Journal of Environmental Management 188 (2017) 195–202

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Review

Collating science-based evidence to inform public opinion on the environmental effects of marine drilling platforms in the Mediterranean Sea

M.C. Mangano [a, b, *], G. Sarà [b]

[a] IAMC-CNR Capo Granitola, Via del Mare 3, 91021, Torretta Granitola, Fraz. di Campobello di Mazara, TP, Italy
[b] Dipartimento di Scienze della Terra e del Mare (DiSTeM), CoNISMa, University of Palermo, Viale delle Scienze Ed. 16, 90128 Palermo, Italy

ARTICLE INFO

Article history:
Received 21 May 2016
Received in revised form
23 November 2016
Accepted 6 December 2016
Available online 14 December 2016

Keywords:
Drilling
Systematic map
Informational gap
Ecosystem component
Good environmental status
Mediterranean Sea

ABSTRACT

The use of rigorous methodologies to assess environmental, social and health impacts of specific interventions is crucial to disentangle the various components of environmental questions and to inform public opinion. The power of systematic maps relies on the capacity to summarise and organise the areas or relationships most studied, and to highlight key gaps in the evidence base. The recent Italian technical referendum (2016) – a public consultation inviting people to express their opinion by voting to change the rules on the length of licence duration and the decommissioning of offshore oil and gas platform drilling licences – inspired the creation of a systematic map of evidence to scope and quantify the effects of off-shore extraction platforms on Mediterranean marine ecosystems. The map was aimed as a useful model to standardise a "minimal informational threshold", which can inform public opinion at the beginning of any public consultation. Produced by synthesising scientific information, the map represents a reliable layer for any future sustainable strategy in the Mediterranean basin by: (i) providing a summary of the effects of marine gas and oil platforms on the Mediterranean marine ecosystem, (ii) describing the best known affected components on which the biggest monitoring efforts have been focused, and (iii) strengthening the science-policy nexus by offering a credible, salient and legitimate knowledge baseline to both public opinion and decision-makers. The map exercise highlights the knowledge gaps that need filling and taking into due consideration before future transnational and cross-border monitoring and management plans and activities can be addressed.

Contents

1. Introduction

At the beginning of this century, Herrick and Sarewitz (2000) proposed that the role of science is not to solve political

* Corresponding author. IAMC-CNR Capo Granitola, Via del Mare 3, 91021, Torretta Granitola, Fraz. di Campobello di Mazara, TP, Italy.
E-mail address: mariacristina.mangano@gmail.com (M.C. Mangano).

http://dx.doi.org/10.1016/j.jenvman.2016.12.013
0301-4797/

Table 1
PICO elements of the research question used to both compose the search strings and drive the selection of studies.

Populations	Intervention	Outcomes	Comparators
Mediterranean marine ecosystem components: abiotic (sediments, drilling muds, water column, water based fluids, produced formation water) and biotic (marine mammals, fish vertebrate, benthic invertebrate, algae, plancton, bacteria)	Oil platform, gas platform, drilling activities, seabed exploration	Measured biological responses on the four main organisation levels: Population (abundance, biomass, non-indigenous species); Community (biodiversity, species richness, Shannon's diversity, community structure, community shift); Individual (size, weight, larval mortality, larval immobilization); Sub-organismal (physiological trauma, bioaccumulation, lysosomal membrane stability, Lipid alteration and accumulation - lipofuscin alteration, survival in air, micronucleus test, benzo(*a*)pyrene monooxigenase activity, acetylcholinesterase activity, metallothionein content, superoxide dismutase, total oxyradical scavenging capacity, catalase activity, content of malondialdehyde, glutathione reductase, genotoxic alterations, toxicity, genetic diversity, sperm cell test, embryo toxicity test)	Reference sites (control areas), predevelopment baseline (i.e. areas where no oil and gas platforms or drilling activities or seabed exploration occurs)

Table 2
Complex and simple search strings arranged using keywords arranged from PICO elements in Table 1. Notes: the wildcard asterix (*) following a search word has been used allowing the search engine to consider and accept the word variations in the search; quotation marks around word indicate the exact word allowed in the search results; as from Fig. 1 the number of records in the library after checking for duplicate, and before performing the screening steps was 191.

Complex search string (search at 25/04/2016)	Scopus "TITLE-ABS-KEY"	ISI WoS "TOPIC"
("petrol" OR "oil" OR "gas") AND ("drill*" OR "exploration" OR "platform") AND ("sea" OR "marine") AND ("biodiversity" OR "diversity" OR "social*"OR "economic*" OR "effect*" OR "impact*" OR "monitor*") AND "Mediterranean"	**139**	**52**
Simple search strings (search at 25/04/2016) on Google Scholar and Google		
Gas platform AND biodiversity AND Mediterranean		
Gas platform AND effects AND Mediterranean		
Oil platform AND biodiversity AND Mediterranean		
Oil platform AND effects AND Mediterranean		

controversy, but to provide a reliable and objective support tool to aid the process of informing public opinion and policy decision-making. In many cases, however, this contradicts the traditional and most widely used approach, where decisions on technical issues are made by technical expert groups and scientists only, excluding the public from scientific and technical assessments. The distance between experts, scientists and the general public, and the consequent disruption to knowledge flows, often stems from the usage of different languages and communication channels. Most scientific documents (e.g. peer-reviewed papers, Annual Agency reports, Technical Assistance reports, etc.) routinely produced to assess the impacts of human actions on the environment and biodiversity (viz. Fishery, aquaculture, drilling platforms or wind farms) as well as sustainability policy protocols and programme reports often remain never read (Fisher et al., 2014). Nor are they downloaded from the official databases (e.g. the World Bank case

