sovereignty in the oceans directly, through international conventions or regulatory bodies, are nations. However, this responsibility is complex. While countries are primarily those responsible for conservation, governments face many other immediate pressures other than conservation (Korngold 2014). Maritime boundaries are often determined by politics rather than ecological factors and their jurisdiction is often incompatible with the scale of the conservation challenges faced. Furthermore, most leaders are not in office long enough to establish, implement or take ownership of ecosystem management issues that may require longer-term planning (Korngold 2014).

Deep-sea drilling often takes place in areas beyond territorial waters (Table 1), which are not fully covered by standard national environmental regulations or monitoring programs. As proposed by Barbier *et al*. (2014) and Gobin and Gustavo da Fonseca (2014), coordination between the multiple organizations and initiatives aimed at regulating activities such as oil, gas, shipping, fishing and trawling should be a priority for managing environmental threats in areas beyond national jurisdiction. This could be done under international environmental law and the UN Convention on the Law of the Sea (UNCLOS; Table 1) to provide better oceans governance (Gobin and da Fonseca 2014) and instruments such as binding dispute-resolution mechanisms (Boyle 1999). As such, UNCLOS and other international agreements constitute an important pillar in nations' obligation to protect the marine environment. However, just as other constitutions, UNCLOS and the CBD (Table 1) need to be concretized and implemented (via national laws, regional protection systems or by empowering of international organization). Regional treaties (e.g., the Barcelona Convention of the Mediterranean and OSPAR: the Oslo and Paris Conventions for the Protection of the Marine Environment of the North-East Atlantic) further elaborate on the nations' responsibilities to protect the marine realm. However, not all countries have yet established the necessary laws and regulations to comply with these international treaties.

Multinational extractive companies often work across international boundaries and markets, must respond to global stakeholders, and must consider time horizons as long as 40-50 years in order to recoup their investment. As such, global corporations with their international scope, resources, marketplace incentives and global workforces (Korngold 2014), can play a key role in the success or failure of cross-boundary management plans for protecting marine biodiversity. Corporate self-interests should align with at least some of the strategies required to tackle the very environmental problems brought about by their own industry. They share with the conservation community the aim of avoiding disasters, while motivations for doing so may be quite different. This may lead to successful joint initiatives (see examples in S3), and can potentially be leveraged by the conservation community early in the policy-shaping and operation-planning process.

What are the emerging prospects that could be leveraged for conservation?

With mounting offshore operations, including in deep-waters (Ramirez-Llodra et al. 2011), conservation scientists and practitioners need to urgently consider the possible prospects that could be leveraged for conservation.

Environmental research and marine oil and gas extraction

As marine hydrocarbon exploration is speedily progressing, there is need to clearly map threatened deep-sea ecosystems for which major basic knowledge gaps currently exist (Davies et al. 2007; Ramirez-Llodra et al. 2010). Because conservation resources are limited, a lag occurs between the start of hydrocarbon exploration and attaining the much-needed scientific information required for conservation planning and actions. Deep-ocean research involves costly technological inventions and operational challenges required to reach the vast three-dimensional extent of this system (Danovaro et al. 2014; Ban et al. 2014; Barbier et al. 2014). Facilities for deep/ultra-deep industry operations should be further leveraged to provide an in-situ scientific base for deep-sea conservation research and monitoring by supporting and allowing scientists access to data, infrastructure and equipment that will advance deep-sea environmental and conservation research.

Recent years have seen discoveries in deep-sea ecology via technological advancements such as submersibles, the development of remotely operated underwater vehicles (ROVs), fiber optic communications, new imaging tools, novel molecular technologies, sensors and *in situ* technologies (Danovaro et al. 2014, Barbier et al. 2014). Discoveries made possible with such advancements indicate that the deep-sea harbors many diversified assemblages (Snelgrove & Smith 2002) and provides unique refuge habitats such as canyons, seamounts, cold-seeps and hydrothermal vents for a range of marine species, such as cold-water corals, fish (Ramirez-Llodra et al. 2010) cephalopods (e.g., giant *Architeuthis* squid; Landman et al. 2004 and octopuses (Boyle & Daly 2000; Voight 2000) and many more. Research suggests that deep-sea ecosystems are critical for global ocean functioning (Danovaro et al. 2008; Loreau 2008; Cerrano et al. 2010). Recent efforts are being undertaken to fill knowledge gaps (Danovaro et al. 2014), including the Census of Marine Life and EU projects (HERMIONE, HERMES), aiming to understand how deep-sea biodiversity supports ecosystem functioning.

The deep sea encompasses one the most extensive ecosystems globally and represents the largest biomass reservoir (Danovaro et al. 2008; http://www.eu-hermione.net/science/slopes-and-basins). While most marine species remain undescribed (Costello et al. 2010) increasing knowledge is uncovering deep-sea habitats with complex geosphere-biosphere and ecological interactions, highlighting the importance of chemosynthetic production in fueling biodiversity (Danovaro et al. 2014). Such findings challenge previous paradigms of the deep sea as being food-poor and metabolically inactive, suggesting the deep-sea is an important component in global carbon cycles (Danovaro et al. 2014). Biodiversity loss in deep-sea ecosystems may lead to an exponential reduction of deep-sea ecosystem functioning (Danovaro et al. 2008), affecting mutualistic interactions (Loreau 2008).

De facto no take zones, conservation monitoring and enforcement efforts

Existing and planned offshore hydrocarbon facilities could be leveraged against other biodiversity threats by exclusion (e.g., restriction of fishing and commercial shipping activities from the vicinity of drilling platforms). The International Maritime Organization (IMO 2013) suggests a safety zone of 500 m around drilling platforms and safety distances can be larger where security is an issue. If such areas are managed in collaboration with conservation authorities and distances are increased, off-limits zones could present opportunities for larval recruitment and increased biomass, as has been demonstrated for no-take marine protected areas (Lester et al., 2009). Offshore platforms may locally enhance recruitment and reproduction of rare or endangered species beneficial for some fish species (Consoli et al. 2013), algae and corals (e.g., *Lophelia pertusa* growing on oil platforms in the North Sea and Gulf of Mexico; Davies et al. 2007). However, offshore platforms may also attract invasive alien species, and once invasives are present on offshore platforms, there are additional management and policy consequences at the decommissioning stage of these platforms (Page et al., 2006).

