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Assessment of goods and services, vulnerability, and conservation status of European seabed biotopes: a stepping stone towards ecosystem-based marine spatial management

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Abstract

The goal of ecosystem-based marine spatial management is to maintain marine ecosystems in a healthy, productive and resilient condition; hence, they can sustainably provide the needed goods and services for human welfare. However, the increasing pressures upon the marine realm threaten marine ecosystems, especially seabed biotopes, and thus a well-planned approach of managing use of marine space is essential to achieve sustainability. The relative value of seabed biotopes, evaluated on the basis of goods and services, is an important starting point for the spatial management of marine areas. Herein, 56 types of European seabed biotopes and their related goods, services, sensitivity issues, and conservation status were compiled, the latter referring to management and protection tools which currently apply for these biotopes at European or international level. Fishing activities, especially by benthic trawls, and marine pollution are the main threats to European seabed biotopes. Increased seawater turbidity, dredged sediment disposal, coastal constructions, biological invasions, mining, extraction of raw materials, shipping-related activities, tourism, hydrocarbon exploration, and even some practices of scientific research, also exert substantial pressure. Although some first steps have been taken to protect the European sea beds through international agreements and European and national legislation, a finer scale of classification and assessment of marine biotopes is considered crucial in shaping sound priorities and management guidelines towards the effective conservation and sustainability of European marine resources.

Keywords: Ecosystem services; marine habitats; protection; sustainability; Europe.

Introduction

Although much political and scientific emphasis has been given to the identification, mapping and ecological monitoring of terrestrial and freshwater ecosystems, difficulties such as the inaccessibility and the inherent biological complexity have resulted in significant knowledge and management gaps in marine ecosystems (Fraschetti *et al*., 2008; 2011; Brown *et al*., 2011). At the same time, increased competition for marine resources and human activities have caused the degradation of the quality status of the marine environment, thus inducing an urgent need for holistic, planned approaches to managing our seas (Fraschetti *et al*., 2008; 2011).

Ecosystem-based marine spatial management (EB-MSM) aims to supply a general framework and strategic tools for the sustainable development of seas and coasts by combining an optimized use with a sustained ecosystem of high quality (Katsanevakis *et al*., 2011a). To this end, mapping biologically and ecologically important areas together with their associated human uses and political and legal arrangements has been emphasized as an important first step (Crowder & Norse, 2008; Ehler & Douvere, 2009).

The goal of EB-MSM is to maintain marine ecosystems in a healthy, productive and resilient condition; hence, they can sustain human uses of the ocean and provide the needed goods and services for human welfare (Foley *et al*., 2010; Katsanevakis *et al*., 2011a). However, the increasing pressures upon the marine realm (Halpern *et al*., 2008) call for a well-planned approach of managing use of marine space to achieve the sustainability of goods and services provided by marine ecosystems. The relative value of seabed biotopes, evaluated on the basis of the goods and services they provide, is an important basis for the spatial management of marine areas (Rönnbäck *et al*., 2007). The assignment of meaningful values to biophysical features of the marine environment allows the direct assessment of related management choices. The concept of total economic value is now widely accepted (Pearce, 1989); it consists of the sum of all market and non-market values in the environment. The distribution of values is complex and EB-MSM will potentially alter their distribution. Hence, a stepping stone for effective EB-MSM is the assessment of all marine biotopes in terms of goods and services provided and their sensitivity to human activities. This knowledge will also allow implementing the Marine Strategy Framework Directive (MSFD), especially regarding some of the 11 descriptors which need to be investigated, including biodiversity and seafloor integrity (Borja *et al*., 2010; Van Hoey *et al*., 2010; Rice *et al*., 2012). This knowledge has already started to be used in assessing the environmental status in some regional seas (Borja *et al*., 2011).

The seas around Europe are home to an exceptionally wide range of marine biotopes and their associated biodiversity (Fraschetti *et al*., 2008). So far, information on goods and services provided by European seabed biotopes, their sensitivity to human activities, and their conservation status was rather scattered (Atkins *et al*., 2011). The aim of the present review is to provide a compilation of such information for most European seabed biotopes. Such a review will be a valuable tool for EB-MSM and the application of marine spatial plans in the European regional Seas.