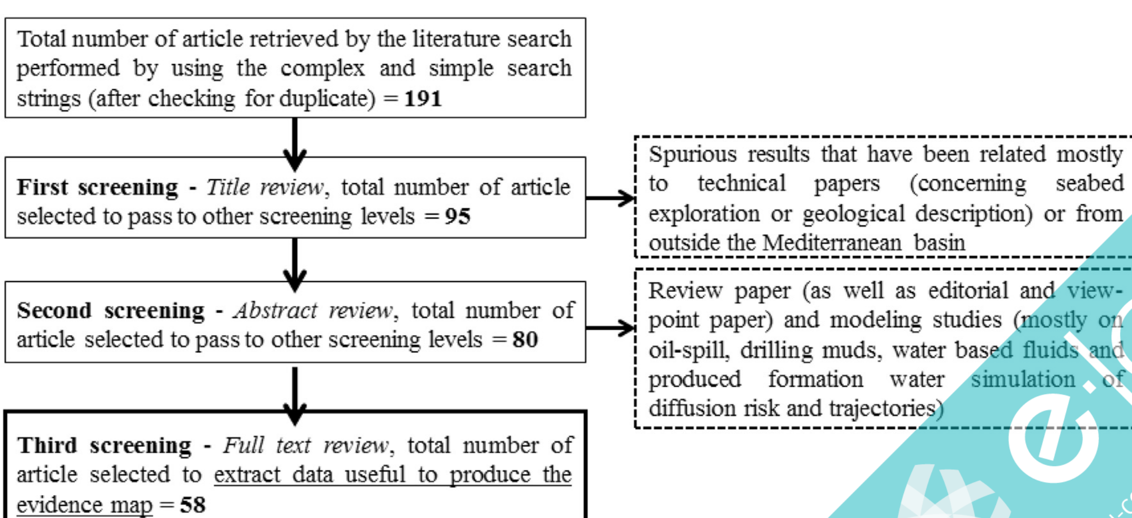

Fig. 1. Schematic diagram of article selection through the three screening steps – Title, Abstract an Full text.

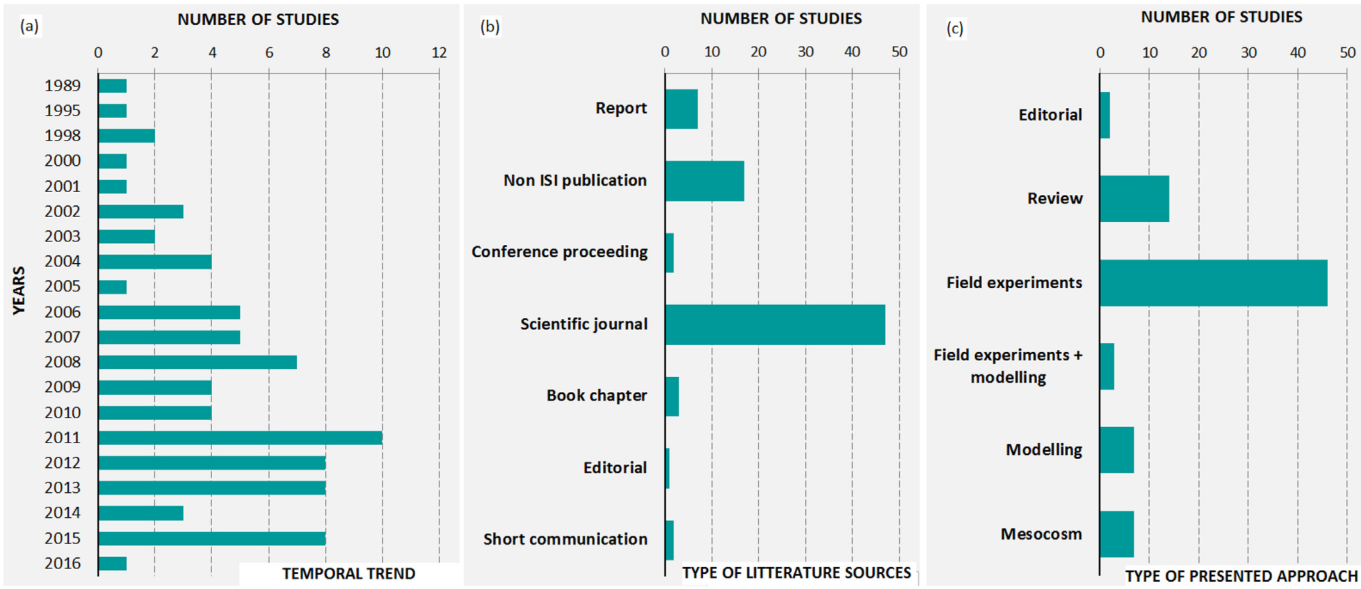

Fig. 2. (a) Temporal trend, (b) type of sources and (c) applied approaches in affording the question after the first and second screenings (Title and Abstract reviews, N = 80).

documented by Doemeland and Trevino, 2014). Highly sectorial scientific information is in fact often retained within specialised literature, which remains barely accessible to the general public, stakeholders and decision-makers, as stated two years ago by the *Washington Post* "*… possible policy solutions could be buried deep in a PDF …*" In their recent influential paper, McKinnon et al. (2015) emphasised the high number of unread studies and recognised the crucial role of experts in evidence synthesis, i.e. solving the problem of knowledge communication to the public by combining numerous data sources to produce systematic maps of evidence that are easy to look up (Pullin et al., 2013; Snilstveit et al., 2013).

The use of rigorous methodologies to assess the environmental, social and health impacts of specific interventions is crucial to informing public opinion (Sarà, 2007; CEE review guidelines, 2013; Pullin, 2012; Bilotta et al., 2014; Bottrill et al., 2014; Bayliss et al., 2015; Mangano et al., 2015a,b; Sciberras et al., 2015). Tools and methods have been developed and applied to locate and combine numerous sources of data, compiling and categorising scientific