Due to the chronic and potentially catastrophic environmental impacts associated with offshore hydrocarbon operations, governments should consider collecting funds from the industry to be designated specifically for conservation activities (Armstrong, 2014). For example, the impact of platforms should be further examined, potentially by establishing independent research grant schemes. Potential contribution of the industry to biodiversity/ecosystems monitoring should also be considered (see SI 3).

Increasing awareness for large-scale marine conservation and spatial planning

Concerns about the impacts of marine oil and gas operations can incentivize marine spatial planning initiatives and conservation efforts. For example, establishment of the Australian Great Barrier Reef (GBR) Marine Park Authority (1975) was partly driven over concerns about oil drilling (Ruckelshaus et al. 2008). In 1994, a long-term strategic plan for managing and preserving the GBR

World Heritage Area was established (Fernandes et al. 2005), with a new long-term Sustainability Plan published in 2015 (http://www.canberraiq.com.au/downloads/2015-1-19-1.pdf). While the GBR provides one of the largest and most exemplary conservation zoning plans globally (Agardy 2010), it too faces major challenges related to the hydrocarbon industry, such as oil spills (e.g., the 2010 spill from the bulk coal carrier MV Shen Neng 1), and threats from a wide range of ports, shipping, current and planned dredging activities and the dumping of dredge spoil (excess material) within and near the Marine Park (Grech et al. 2013).

Collaboration conflicts and opportunities

Conservationists are often reluctant to collaborate with gas and oil enterprises; however such collaboration is not rare and has been developed in various cases (Flemming & McCall 2000), as detailed in SI 3. Mutually beneficial agreements can be reached with the relevant factors weighted and taken into account. For example, the Energy and Biodiversity Initiative (EBI) was formed by energy companies (BP, ChevronTexaco, Shell, Statoil) and conservation organizations (Conservation International, The Nature Conservation, Fauna & Flora International, Smithsonian Institute, IUCN), aiming to develop and promote biodiversity conservation practices, and operated between 2001-2007. The partnership has produced practical guidelines, tools and models aimed to improve the environmental performance of energy operations, minimize harm to biodiversity, and create opportunities for conservation where oil and gas resources are developed (Tully 2004; SI 3).

It has long been recognized that partnerships formed between governments and the industry can enhance oil spill response. Efforts have been put in place over the past 25 years to enable cross-boundary response. The International Convention on Oil Pollution Preparedness, Response and Co-operation (1990) defines avenues for collaboration between national authorities and the oil and shipping industries to unify response efforts (Moller et al. 2003). The global initiative, launched in 1996, provides an oil spill preparedness and response programme for cooperation between governments and the industry. It is implemented by the International Maritime Organization, a UN specialized agency and IPIECA (International Petroleum Industry Environmental Conservation Association; Taylor et al. 2011). In 2013, the Arctic Council (Canada, Denmark, Finland, Iceland, Norway, Russia, Sweden, US) signed an agreement on Cooperation on Marine Oil Pollution Preparedness and Response in the Arctic (http://www.arctic-council.org/eppr/agreement-on-cooperation-on-marine-oil-pollution-preparedness-and-response-in-the-arctic/). Such emerging platforms can potentially provide an important space for conservationists to become involved and advance actions emphasizing conservation needs and goals.

Legislation changes drivers

In places where the marine hydrocarbon industry is new and fast progressing, there should be a strong driver for public discussion that can prompt further action by legislators and regulators in a conservation context. The magnitude of damage from several recent oil spills should increase both scientific and public discussion in regions that until now were far from public attention. Subjects such as deep-sea operations, high seas/open sea marine conservation strategies and protected areas, cross-boundary marine parks, the need to update laws and regulations to cover ecosystem risks that the industry poses, corporate responsibility issues, and the potential to include conservation plans and actions in hydrocarbon operations should become a greater part of conservation science discourse.

In the case of frontier activities (e.g., deep-sea drilling), anachronistic legislation, along with spatial jurisdiction ambiguity, may result in “regulatory capture”, with regulatory agencies favoring the hydrocarbon industry at the expense of environmental protection, precaution or conservation (Portman 2014). The conservation community and scientists therefore have an important role in explicitly raising the conservation agenda at early stages in discussion tables, taking part in shaping plans and eventually conservation outcomes of actions (or inactions) in the deep-sea.

The natural gas industry is sometimes supported by environmentalists arguing that it provides efficient and less polluting natural gas substitutes to other fossil fuels (e.g., coal) (Gagnon et al. 2002). In the marine environment, liquid petroleum seeps usually have a longer-term presence than gas seeps as gases are more quickly assimilated into the surrounding water or more rapidly lost to the atmosphere (Kvenvolden & Cooper 2003). Marine transport of liquefied natural gas is expected to be safer as its leakage from ships is less probable (Pitblado et al. 2005). Nevertheless, while offshore natural gas reserves may be environmentally compelling compared with oil, they too pose challenges for conservation. Methane leaks during production are larger than previously known, contributing to greenhouse gas emissions (Alvarez et al. 2012; Tollefson 2012). Therefore, further discussion within the conservation community around the relative impacts of different energy sources is important.

Conservation prioritization in the face of emerging threats

Micheli et al. (2013) examined the spatial overlap between conservation priority areas as defined in multiple conservation schemes proposed for the Mediterranean Sea (Fig. 2d). Only two of the 12 conservation proposals explicitly took into account oil or gas activity areas. These priority areas show substantial overlap of ~130,000 km^2 between the hydrocarbon exploration/exploitation concession areas in the Mediterranean. Future conservation planning efforts should explicitly incorporate hydrocarbon industry infrastructure and threats. Such information can be included in conservation planning using a range of conceptual and practical approaches. For example, it could be incorporated as an “insurance factor” (Allison et al. 2003), identifying the optimal inter-reserve distance necessary to minimize the risk that several reserves will be impacted by a single oil spill (Wagner et al. 2007), as well as by explicitly including threats using spatial prioritization software (Game et al. 2008). Recently developed decision support tools (e.g., Marxan with Probability) allow us to explicitly incorporate threats (e.g., probability of extinction due to oil spills), multiple objectives (e.g., Marxan with Zones; Watts et al. 2009) and trade-offs (Mazor et al. 2014).