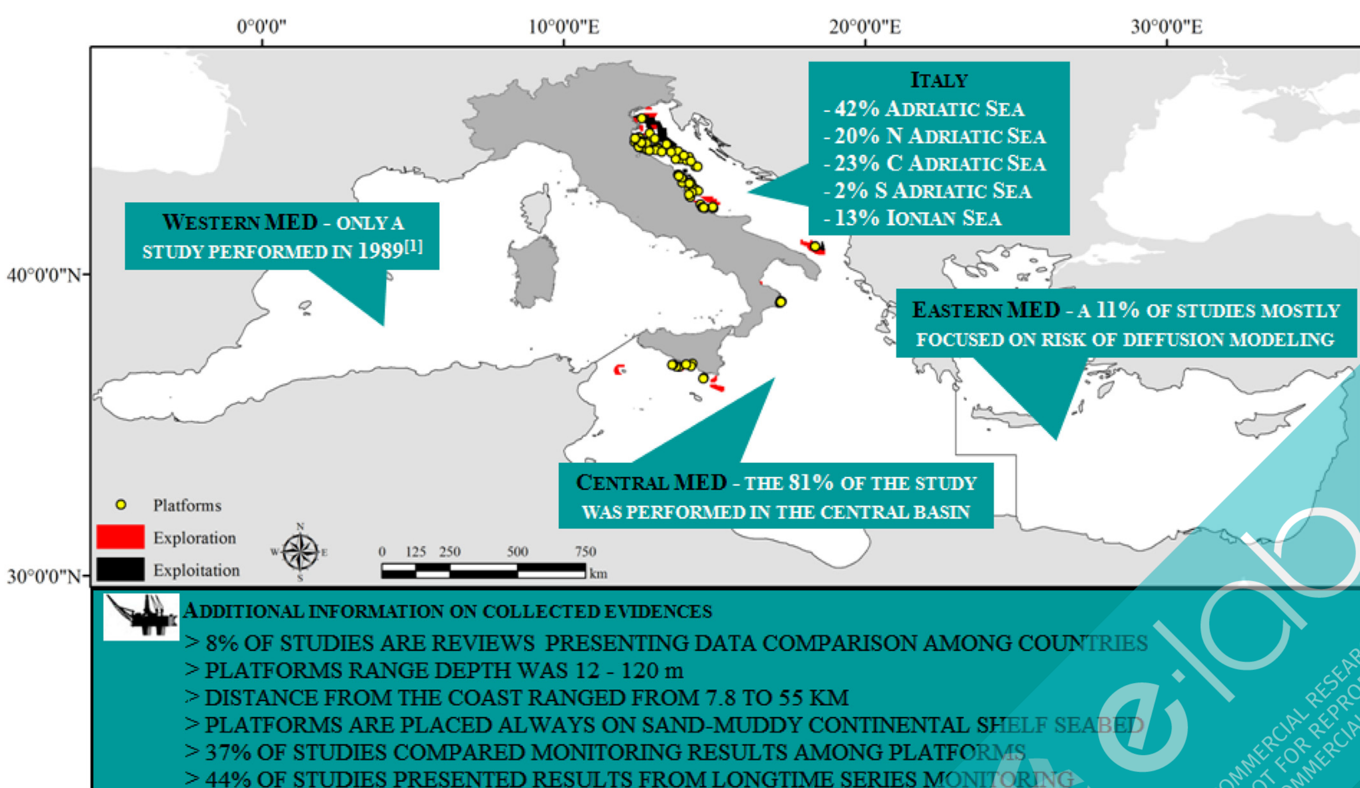

Fig. 3. Infographic to summarise evidence on the geographic locations (N = 80); platform points (yellow dots), exploration and exploitation zone have been downloaded from http://www.emodnet.eu/human-activities. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

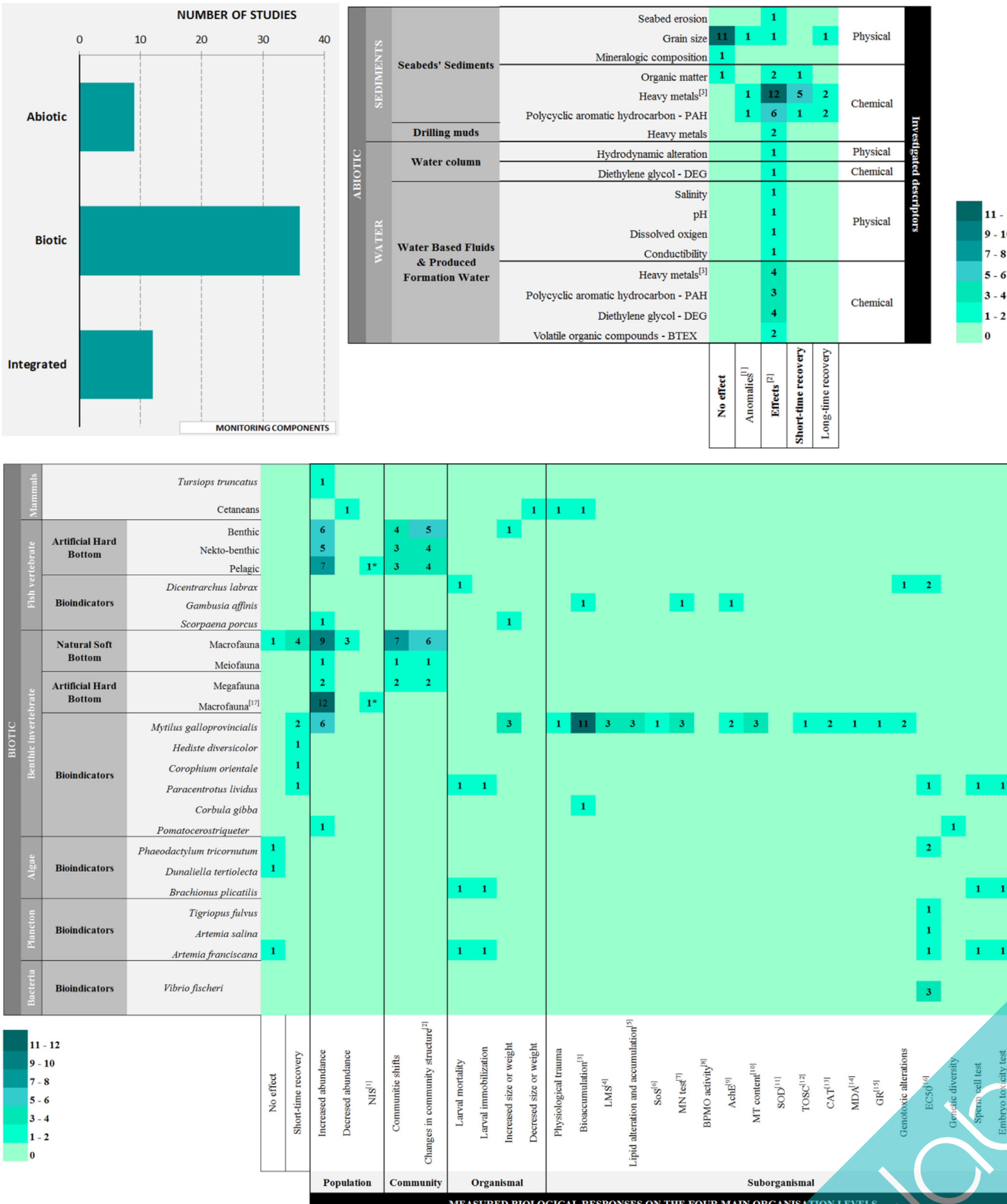

Fig. 4. The evidence map produced by collecting studies that describe the effects of offshore platforms (oil and gas) on the marine ecosystem components considered (both abiotic up on the right and biotic on the bottom) and the respective investigated descriptors and measured responses (N = 57 after all the screening steps). Knowledge gap and gluts of immediate visualisation from lighter to darker colour (number of occurrence are also reported). The 57 studies have been also grouped to highlight the two main monitoring components (abiotic and biotic) and the integrated approaches (histogram up on the left). [The zero values were not inserted to facilitate the visualisation, the respective referring colour is represented]. **Notes**: Abiotic matrix [1]Anomalies = as referred by the Authors peaks of measured values with not clear effects along the spatial or temporal scale of monitoring; [2]Effects = general increase from CTRL or previous monitoring; [3]Heavy metals = Al, Cd, Cr, Ba, Cu, Hg, Ni, Pb, Zn. Biotic matrix [1]NIS= Non-indigenous Species;

data in a particular area (e.g. environmental risk, conservation and protection). In this regard, the power of systematic maps relies on the capacity both to show, at a glance, the area or relationships that have been most studied, and to highlight key gaps in the evidence base. Systematic maps are particularly useful for disentangling the components of environmental questions and, by way of immediate visualisation, inform public opinion (McKinnon et al., 2015). First developed in social science to reliably catalogue evidence on a specific subject, systematic maps are highly useful for research, policy and practice communities, providing assessments of the knowledge gaps and gluts needed to promote best practices and direct research resources (Haddaway et al., 2016).

Here, inspired by the recent Italian technical referendum (April 17th, 2016), a public consultation inviting people to express their opinion by voting on the length of time of oil and gas platform drilling licences, we decided to create an evidence map (systematic map based on evidence from the literature *sensu* McKinnon et al., 2015) to scope and quantify the existing evidence on the effects of off-shore extraction platforms on Mediterranean marine ecosystem components. The referendum's implicit core question concerned the opportunity to maintain operating drilling platforms over a defined time period (i.e. until licence expiration) or for longer (i.e. until the extinction of the deposit) without providing information on the development of a sustainable strategy along the Italian coastal areas to cope with environmental risks. As such, the referendum involved some controversial and much debated issues of an ecological, social, economic and cultural nature which complicated the assimilation of public opinion on the decisional processes (e.g. the role played by platforms in increasing local contamination and detrimental effects on fauna and flora, the rules adopted by oil companies in exploiting national resources, the loss of national sovereignty, unemployment issues related to maintenance and decommissioning, etc.). In this regard, a lack of evidence-based knowledge to inform the decision process clearly emerged from the public debate. People were left to assume the need to justify an intervention, and so vote, as most commonly happens, according to what is familiar rather than what is proven (Pullin et al., 2013).

We decided to set up and execute an evidence map as a useful model for standardising a “minimal informational threshold”, designed to inform public opinion at the beginning of public consultations. The map, produced by synthesising scientific information, also comprises a layer for any future sustainable strategy in the Mediterranean basin by enabling: (i) the identification of current scientific efforts in monitoring drilling platform effects on both the abiotic and biotic marine ecosystem components and (ii) pointing out possible scientific information gaps.

The entire Mediterranean Basin was selected as a model area in the context of risk knowledge data capture accounting for the peculiar chemical, physical and biological processes acting at mesoscale spatial level (Coll et al., 2010, 2012).

2. Materials and methods

To answer our primary question “*What effects do offshore extraction platforms have on the Mediterranean marine ecosystem components?*” we searched for relevant studies using two main publication databases (ISI Web of Knowledge and Scopus) and a complex search string involving specific keywords generated by the Population, Intervention, Comparator and Outcome elements (CEE review guidelines, 2013) along with the Boolean operators and the *wildcard* “*” (Tables 1 and 2). The Aquatic Sciences and Fisheries Abstracts (ASFA) database was used to access grey literature, whilst an additional search limited to Word, PDF and/or Excel documents was performed on Google scholar and Google; the first 50 hits were examined (CEE review guidelines, 2013). To address our evidence map, we sought peer-reviewed information to meet criteria for environmental monitoring in the vicinity of offshore oil and gas installations proposed by the International programmes OSPAR Convention (2009). This entailed (i) monitoring selected chemical and physical variables of water column and sediment; (ii) evaluating effects on biota, and (iii) identifying spatial-temporal trends of the eventual alteration that occurred. Chemical and physical monitoring of drilling muds, Water Based Fluids (WBF) and Produced Formation Water (PFW) were also included in our analysis. A series of measured biological responses (herein also referred to as Outcomes) were synthetised. A set of selection criteria was defined to screen studies identified by the literature search that could be used later to produce the evidence map. The first screening sifted out, by title alone, any spurious results related mostly to technical papers (concerning seabed exploration or geological description) or from outside the Mediterranean basin (Fig. 1). A second, more detailed screening set was based on inclusion criteria and was performed on abstracts and full title readings. Inclusion criteria concerned the presence of: (i) relevant subject, marine ecosystem components such as abiotic and biotic components listed in Table 1 (see Population column); (ii) relevant exposure type, both offshore oil and gas platforms, and (iii) relevant outcomes including changes in measured biological responses at the four main organisation levels listed in Table 1 (see Outcome column).

Articles retained from the first search phase were organised to: rebuild a temporal trend on the available literature sources, visualise the main type of literature sources, and describe the predominant applied approaches. The evidence collated from data extraction on articles that passed all the screening steps was synthesised by using a systematic map - a matrix containing all the evidence concerning the effects of offshore platforms on marine ecosystem components and the related measured responses, along with detailed descriptive information. An integrated narrative description of the main evidence and gaps was also provided. The evidence was extracted according to its being either a “non-effect”, “anomalies” or “effect” (the exact commonly reported terminology used by authors when presenting their results).

The word “effect” was specifically detailed in terms of biological responses at four levels of organisation: population, community, organismal and sub-organismal, and where clearly reported in the study, recovery times were also recorded. In addition, some complementary details were recorded, i.e. geographic location, minimum and maximum distance of the platforms from the coasts and depth range of installation, nature of the seabed, name of the platform, monitoring time, and number of the compared platforms (in comparison studies). To assess quality of studies and evaluate the reliability of the reviewed results, a quality assessment framework was adapted from the systematic review guidelines for

[2]Change in community structure = increased richness and diversity; [3]Bioaccumulation = accumulation of heavy metals or PAHs; [4]LMS = Lysosomal membrane stability; [5]Lipid alteration and accumulation = include Lipofuscin alteration; [6]SoS = Survival in air; [7]MN test = Micronucleus test; [8]BPMO activity = Benzo(*a*)pyrene monooxigenase activity; [9]AchE = Acetylcholinesterase activity; [10]MT = Metallothionein content; [11]SOD = Superoxide dismutase; [12]TOSC = Total Oxyradical Scavenging Capacity; [13]CAT= Catalase activity; [14]MDA = Content of malondialdehyde; [15]GR = Glutathione reductase; [16]EC50 = Toxicity; [17]Macrofauna = Refer to macrofouling. * = Nine alien species molluscs were reported *Barbatia trapezina, Chama asperella, Chama brassica elatensis, Hyotissa hyotis, Isognomon ephippium, Leiosolenus hanleyanus, Malvufundus decurtatus, Parahyotissa imbricata, Plicatula chinensis, Septifer bilocularis*. ** = First record of blue jack mackerel, *Trachurus picturatus* T. E. Bowdich, 1825 (Osteichthyes: Carangidae). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

conservation (CEE review guidelines, 2013, Haddaway et al., 2016). Results with significant *p*-values were considered in selecting the evidence to extract, synthetise and discuss.