The wheels are turning…the risks in the prospects

The primary motivations of the hydrocarbon industry and of conservationists rarely overlap. The industry's main goal is to provide energy sources and be profitable, while conservationists often aim to maintain and restore native, threatened and representative biodiversity and reduce risks to long-term ecosystem functioning and services. No industry player, however, wants bad public relations and to bear the cost of tremendously expensive implications of an oil or gas disaster as a result of its operations, which presents a common ground for discussion. Corporate industrial activities and corporate responsibility must thus lead to an incentive to move from a profit-oriented traditional management paradigm to one which aims is to minimize the environmental impact (Shrivastava 1995). In practice, the offshore oil and natural gas industry, supported by governments and large businesses, is effectively moving ahead with or without the conservation community's involvement. Therefore, conservationists may have little choice but to respond and act quickly, aiming to introduce conservation considerations into spatial plans as early as possible to minimize potential harms, and leveraging opportunities for conservation actions that arise. This includes arguing for the urgent need for new biodiversity conservation, planning and monitoring funds and environmental offsetting schemes as a crucial part of the multi-billion dollar hydrocarbon operations in the seas and oceans, and clearly demonstrating to the fossil fuel industry that taking costly steps and actions in the short-term may help prevent potentially far more costly fines and negative impacts to biodiversity/ecosystems in the long term. The conservation community, including scientists, should feel incentivized to intervene and become involved at the earliest planning and exploration phases and throughout operations to influence practical decision-making and promote continuous monitoring of the status of biodiversity and ecosystems. Experience and especially successful strategies from around the world should be shared across the global conservation community. Transparent and productive long-term relationships can also help industry players become more aware of the risks and implications of their operations on biodiversity. This may eventually lead to changes in industry operations that will help prevent, minimize and address future threats (SI 3) (Esty & Winston 2009).

There are risks involved in cooperating with the oil and natural gas industry, resulting from the inherent difference in the objectives that motivate the hydrocarbon industry vs. the conservation or scientific communities. Collaboration may lead to delays in conservation action. It may lack transparency due to agendas of industry stakeholders, handling of proprietary information, and a lack of trust across the communities. This may lead to further conservation delays, added costs and further threats to biodiversity and ecosystems. Therefore, the discussion of when, where, how and to what extent conservationists will collaborate with the hydrocarbon industry remains to be weighed and determined for each case, region and point in time. This discussion, however, must be an explicit part of conservation planning and strategic conservation decisions and actions.

The implications of fossil fuel operations to conservation provide an important area for future research and inter-disciplinary collaborations. Advancements in the science of oil spill modeling (Ji et al. 2011) allow scientists to better estimate the risk of oil spills for marine and coastal areas. However, there are important gaps in our understanding of deep-sea currents, their spatial and temporal patterns and interactions with various chemical components of oil and gas discharges, as well as the consequential biodiversity impacts and required actions and restoration following spills. An important future direction should be to develop collaborative research between marine hydro-geophysicists, ecologists and conservation experts, which may provide a better foundation for predicting the impacts of spills and recognizing actions to best mitigate threats to biodiversity (e.g., Goldman et al. 2014). Future work would benefit from further exploring how to better incorporate ongoing hydrocarbon operations into spatial conservation planning and how the fossil fuel industry can better incorporate conservation needs, including in deep-sea and frontier regions.

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Supporting Information

Detailed examples of oil and gas operations in the Mediterranean Sea (Supplementary Information 1) and The Congo Basin (Supplementary Information 2) are available online. Examples of collaborations between the oil and gas industry and conservation are included in Supplementary Information 3. The authors are solely responsible for the content and functionality of these materials. Queries (other than absence of the material) should be directed to the corresponding author.

Tables

Table 1

Glossary of Terms related to sovereignty and maritime jurisdictions

UNCLOS	The UN Convention on the Law of the Sea (UNCLOS), from December 1982, provides for the basic sovereign rights and duties of the coastal states and the international community of states in the ocean.
Territorial waters	Areas within 12 nautical miles from the baseline of a coastal state, where it exercises full sovereignty (UNCLOS Part II).
Contiguous Zone	In a zone contiguous to its territorial sea, within 12 further nautical miles, termed the Contiguous Zone, the coastal State may exercise the control necessary to prevent and punish infringement of its customs, fiscal, immigration or sanitary laws and regulations within its territory or territorial sea (Article 33 of UNCLOS).
Exclusive Economic Zone (EEZ)	Coastal states can declare an exclusive economic zone, a region reaching up to 200 nautical miles from the coastal baseline, in which nations have sovereign rights over all natural resources, but additionally, the responsibility for the conservation and management of the zone (Part V and Article 61 of UNCLOS).
Continental Shelf	According to UNCLOS, coastal states have sovereign rights to explore and exploit the continental shelf, which is set as far as 350 nautical miles from their baselines or, where it is more favorable to the coastal nation concerned, to 100 miles beyond the 2,500-meter isobaths (Roy 2012; Article 76 of UNCLOS). However, the boundary of the shelf itself is sometimes debated, and the extent of continental crust is still being explored, opening the floor to further debates around territorial claims (James 2011).