3. Results

We found a total of 191 sources corresponding to the search criteria defined in this study. Only 80 of these passed the title and abstract screenings and thus represented the amount of literature strictly related to our primary question (Fig. 1). A complete list of reviewed references is provided in the Supplementary Material section. In this dataset we looked at the range of publication year (temporal trend), the type of literature source and the proposed applied approach in dealing with the question (Fig. 2). Looking at the plotted temporal trend of retained literature sources, from 1989 to today, a positive increasing trend can be observed, with a peak in 2011 (Fig. 2a). Only 33% of screened sources is represented by grey literature (Fig. 2b: 7 "reports" - 3 project reports, 2 technical Working Group reports, 1 European Policy report and 1 from NGOs; several non ISI publication and conference proceedings). The majority of monitoring studies relied on field experiments; reviews have also been published, mainly suggesting the need for an integrated approach in monitoring; several modelling exercises have been performed on oil-spill and secondary products (drilling muds and waters) diffusion, and mesocosm experiments have focused on bio-essay, mostly based on macroinvertebrate sub-organismal responses. The biggest amount of field monitoring studies has been performed in the central Mediterranean basin, where the Italian peninsula represents a "focal drilling area", an area where most studies were examining drilling effects and where a lot of drilling takes place (Fig. 3, in dark grey). Several useful data from the literature are summarised in the infographics in Fig. 3. Evidence of the effects of drilling platforms on the marine ecosystem components was synthesised and described using a systematic map (Fig. 4). This main matrix contains all the evidence concerning these effects, plus the related measured responses (the remaining 57 sources at the end of the full text screening step). The maps identify the most surveyed components of the Mediterranean marine ecosystem, sediments and benthic macrofauna (both from natural and artificial substrata). They also focus on the most investigated descriptors (heavy metals, PAHs and grain size) and the most frequently measured biological responses. The suspension-feeder *Mytilus galloprovincialis* was the most used sentinel species to detect platforms' putative effects (see the bottom part of Fig. 4 for more details on each of the most studied species). Only two studies reported on non-indigenous species attracted to the vicinity of platform pillars, and only one analysed the trophic relationships within fish assemblages colonising drilling infrastructures. Overall, our analysis showed that almost 100% of studies on both abiotic and biotic components detected the effect sought at the beginning of the current study, although more focused on the biotic components (36%; see also histogram in Fig. 4, top left). Generally speaking, both the abiotic and biotic components were highly resilient and showed short recovery times. The map also flagged up gaps in research, revealing, for instance, the significantly low number of monitoring studies on the water column both in terms of physical and chemical measurements, and on the drilling muds and water based fluids. Most studies considered the population level variables (e.g. abundance), while relatively few used only sub-organismal variables (e.g. genotoxic damage).

4. Discussion

Evidence maps can be applied to a broad range of topics central to sustainable development (e.g. renewable energy, food security, disaster risk management, resources exploitation). The present work provided us with a snapshot of the current status of knowledge about the effects of oil and gas platform extraction activity on ecosystem components. Our evidence map enabled us to: (i) produce a credible summary of the effects of marine gas and oil platforms on the Mediterranean marine ecosystem (*sensu* Cash et al., 2003), (ii) organise a salient description of knowledge gaps and gluts (iii) inform public opinion and policy−makers by offering a relevant set of objective scientific evidence as an effective and active information, translation and mediation tool to apply to human-environmental systems.

Looking at the evidence obtained, we saw that although gas extraction is not yet well established in the Mediterranean Sea as a whole, the Adriatic shelf off the Italian Peninsula is crowded with platforms. Furthermore, despite the deeper waters and seismic activity, intensive prospecting surveys are currently being carried out in the south eastern Mediterranean Sea, while exploration and production are ongoing in the Black Sea (Katsanevakis et al., 2015).

A growing social interest in the effects of off-shore drilling platforms and, specifically, the peak in the amount of research published in 2011, might be due to two big disasters: the Deepwater Horizon (sank on 22 April 2010 in the Gulf of Mexico causing the largest oil spill in U.S. waters, an eruption of a slushy combination of drilling mud, methane gas, oil and water) and the Aban Pearl (first offshore gas state-owned rig operated in Venezuela, sank in May 2010). The huge impact of these two disasters on human health and ecosystems appears to have attracted the attention of scientists, stakeholders and public opinion alike (Camilli et al., 2010; Peres et al., 2016; Stefansson et al., 2016; Wade et al., 2016).

The greatest amount of evidence pertained to sediments, benthic invertebrates and fish communities. The sedimentary physical component grain size appeared to remain unaffected by the presence of platform infrastructures, even if the dynamic of water currents at the bottom of the drilling platform resulted influenced by the presence of these structures, creating potential erosion phenomena (Frascari et al., 2000). The presence of heavy metals and Polycyclic Aromatic Hydrocarbons (PAHs) represented the biggest effects on sediments, depending on the temporal and spatial scale considered. Some elements showed several anomalies (not linear in trend) in concentrations mainly in proximity to the anodes (e.g. cadmium; De Biasi et al., 2007; Gomiero et al., 2011). The macrobenthic communities, both in terms of infaunal specimens inhabiting the soft seabed around the platform's legs and the encrusting macrofouling species, decreased in terms of abundance and biomass. However, these communities seemed to display different structures with respect to control areas (Manoukian et al., 2010; Punzo et al., 2015). Overall, the powerful attraction of the submerged portions of the platforms, true hotspots of biodiversity, may be considered in a context of non-indigenous species (NIS) establishment, representing potential bridgeheads for new invasions, and focal areas that can drive and enhance the pathways of spread (Zenetos et al., 2005; Bolognini et al., 2015).

Knowledge gaps. The mapping exercise also highlighted knowledge gaps that must be filled and taken into due consideration before addressing future transnational and cross-border monitoring and management plans and activities. The growing interest showed by the extraction companies, as well as the emission of public consultations, underline the importance of producing independent scientific evaluation of the ecological effects and risks related to offshore drilling in the near future, replacing the reviews carried out or commissioned by the oil companies; these should, at least, take the gaps into account, as follows:

- The lack of knowledge about the **effects in the water columns** represents a particular gap in the Mediterranean context, where water masses are characterised by a low turnover time (Robinson et al., 1992).

- **Modelling studies** on the production diffusion and toxicity of drilling muds and Water Based Fluids (WBF), as well as risk analysis studies of oil-spill impact on the coasts should be encouraged, considering the semi-enclosed nature of the Mediterranean basin and the amount of cross-border rocky shores (Alves et al., 2014, 2015; Brenner, 2015).
- The effects on **algal and faunal meiobenthic communities** should be also studied, considering the accuracy of detecting responses by the latter component (Fraschetti et al., 2016).
- The **synergistic effects** with local and global stressors of an anthropogenic and climatic nature should be considered when planning future mesocosm "multiple stressor" studies to simulate the additive effects due to temperature or CO_2 increase (e.g. future climatic scenarios; IPCC, 2014), or rather shifts in oxygen rate to simulate seasonal localised deoxygenation phenomena, which are typical of the Mediterranean Sea (Turley, 1999; Diaz and Rosenberg, 2008; Kountoura and Zacharias, 2014).
- **Integrated studies** on a wide range of ecosystem components should be encouraged and systematically adopted to depict the Good Environmental Status (GES) of the ecosystems according to the Marine Strategy Framework Directive requirements (European Directive, 2008/56/EC) to produce accurate assessment of a heavily human-stressed area (D'Alessandro et al., 2016).
- The "**attractive effect**", i.e. the power to attract vagile fauna (e.g. fishes and marine mammals) mainly due to the refuges offered by platform infrastructures (Consoli et al., 2007, 2013; Fabi et al., 2002, 2004), should be investigated in depth by looking at the food web levels (Castriota et al., 2012). Studies on the ontogenetic transfer and magnification along the trophic food web up to the top predators should be encouraged (Corsolini et al., 2007).

Finally, the largest gap from a scientific point of view concerned the choice and selection of "control" sites when designing experimental studies. Unclear selection methods combined with the difficulty of disentangling autocorrelation phenomena (Fiorentino et al., 2012) can produce anomalies in measurement and responses of not easy understanding (Gomiero et al., 2015). Attention should be paid to both spatial and temporal monitoring scales, where using the widest and longest possible is recommended for reconstructing the recovery time of ecosystems (Fattorini et al., 2008).

Evidence for a global challenge: strengthening the science-policy nexus. Scientific knowledge remains largely untapped to the public and to policy makers (Doemeland and Trevino, 2014) due to the absence of a timely and definitive synthesis of evidence. This gap in science-policy communication can be narrowed by collating and describing all the available published research evidence on a topic in an objective, repeatable and transparent manner (i.e. systematic mapping, CEE, 2013). By cataloguing science-based knowledge, we here provided a set of knowledge gaps and gluts, and a credible, salient, legitimate baseline that is easily and quickly recognisable for decision-makers (Cash et al., 2003). This will strengthen the science-policy nexus, i.e. the relationship between environment-related science and policy (*sensu* Hickey et al., 2013). Our systematic map may be easily presented during focus groups within various target groups (e.g. scientists, policy-makers, the public) representing the contextualised knowledge required to support a discussion circle and to strengthen a culture of policy-relevant research and evidence-based policy on the environment (Hickey et al., 2013). The proposed approach provides a rigorous way of translating scientific information into Knowledge Dissemination Interventions (Lafrenière et al., 2013) to create, promote and encourage dialogue and cooperation between knowledge producers (scientists), knowledge users (policy-makers) and end-users (the public) for sustainable development.

Interdisciplinary and international working groups such as SNAP - Science for Nature and People Partnership (http://snappartnership.net/), are underlining the need to broadly apply evidence mapping to sustainable development. We welcome this challenge, as the need is clear and, moreover, we are keen to readdress this advice in a Mediterranean context. The Mediterranean Sea is a semi-enclosed basin hosting 8% of global marine species, amongst which are several endangered and vulnerable allocated for protection (UNEP-MAP, 2010). Furthermore, it is a "busy" sea with a high rate of human disturbance (e.g. Coll et al., 2010; Mangano et al., 2015a,b) that has existed for a long time, with very little consideration for sustainability (Claudet and Fraschetti, 2010; Coll et al., 2012). It is also a melting pot of cultures and the cross-border conflicts this can produce. The generation of free available and updated maps has been proposed as a useful tool to help researchers to track progress in plugging knowledge gaps (McKinnon et al., 2015), and to drive decision-makers, stakeholders and public opinion in taking evidence-based decisions. Additionally, in a context of global change, the collection of information on the most effective interventions, measures and strategies for sustainable development may be a challenging solution, also for the Mediterranean arena, and may help, both to produce policy roadmaps and help the public to understand scientific progress and knowledge (Lu et al., 2015).

Competing financial interests

The authors declare no competing financial interests.

Author contributions

Both authors equally contributed to all phases of this study.

Acknowledgements

PRIN TETRIS 2010 grant n. 2010PBMAXP_003, funded by the Italian Minister of Research and University (MIU) supported this research. We thank the critical mass represented by the all the UDU Student Association at the University of Palermo for their kind invitation to chair a public speech in occasion of the recent Italian technical referendum that generated this moment of reflection. The authors would like to recognise the inspiring time spent at the Centre for Evidence Based Conservation (CEBC, Bangor University) learning on systematic review tools and evidence-based conservation. We would also like to thank two anonymous reviewers for their effort in providing useful insights which improved the original version of the ms.

Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.jenvman.2016.12.013.