High Seas	All parts of the sea or ocean that are not part of the exclusive economic zone, the territorial waters or the internal waters of a State, and are not part in the archipelagic waters of an archipelagic State. Usually refers to the water rather than to the seabed (Article 86 of UNCLOS).
Areas Beyond National Jurisdiction (ABNJ)	Areas Beyond National Jurisdiction (ABNJ), also known as high seas and international waters. Refers to the seabed and minerals therein (Part XI and Article 1 of UNCLOS).
International Seabed Authority (ISA)	The International Seabed Authority (ISA), an autonomous international organization established under UNCLOS, has jurisdiction over mineral resources in international waters. It has been recommended that conservation policies should become an integral part of international seabed regulation before the ISA grants the first exploration and mining licenses (Van Dover 2011).
Convention on Biological Diversity (CBD)	The Convention on Biological Diversity (CBD) was entered into force on 29 December 1993. Its objectives are the conservation of biological diversity, the sustainable use of the components of biological diversity and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources
International Maritime Organization (IMO)	The International Maritime Organization (IMO) is the United Nations' specialized agency with responsibility for the safety and security of shipping and the prevention of marine pollution by ships.

Figure legend

Figure 1

An overview of marine oil and gas exploitation stages, from exploration to production and abandonment. Exploration often begins with a seismic survey, during which air guns are used as a sound-wave source to penetrate the rock layers and reveal their structure (A). Exploration drills are made at targets that have been identified in advance. The type of drilling rig will depend on both the water depth and underground target depth (B). When oil or natural gas is discovered, additional wells are often drilled to appraise reservoir size and quality. If the reservoir is proven to be economically feasible for further development additional drilling will take place. The wells are then connected via pipes to a production platform (which could be at a remote location) where gas, oil and water are separated and transported to other facilities. When the pressure in the well drops to a level where it is no longer economic to produce, the well will be blocked with cement, the area restored and then abandoned. Potential pollution sources range from noise pollution at the seismic survey to a range of other possible pollution sources at the drilling and production stages such as drilling fluids (drilling mud), cement used for casings, cuttings from extracted rock layers, oil and gas leaks, produced formation water and water in the condensed gas, and pollutants from the rig itself and the neighboring ships (C).

*Drawing 1B was adopted with changes from the following source:
http://oceanexplorer.noaa.gov/explorations/06mexico/background/oil/media/types_600.html
Drawing C was adopted with changes from the OSPAR report (2009).

Figure 2

Oil and natural gas concession areas and active platforms in the Mediterranean Sea. Concession areas, existing oil and gas platforms, and offshore single point moorings (SPM) adopted data from Infield Offshore Energy Database (Infield 2013). Fig 2a shows the location of concessions areas and existing drilling with respect to the bathymetry and to marine boundaries of exclusive economic zones (source: VLIZ 2012). Fig 2b shows Mediterranean concessions in relation to recorded oil spills in the 35 years between Jan 1977 and July 2013 (n = 778; SI 1; IMO 2013). Fig 2c shows seismic activities (major earthquakes in the 20th century) and major faults in the Mediterranean in relation with oil and gas concessions (source of faults data: Asch 2003; source of earth quakes data: USGS 2013). Fig 2d maps the oil and natural gas concessions in relation to proposed conservation priority areas that were found to be in consensus between at least five proposed schemes (adopted from Micheli et al 2013).