References

Alves, T.M., Kokinou, E., Zodiatis, G., 2014. A three-step model to assess shoreline and offshore susceptibility to oil spills: the South Aegean (Crete) as an analogue for confined marine basins. Mar. Pollut. Bull. 86 (1), 443–457.
Alves, T.M., Kokinou, E., Zodiatis, G., Lardner, R., Panagiotakis, C., Radhakrishnan, H., 2015. Modelling of oil spills in confined maritime basins: the case for early response in the Eastern Mediterranean Sea. Environ. Pollut. 206, 390–399.
Bayliss, H.R., Schindler, S., Essl, F., Rabitsch, W., Pullin, A.S., 2015. What evidence

exists for changes in the occurrence, frequency or severity of human health impacts resulting from exposure to alien invasive species in Europe? A systematic map protocol. Environ. Evid. 4 (1), 1.
Bilotta, G.S., Milner, A.M., Boyd, I., 2014. On the use of systematic reviews to inform environmental policies. Environ. Sci. Policy 42, 67–77.
Bolognini, L., Domenichetti, F., Grati, F., Polidori, P., Scarcella, G., Fabi, G., 2015. New record of the blue jack mackerel, Trachurus picturatus TE Bowdich, 1825 (Osteichthyes: Carangidae) from the northern Adriatic sea. Acta Adriat. 56 (2), 305–307.
Bottrill, M., Cheng, S., Garside, R., Wongbusarakum, S., Roe, D., Holland, M.B., et al., 2014. What are the impacts of nature conservation interventions on human well-being: a systematic map protocol. Environ. Evid. 3 (1), 1.
Brenner, S., 2015. Oil spill modeling in the southeastern Mediterranean Sea in support of accelerated offshore oil and gas exploration. Ocean. Dyn. 65 (12), 1685–1697.
Camilli, R., Reddy, C.M., Yoerger, D.R., Van Mooy, B.A., Jakuba, M.V., Kinsey, J.C., et al., 2010. Tracking hydrocarbon plume transport and biodegradation at Deepwater Horizon. Science 330 (6001), 201–204.
Cash, D.W., Clark, W.C., Alcock, F., Dickson, N.M., Eckley, N., Guston, D.H., et al., 2003. Knowledge systems for sustainable development. Proc. Natl. Acad. Sci. 100 (14), 8086–8091.
Castriota, L., Falautano, M., Finoia, M.G., Consoli, P., Pedà, C., Esposito, V., et al., 2012. Trophic relationships among scorpaeniform fishes associated with gas platforms. Helgol. Mar. Res. 66 (3), 401–411.
CEE (Collaboration for Environmental Evidence), 2013. Guidelines for Systematic Review and Evidence Synthesis in Environmental Management. Version 4.2. Environmental Evidence: http://environmentalevidence.org/Documents/Guidelines/Guidelines4.2.pdf.
Claudet, J., Fraschetti, S., 2010. Human-driven impacts on marine habitats: a regional meta-analysis in the Mediterranean Sea. Biol. Conserv. 143 (9), 2195–2206.
Coll, M., Piroddi, C., Steenbeek, J., Kaschner, K., Lasram, F.B.R., Aguzzi, J., et al., 2010. The biodiversity of the Mediterranean Sea: estimates, patterns, and threats. PloS One 5 (8), e11842.
Coll, M., Piroddi, C., Albouy, C., Ben Rais Lasram, F., Cheung, W.W., Christensen, V., et al., 2012. The Mediterranean Sea under siege: spatial overlap between marine biodiversity, cumulative threats and marine reserves. Glob. Ecol. Biogeogr. 21 (4), 465–480.
Consoli, P., Azzurro, E., Sarà, G., Ferraro, M., Andaloro, F., 2007. Fish diversity associated with gas platforms: evaluation of two underwater visual census techniques. Ciencias Marinas 33 (2).
Consoli, P., Romeo, T., Ferraro, M., Sarà, G., Andaloro, F., 2013. Factors affecting fish assemblages associated with gas platforms in the Mediterranean Sea. J. Sea Res. 77, 45–52.
Corsolini, S., Sarà, G., Borghesi, N., Focardi, S., 2007. HCB, p, p'-DDE and PCB ontogenetic transfer and magnification in bluefin tuna (Thunnus thynnus) from the Mediterranean Sea. Environ. Sci. Technol. 41 (12), 4227–4233.
D'Alessandro, M., Esposito, V., Giacobbe, S., Renzi, M., Mangano, M.C., Vivona, P., et al., 2016. Ecological assessment of a heavily human-stressed area in the Gulf of Milazzo, Central Mediterranean Sea: an integrated study of biological, physical and chemical indicators. Mar. Pollut. Bull. 106 (1), 260–273.
De Biasi, A.M., Fabi, G., Pacciardi, L., Puletti, M., 2007. Heavy metals and polyciclic aromatic hydrocarbons near an off-shore gas-platform (Adriatic Sea): a 3-year monitoring study. Atti Soc. Toscana Sci. Nat. Mem. Ser. B 114, 23–33.
Diaz, R.J., Rosenberg, R., 2008. Spreading dead zones and consequences for marine ecosystems. Science 321 (5891), 926–929.
Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008.
Doemeland, D., Trevino, J., 2014. Which World Bank Reports Are Widely Read? World Bank Policy Research Working Paper, (6851).
Fabi, G., Grati, F., Lucchetti, A., Trovarelli, L., 2002. Evolution of the fish assemblage around a gas platform in the northern Adriatic Sea. ICES J. Mar. Sci. J. du Conseil 59 (Suppl. l), S309–S315.
Fabi, G., Grati, F., Puletti, M., Scarcella, G., 2004. Effects on fish community induced by installation of two gas platforms in the Adriatic Sea. Mar. Ecol. Prog. Ser. 273, 187–197.
Fattorini, D., Notti, A., Di Mento, R., Cicero, A.M., Gabellini, M., Russo, A., Regoli, F., 2008. Seasonal, spatial and inter-annual variations of trace metals in mussels from the Adriatic sea: a regional gradient for arsenic and implications for monitoring the impact of off-shore activities. Chemosphere 72 (10), 1524–1533.
Fiorentino, D., Caruso, T., Terlizzi, A., 2012. Spatial autocorrelation in the response of soft-bottom marine benthos to gas extraction activities: the case of amphipods in the Ionian Sea. Mar. Environ. Res. 79, 79–85.
Fisher, B., Balmford, A., Ferraro, P.J., Glew, L., Mascia, M., Naidoo, R., Ricketts, T.H., 2014. Moving Rio forward and avoiding 10 more years with little evidence for effective conservation policy. Conserv. Biol. 28, 880–882.
Frascari, F., Marcaccio, M., Spagnoli, F., Modica, A., 2000. Effects of offshore drilling activities on the geochemical and sedimentological processes in the Northern Adriatic coastal area. Period. Biol. 102, 225–241.