777 **Figure 1**

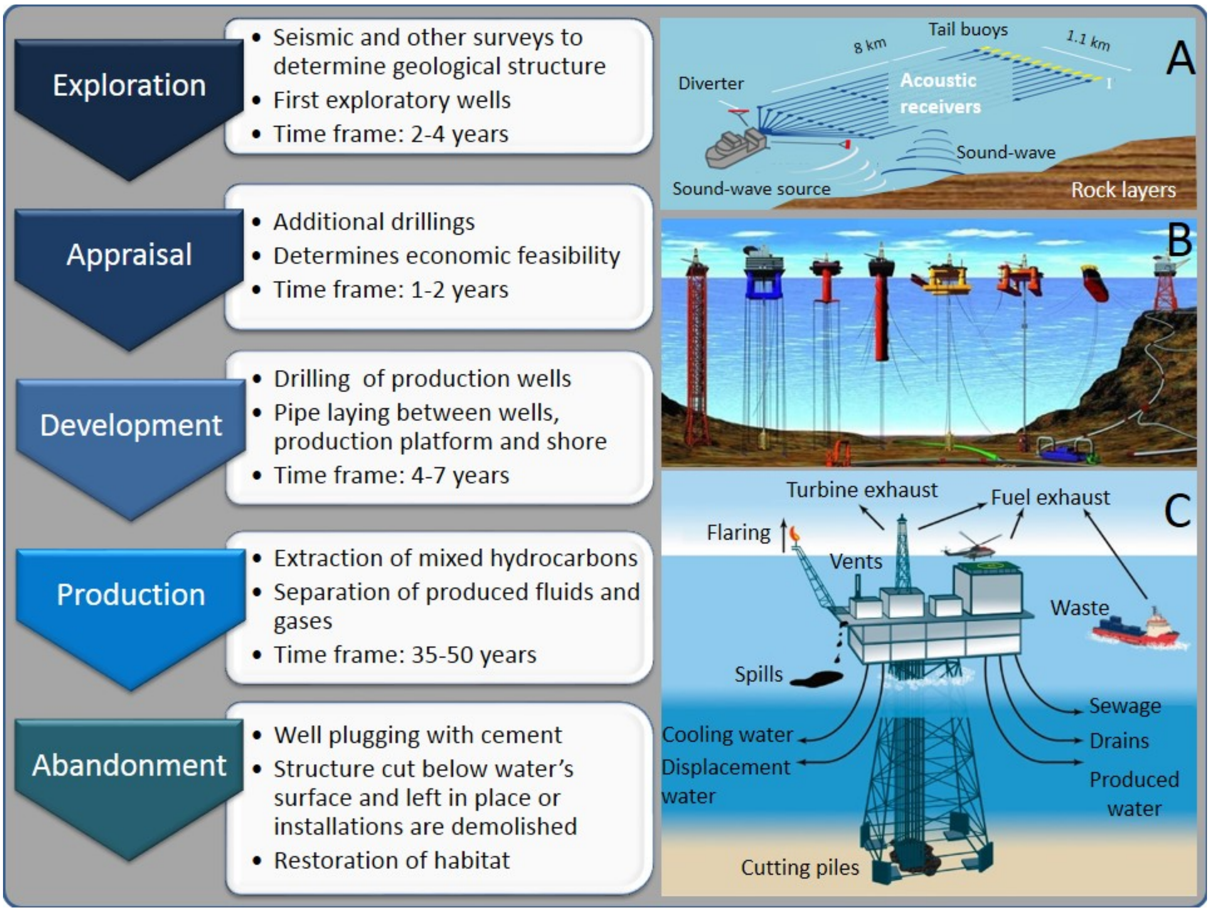

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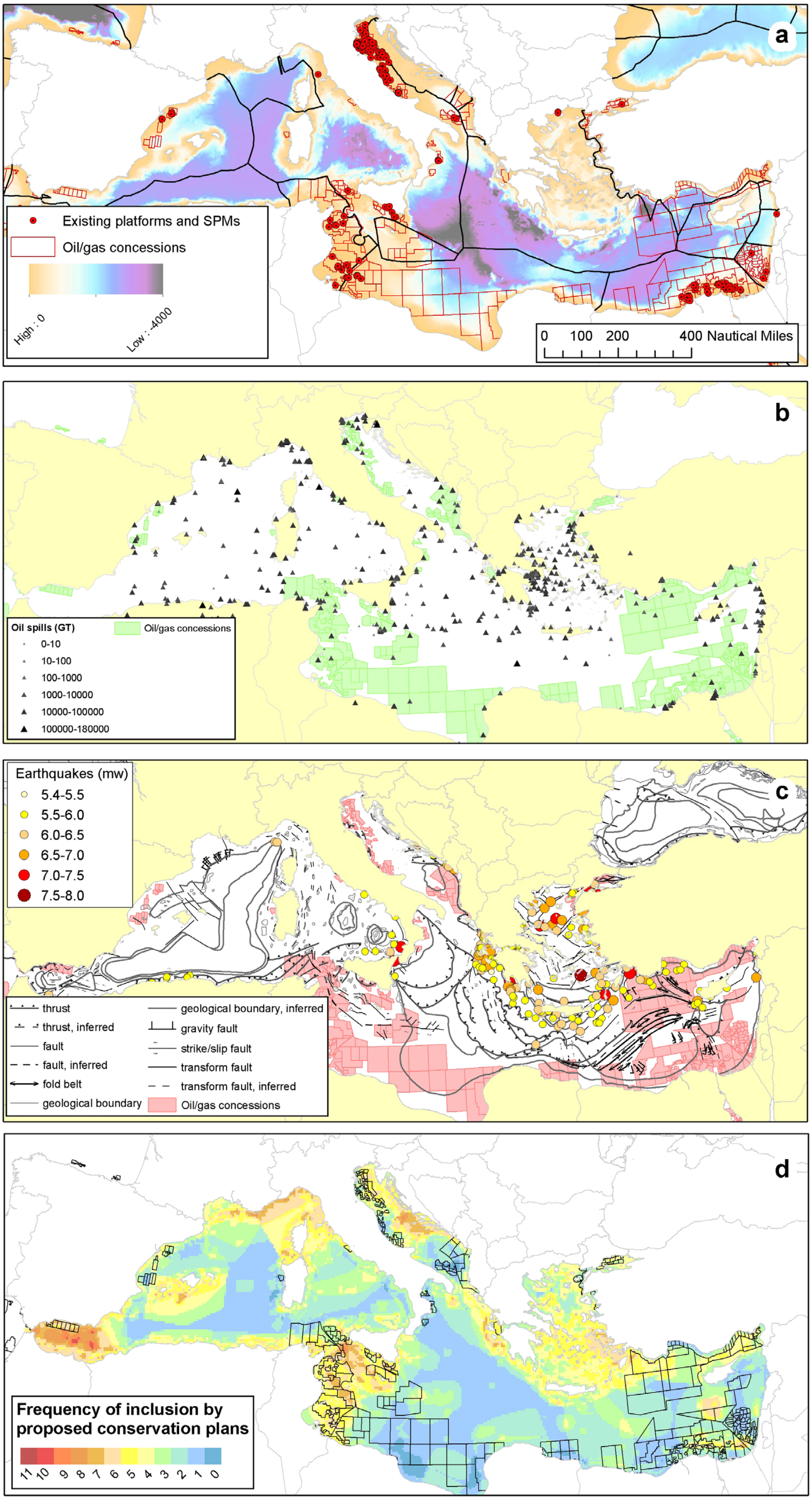
Figure 2


a
Existing platforms and SPMs
Oil/gas concessions
High : 0
Low : -4000
0 100 200 400 Nautical Miles
b
Oil spills (GT)
Oil/gas concessions
0-10
10-100
100-1000
1000-10000
10000-100000
100000-180000
c
Earthquakes (mw)
5.4-5.5
5.5-6.0
6.0-6.5
6.5-7.0
7.0-7.5
7.5-8.0
thrust
thrust, inferred
fault
fault, inferred
fold belt
geological boundary
geological boundary, inferred
gravity fault
strike/slip fault
transform fault
transform fault, inferred
Oil/gas concessions
d
Frequency of inclusion by proposed conservation plans
11 10 9 8 7 6 5 4 3 2 1 0

Supplementary Information 1

Oil and gas exploration in the Mediterranean Sea

The Mediterranean Sea is a sensitive and unique enclosed basin (Coll et al 2012; Micheli et al 2013) shared by over 20 countries across three continents (Europe, Asia and Africa; Mazor et al. 2013, 2014). The U.S. Geological Survey has estimated that the Eastern Mediterranean holds 345 trillion cubic feet (Tcf) of recoverable natural gas, 3.5 billion barrels of recoverable oil and six billion barrels of natural gas liquids (Schenk et al. 2010; Kirschbaum et al. 2010). The proximity of the Mediterranean Sea to the European market makes gas discoveries in this area commercially attractive (Belopolsky et al. 2012). Recent gas discoveries by Israel and Cyprus, including the large Leviathan Gas Field are estimated to contain a combined 980 Billion cubic meters (35 Tcf), and have spurred a flurry of exploration activities especially in the Eastern and Southeastern Mediterranean (Darbouche et al. 2012), as evidenced by the spatial distribution of the concessions (Fig. 2). In the Mediterranean, where vast natural gas fields have recently been discovered and are being developed at a rapid pace, 68% of 152 existing offshore natural gas and oil fields and approximately 75% of the 174 planned offshore fields lie beyond territorial waters (Pruett 2013; Infield 2013; Fig. 2a, SI 1).

The present spatial distribution of drilling wells and of most concessions in the Mediterranean Sea is limited to shallow waters (Fig. 2a). However, with technological advances, offshore operations in the Mediterranean are expanding into deeper waters. While the spatial distribution of past oil spills may be more closely related to shipping routes and ports than to the location of drilling wells (Fig. 2b), some of the concessions are located in seismically sensitive areas, where there are higher risks of earthquakes (Fig. 2c). There are some alarming sites, especially in the Aegean and Ionian Seas, where oil operations must consider the seismic activity within their risk models. These areas are also of special importance to the Mediterranean monk seals, which are a critically endangered endemic Mediterranean mammal and other species (IUCN 2012).

The Mediterranean Sea is considered one of the highest oil pollution risk regions (Martini & Patruno 2005). During the five-year period between 1999 and 2004, a total of 897 to 2,297 oil slicks were identified annually within the Mediterranean using remote sensing methods (Ferraro et al. 2009). A total of 778 oil spills were recorded in the Mediterranean Sea in the 35 years between 1/1977 and 7/2013 (IMO 2013; Fig. 2c). However, the level of oil-spill preparedness in this region for responding to oil spills is limited (Moller et al. 2003). While the probability of major oil spills is low, particularly since the recent Eastern Mediterranean discoveries are mostly of natural gas, such a spill could have major impacts. One should take note that beneath the large gas fields there are suspected oil fields and due to very high economic value the industry will attempt, sooner or later, to extract the oil (see Noble Energy Analyst Conference, 17 December 2013 for an illustration and plan for the suspected oil fields under the Leviathan gas field; http://www.nobleenergyinc.com/Operations/Eastern-Mediterranean-128.html). Negative impacts of oil spills may be even greater in the Mediterranean Sea, due to its enclosed structure, the development of multiple water desalination projects along the Mediterranean Coast (e.g., in Israel), the role of the Mediterranean Sea as a major transportation pathway for ships using the Suez Canal (Huijer 2005), and its deep isolated basins (Fig 2a). There is a range of preparedness plans for oil spills of Mediterranean Basin governments, and cross-boundary conflicts in part of the range and particularly in the eastern Mediterranean (Levin et al. 2013) that lead to difficulty in reaching relevant cooperative agreements, which could improve the readiness and preparedness of the eastern Mediterranean in the face of oil spills (Martini and Patruno 2005). Past reviews of oil spills from tankers identified the Mediterranean Sea as a global hotspot of oil spills (O'Rourke and Connolly 2003). The Mediterranean Sea provides a timely case study for examining the complex interactions and potential conflicts related to the newly discovered marine energy resources (e.g. Copinni et al 2011), located in an area of high seismic risks (Fig. 2c), and is an area of regional and global biodiversity conservation priority (Fig. 2d), including deep sea corals (Taviani et al 2011), a range of threatened marine vertebrates (Kerem et al 2012; Dede et al 2012; Casale and Margaritoulis 2010; IUCN 2012) and unique habitats (e.g., sea mounts and canyons; Öztürk et al. 2010, 2012).

The new deep-water and ultra-deep-water explorations in the Mediterranean Sea (Fig. 1) have provided some of the best offshore global discoveries of natural gas in recent decades. The scarcity of data on the ecology and oceanography of the deep water of the Mediterranean (Levin et al. 2014) and the unknown impacts to biodiversity resulting from developing marine oil and natural gas operations challenge conservation efforts and environmental decisions. It is imperative that new findings within the Mediterranean of highly profitable oil and gas discoveries and their exploitation will be considered in due caution by all Mediterranean countries. Political threats and instability should also be included in future risk analyses in the conservation context.

In general, recovery from disturbances in deep water is poorly understood (Gates & Jones 2012). The magnitude of impact of extraction platforms and other operational infrastructure on marine ecosystems and biodiversity will depend on many factors, such as the habitat and ecological context and the distance from the platforms (Terlizzi et al. 2008; Gates & Jones 2012). The impact and response also largely depends on the focal taxon and group. For example, while arthropods were shown to be relatively resilient to disturbances (McCall & Pennings 2012), megabenthic assemblages have been estimated to regain more slowly post disturbance; and Jones et al. (2012).

In the eastern Mediterranean marine border disputes between Lebanon and Israel, as well as between Cyprus and Turkey, have fuelled other conflicts between these countries (Shaffer 2011). Offshore exploitation of hydrocarbon reservoirs can in some cases motivate countries to declare their exclusive economic zones (EEZs). This momentum of EEZ declaration can be observed in recent years in the Eastern Mediterranean (also called the Levant). For example, Cyprus and Israel have recently reached an agreement on their maritime boundaries following the large offshore gas discovery in Israel (Leviathan; the largest gas field found in the Mediterranean) (Wählisch 2011; EIA 2013). The prospect of joint exploration of oil and gas reserves between Cyprus and Israel enhances socio-economic relations (Shaffer 2011). As suggested by Buszynski and Sazlan (2007), cooperation arrangements between national companies with regards to joint exploration, drilling and production, even when maritime claims are not settled, may lead to socio-political ties that in turn may enhance conservation collaborations. Eventually, such cooperation may advance between-country and cross-boundary collaboration in conservation and environmental efforts (Levin et al. 2013, Kark et al. 2015), which can be examined and leveraged by the conservation community early in the policy-shaping process.