Fraschetti, S., Guarnieri, G., Gambi, C., Bevilacqua, S., Terlizzi, A., Danovaro, R., 2016. Impact of offshore gas platforms on the structural and functional biodiversity of nematodes. Mar. Environ. Res. 115, 56–64.
Gomiero, A., De Biasi, A.M., Da Ros, L., Nasci, C., Spagnolo, A., Scarcella, G., Fabi, G., 2011. A multidisciplinary approach to evaluate the environmental impact of offshore gas platforms in the western Adriatic Sea. Chem. Ecol. 27 (Suppl. 2), 1–13.
Gomiero, A., Volpato, E., Nasci, C., Perra, G., Viarengo, A., Dagnino, A., et al., 2015. Use of multiple cell and tissue-level biomarkers in mussels collected along two gas fields in the northern Adriatic Sea as a tool for long term environmental monitoring. Mar. Pollut. Bull. 93 (1), 228–244.
Haddaway, N.R., Bernes, C., Jonsson, B.G., Hedlund, K., 2016. The benefits of systematic mapping to evidence-based environmental management. Ambio 1–8.
Herrick, C., Sarewitz, D., 2000. Ex Post Evaluation: AMore Effective Role for Scientific Assessments in Environmental Policy, Science, Technology, and Human Values, vol. 25, pp. 309–331.
Hickey, G.M., Forest, P., Sandall, J.L., Lalor, B.M., Keenan, R.J., 2013. Managing the Environmental Science–policy Nexus in Government: Perspectives from Public Servants in Canada and Australia. Science and Public Policy sct004.
Katsanevakis, S., Levin, N., Coll, M., Giakoumi, S., Shkedi, D., Mackelworth, P., et al., 2015. Marine conservation challenges in an era of economic crisis and geopolitical instability: the case of the Mediterranean Sea. Mar. Policy 51, 31–39.
Kountoura, K., Zacharias, I., 2014. Annual hypoxia dynamics in a semi-enclosed Mediterranean gulf. J. Mar. Syst. 139, 320–331.
Lafrenière, D., Menuz, V., Hurlimann, T., Godard, B., 2013. Knowledge dissemination interventions. SAGE Open 3 (3), 2158244013498242.
Lu, Y.L., Nakicenovic, N., Visbeck, M., Stevance, A.S., 2015. Five priorities for the UN sustainable development Goals (vol 520, pg 432, 2015). Nature 521 (7550), 28–28.
Mangano, M.C., Kaiser, M.J., Porporato, E.M.D., Lambert, G.I., Spanò, N., 2015a. Trawling disturbance effects on the trophic ecology of two co-generic Astropectinid species. Mediterr. Mar. Sci. 16 (3), 538–549.
Mangano, M.C., O'Leary, B.C., Mirto, S., Mazzola, A., Sarà, G., 2015b. The comparative biological effects of spatial management measures in protecting marine biodiversity: a systematic review protocol. Environ. Evid. 4 (1), 1.
Manoukian, S., Spagnolo, A., Scarcella, G., Punzo, E., Angelini, R., Fabi, G., 2010. Effects of two offshore gas platforms on soft-bottom benthic communities (northwestern Adriatic Sea, Italy). Mar. Environ. Res. 70 (5), 402–410.
McKinnon, M., et al., 2015. Map the evidence. Comment Nat. 528, 185–187.
OSPAR Commission, 2009. Assessment of Impacts of Offshore Oil and Gas Activities in the North-East Atlantic. OSPAR Commission, London.
Pachauri, R.K., Allen, M.R., Barros, V.R., Broome, J., Cramer, W., Christ, R., et al., 2014. Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC).
Peres, L.C., Trapido, E., Rung, A.L., Harrington, D.J., Oral, E., Fang, Z., et al., 2016. The Deepwater Horizon Oil Spill and Physical Health Among Adult Women in Southern Louisiana: the Women and Their Children's Health (WaTCH) Study. Environ Health Perspect.
Pullin, A.S., 2012. Realising the potential of environmental data: a call for systematic review and evidence synthesis in environmental management. Environ. Evid. 1 (1), 1.
Pullin, A.S., Bangpan, M., Dalrymple, S., Dickson, K., Haddaway, N.R., Healey, J.R., et al., 2013. Human well-being impacts of terrestrial protected areas. Environ. Evid. 2 (1), 1.
Punzo, E., Strafella, P., Scarcella, G., Spagnolo, A., De Biasi, A.M., Fabi, G., 2015. Trophic structure of polychaetes around an offshore gas platform. Mar. Pollut. Bull. 99 (1), 119–125.
Robinson, A.R., Malanotte-Rizzoli, P., Hecht, A., Michelato, A., Roether, W., Theocharis, A., et al., 1992. General circulation of the eastern Mediterranean. Earth Sci. Rev. 32 (4), 285–309.
Sarà, G., 2007. A meta-analysis on the ecological effects of aquaculture on the water column: dissolved nutrients. Mar. Environ. Res. 63 (4), 390–408.
Sciberras, M., Jenkins, S.R., Mant, R., Kaiser, M.J., Hawkins, S.J., Pullin, A.S., 2015. Evaluating the relative conservation value of fully and partially protected marine areas. Fish Fish. 16 (1), 58–77.
Snilstveit, B., Vojtkova, M., Bhavsar, A., Gaarder, M., 2013. Evidence Gap Maps—a Tool for Promoting Evidence-informed Policy and Prioritizing Future Research. World Bank Policy Research Working Paper, (6725).
Stefansson, E.S., Langdon, C.J., Pargee, S.M., Blunt, S.M., Gage, S.J., Stubblefield, W.A., 2016. Acute effects of non-weathered and weathered crude oil and dispersant associated with the deepwater horizon incident on the development of marine bivalve and echinoderm larvae. Environ. Toxicol. Chem. http://dx.doi.org/10.1002/etc.3353.
Turley, C.M., 1999. The changing Mediterranean Sea—a sensitive ecosystem? Prog. Oceanogr. 44 (1), 387–400.
UNEP-MAP RAC/SPA, 2010. In: By Bazairi, H., Ben Haj, S., Boero, F., Cebrian, D., De Juan, S., Limam, A., Lleonart, J., Torchia, G., Rais, C. (Eds.), The Mediterranean Sea Biodiversity: State of the Ecosystems, Pressures, Impacts and Future Priorities. RAC/SPA, Tunis, p. 100.
Wade, T.L., Sericano, J.L., Sweet, S.T., Knap, A.H., Guinasso, N.L., 2016. Spatial and temporal distribution of water column total polycyclic aromatic hydrocarbons (PAH) and total petroleum hydrocarbons (TPH) from the Deepwater Horizon (Macondo) incident. Mar. Pollut. Bull. 103 (1–2), 286–293.
Zenetos, A., Çinar, M.E., Pancucci-Papadopoulou, M.A., Harmelin, J.G., Furnari, G., Andaloro, F., et al., 2005. Annotated list of marine alien species in the Mediterranean with records of the worst invasive species. Mediterr. Mar. Sci. 6 (2), 63–118.