Along with recent oil and natural gas exploration, local and regional marine conservation initiatives are also growing in the Mediterranean Sea. These initiatives are mostly in the form of creating marine protected areas networks at both national and regional scales with currently only one trans-boundary park in the Mediterranean Sea beyond territorial waters (Levin et al 2013, Micheli et al. 2013). However, only few large-scale conservation initiatives (see Table 2 in Micheli et al. 2013) have explicitly considered the negative impacts of oil and gas exploration and how they may overlap with conservation priorities and conservation objectives,. The overlap between oil and gas exploration and exploitation concession areas and priority conservation areas (selected by five or more initiatives, as shown in Fig. 2d, see Micheli et al. 2013) covers nearly 130,000 km^2, equal to 17% of the total size of the concession areas, and to 27% of the total size of the priority conservation areas (Fig. 2d). When examining whales and dolphins high priority areas such as the areas suggested by ACCOBAMS (in 2010) we find that 12% of these areas are within oil and gas exploration concession areas. Future work in the Mediterranean Sea would benefit from incorporating emerging oil and gas plans into conservation prioritization and understanding how the threats could be minimized while leveraging emerging prospects for conservation.

Supplementary Information 2

Long-term conservation investments in Congo Basin Coast

The Congo Basin Coast region represents one of the most biologically diverse areas on Earth (Alonso et al. 2006), where the beaches shelter the world's largest nesting population of leatherback sea turtles and its waters provide habitats for whales, manatees and dolphins, including the highly endangered humpback dolphin (wcs.org/saving-wild-places/ocean/Congo-basin-coast-seascape). Coastal mangroves serve as a spawning ground for a variety of fish and adjacent forests, still relatively pristine, are home to many large mammals, such as elephants, gorillas, leopards, buffalo, and chimpanzees, many of which are threatened with extinction in Gabon (quandl.com/WORLDBANK/GAB_EN_MAM_ THRD_NO-Gabon-Mammal-species-threatened).

The region also provides several examples of ongoing collaborations between international conservation non-governmental organizations (NGOs) and the oil and gas industry. For example, the Gabon Biodiversity Program is a partnership between the Smithsonian Conservation Biology Institute, Shell Gabon and other stakeholders, and additional site-specific projects are led by the Wildlife Conservation Society (WCS), a large global non-governmental organization, in collaboration with a number of international energy companies (e.g., Tullow Oil, Total-Gabon, Shell-Gabon, Perenco, and Vaalco). One of the earliest offshore collaborations in this region was between WCS and Angola Liquefied Natural Gas (consisting of Chevron, Total, BP, and Sonogol) in 2006, which allowed for a major assessment of the status of Angola's marine mammal and marine turtle populations in the near shore and deep-water offshore environments, in part by using expensive marine autonomous recording units (Maruca et al. 2012). One of the project's early successes was the protection of turtle nests. On the Sereia Peninsula, animal and human predation of sea turtles decreased from 54% of affected nests during the 2007-2008 breeding season to 19% in 2008-2009 (ipieca.org/topic/biodiversity/biodiversity-case-studies/angola).

In July 2012, WCS signed an agreement with the British oil company Tullow Oil, the biggest license holder in Africa which has interests in 15 African countries. The aim of this agreement was to establish the first comprehensive marine environmental research and oil industry no-net loss of biodiversity and offset program in the Congo Basin Coast (CBC) region of Africa, specifically the ocean and coastal areas of Gabon, Congo and Equatorial Guinea. Using the mitigation hierarchy framework (The Business and Biodiversity Offsets Programme 2012), the 30-month project was designed to respond to two interrelated conservation challenges in the coastal and offshore environments of the Congo Basin Coast: 1) the potential threats to the critical habitats of cetaceans and other large and often highly migratory marine wildlife from ongoing oil and gas exploration, development and production and 2) regional oil spill preparedness and response, which includes building the capacity of individuals and institutions working at species, ecosystem, community, institutional, and societal levels in the region.

The nations of the Congo Basin Coast are rapidly expanding trade and intensifying their natural resource extraction activities along the entire coastline, posing serious challenges for its globally important biodiversity. For example, in Gabon, the upstream oil industry plays a critical role in the national economy, representing approximately 90% of the country's export revenues and nearly 56% of its GDP (International Monetary Fund 2011). Nevertheless, the President of Gabon recently declared Gabon Bleu, an effort to both establish a large network of marine protected areas and reform fisheries, as the fourth pillar of his country's Plan d'Emergence. To support this Presidential initiative, the project has three primary objectives: 1) to gather, evaluate, and make available verified baseline biodiversity, socioeconomic, and land/sea-use data to guide decision making and support the achievement of positive gains in biodiversity and natural resource conservation from Tullow's and other extractive activities in the region, 2) to design and develop land- and marine resource-use planning mechanisms and transparent stakeholder engagement tools to enhance the capacity to deliver programs that ensure positive conservation outcomes; and 3) to design and implement long-term programs that demonstrate how to mitigate current adverse impacts, if any, deliver positive conservation results, and preempt risks to biodiversity and livelihoods. This includes measures to offset and compensate for residual impacts. The project has provided the shared foundation for both industry engagement in conservation and the integration of conservation goals directly into the operational activities of the company and has already had several practical conservation outcomes. For example, in 2013, the schedule for drilling two of Tullow's exploratory wells began to slip into sea turtle nesting season. In collaboration with WCS, the company responded in two ways. They incorporated into their operational budget the costs of helping to determine whether their activities, both the current exploratory activities as well as future development and production activities, might impact the threatened and little understood Olive Ridley turtle (*Lepidochelys olivacea*). By incorporating the costs of this research into their operations, Tullow, and subsequently their partners, acknowledged to their shareholders that determining these impacts was essential to their core business. Second, Tullow modified the plans for their exploratory wells on the advice of WCS scientists (J. Polsenberg, pers. comm.). Although the company lost some benefits from a geological point of view, Tullow allowed that the changes, which in the event of an oil spill would provide more time to stop spilled oil from hitting these crucial beaches during nesting season, far outweighed any advantage that may have accrued from their original plans (J. Polsenberg, pers. comm.).

Supplementary Information 3

In this section, we provide several examples of joint efforts that incorporate conservation considerations into marine hydrocarbon industry practices.

Examples of industry-conservation collaborations and initiatives

The International Association of Oil and Gas Producers (OGP) produced a document aimed at highlighting the benefits of effective environmental monitoring programs (OGP 2012). However, the report defines the marine environment as only the water column and the sediment compartments seaward of the intertidal zone (OGP 2012). By its own admission, it does not include monitoring of beach or other onshore zones or the impacts from seismic operations and oil spills. Such monitoring should ideally be done by independent conservation experts and scientists rather than by the oil and gas companies.

The World Ocean Council, a new international cross-sectoral industry alliance on Corporate Ocean Responsibility designed to bring together leaders from across ocean industries, is supporting a fledgling program entitled “Smart Ocean/Smart Industries” (SO/SI). Its stated purpose is to engage operators to coordinate their various platforms (ships, rigs, ROVs) into an integrated network for ocean observation. It is likely that such cross-sectoral consortia, will need to be established in order to initiate substantial and meaningful industry contributions toward monitoring and environmental science. However, given they are industry-led and voluntary, it is unlikely that the main focus will be on monitoring potential biodiversity impacts from industrial activities. Conservation scientists, NGOs and governmental units working in the conservation realm could help advance the inclusion of potential biodiversity impacts and monitoring as focus of such efforts (see detailed example from The Congo Basin, West Africa in SI 2).

In 1965, the US enacted the Land & Water Conservation Fund (LWCF Public Law 88-578 Title 16). Its stated purposes are “to assist in preserving, developing and assuring accessibility to outdoor recreation resources and to strengthen the health and vitality of U.S. citizens by providing funds and authorizing federal assistance to states in planning, acquiring and developing land and water areas and facilities, and by providing funds for federal acquisition and development of lands and other areas". Funds are collected primarily from oil and gas activities on the outer continental shelf, and the annual income to the fund is currently set at a minimum of $900 million. While the LWCF is not designed to directly offset harms that may be associated with offshore oil and gas activities, the funds are strictly intended for the purpose of conservation and natural-area recreation activities.

In direct response to the damages caused by oil spills, the US currently mandates a Natural Resources Damages Assessment to calculate the costs, which become the responsibility of the offending party, of "damages to, destruction of, or loss of natural resources resulting from a discharge of oil or release of a hazardous substance" (Comprehensive Environmental Response, Compensation, and Liability Act of 1980, 42 United States Code 103 and the Oil Pollution Act of 1990). In addition, following the BP Deepwater Horizon spill, the United States enacted in 2012 the RESTORE Act, which designates a portion of the legal fines that would be levied against the companies responsible for the spill toward, in part, the restoration of the environment and economy of the Gulf of Mexico Coast region. In the case of the RESTORE Act, the restoration and economic activities does not need to be directly associated with the damages caused by the Deepwater Horizon spill alone but could also be used to address decades of impacts caused by the long history of offshore oil and gas activities in the region.

In recent decades, several collaborative initiatives have been established around the world. Norway has registered a range of collaborations between the industry and environmental scientists through the years. Armstrong and van den Hove (2008) present a chain of events leading from the capture of the first photos of cold water corals by a Norwegian oil company (Statoil) in 1982, through the company's decision to bypass coral reefs while laying their pipelines, to the eventual conservation of cold water corals largely via government closures to bottom trawling. These actions form part of a Biodiversity and Ecosystem Services Working Group set up by the International

Petroleum Industry Environmental Conservation Association (IPIECA) and the International Association of Oil and Gas Producers (OGP). The group’s declared goal is to increase awareness about biodiversity in the petroleum industry and to develop guidelines and tools to preserve biodiversity. They participate in the “Scientific and Environmental ROV Partnership using Existing iNdustrial Technology” (SERPENT) program (http://www.serpentproject.com/) whereby remotely operated underwater vehicles (ROVs) for subsea installations are also used for mapping and monitoring activities (Jones 2009). The SERPENT program was first implemented in 2002 (Hudson et al., 2005) and focuses on two major research areas, including (i) deep-sea biodiversity and ecosystem functioning and the assessment of disturbances and (ii) recovery from activities of the hydrocarbon industry. Expanding the collaborations between the industries that exploit deep-sea resources and marine science may be key for significantly advancing our knowledge on the oceans.

The Energy and Biodiversity Initiative (EBI; http://www.theebi.org/) was formed by energy companies (BP, ChevronTexaco, Shell, Statoil) and conservation organizations (Conservation International, The Nature Conservation, Fauna & Flora International, Smithsonian Institute, IUCN), aiming to develop and promote biodiversity conservation practices, so as to integrate biodiversity conservation into oil and gas development. This partnership, which began in 2001 and ended in 2007, is an example for establishing dialogue and trust between the business and conservation communities on controversial questions such as mining. The partnership has produced practical guidelines, tools and models to improve the environmental performance of energy operations, minimize harm to biodiversity, and maximize opportunities for conservation wherever oil and gas resources are developed. The partnership has produced practical guidelines, tools and models aimed to improve the environmental performance of energy operations, minimize harm to biodiversity, and create opportunities for conservation where oil and gas resources are developed (Tully 2004). An additional example for such collaboration is the Joint Industry Programme (JIP, members of which include for example BP, Chevron and Santos), supporting research to increase our understanding regarding the effects of sound generated by oil and gas exploration and production activity on marine life (http://soundandmarinelife.org/). Organizations such as the Global Oil and Gas Industry Association for Environmental and Social Issues aim to collaborate with biodiversity conservation efforts by initializing plans such as the biodiversity action plan (BAP), a set of actions that they declare as intended to lead to the conservation or enhancement of biodiversity (http://www.ipieca.org/). In some cases contributions arise following major oil spill incidents, for instance BP's $500 million grant for research on the effects of oil pollution on the environment, which was provided following the BP/Deepwater Horizon Disaster (Schrope 2011).

A review and evaluation of the effectiveness of a range of collaborative industry-science-conservation programs would comprise a useful step towards determining the importance and optional structures of such efforts in the future and towards better incorporation of conservation into the wide ranging marine and terrestrial fossil fuel extraction activities.

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