Materials and Methods

There is a dispute and confusion in the scientific community on the use of the terms 'biotope' and 'habitat' (Dauvin *et al*., 2008a;b). A biotope was originally defined by Dahl (1908) as a complex of factors, which determine physical conditions of existence of a biocoenosis. As such, biotope and biocoenosis were respectively considered as the abiotic and biotic parts of an ecosystem. This original concept was widely used, until the 1990's, when a new definition of biotope emerged in the context of classifying marine habitats in the coastal zone. In that sense, a biotope was defined as the combination of an abiotic habitat and its associated community or assemblage of species (Connor *et al*., 2004; Costello, 2009; Davies *et al*., 2004). Although the classical definition of habitat has been "the locality in which a plant or animal naturally lives" (Darwin, 1859), today the term is rather defined as an 'organism-environment complex', i.e. a recognizable space which can be distinguished by its physical characteristics and associated biological assemblage, the most striking such example lying in the EU Habitats Directive 92/43/EC (EC, 1992). In that sense the two terms are currently used as synonyms. Herein, we adopted the term 'biotope', representing distinct benthic complexes which, sharing common biological characteristics, may be collectively addressed for management and conservation purposes.

All benthic biotopes considered in this review were identified and classified according to the European Nature Information System (EUNIS, 2002). The EUNIS database (http://eunis.eea.europa.eu) comprises, among others, a large variety of ecosystem units (from natural to artificial, from terrestrial to freshwater and marine, from coastal to deep waters, etc.) and their associated flora and fauna. Although several other regional classification systems do exist (see for example Dauvin *et al*., 2008b; Fraschetti *et al*., 2011 and references therein), often allowing for more refined approaches (e.g. Bianchi *et al*., 2010), the EUNIS strong point lies in that it provides a comprehensive hierarchical pan-European framework, which facilitates the harmonized description and collection of data across Europe (EUNIS, 2002). Still, for most of these benthic sub-categories either no information or very limited data had so far been provided, a fact which is even more pronounced for the Mediterranean, the Black Sea (Pontic), and the deep seabed. This review focuses on sublittoral, fully marine EUNIS habitat types at level-4 and beyond (EUNIS, 2002), leaving out intertidal, brackish and freshwater habitats. As, by definition, habitat types at EUNIS level-4 and beyond are determined by both their biotic and abiotic features, they are hereby addressed as 'biotopes'.

In total, 56 biotopes at EUNIS level-4 were assessed, 2 of which are newly inserted for the Black Sea (Pontic biotopes). The names used to describe each biotope are the currently accepted EUNIS titles, as they appear in the official (online) database. For newly inserted biotopes and sub-biotopes, optional names and numberings - indicated by an asterisk (*) - were proposed. All existing and readily available information on the biotopes' goods and services, sensitivity to human activities (reported or anticipated threats jeopardizing the biotopes' existence or ecological status), and conservation and protection status (current protection and management tools which apply for each biotope at international and European level, as well as any critical issues and general recommendations to address management purposes) was herein compiled.

Goods and services were classified based on an adaptation of the categories proposed by MEA (2003) and Beaumont *et al*. (2007), and rated into three major evaluation classes "*High"*, *"Low"*, "*Negligible / Irrelevant / Unknown*". No absolute metric was used to classify goods and services of each biotope into one of these classes; evaluation was based on expert judgement and the following guidelines: when the provision of a specific service is well documented in the scientific literature and is widely accepted as important, it was classified as *High* (e.g. the role of seagrass beds in sediment retention and prevention of coastal erosion, which is vital in many coastal areas); when a service is or could be provided by a biotope but to a substantially lower magnitude than by other biotopes and without being vital for the persistence of an important human activity, it was classified as *Low*; in all other cases goods and services were classified as *Negligible / Irrelevant / Unknown*. The goods and services categories used herein are given in detail in Annex 1.

Mediterranean and Pontic communities of infralittoral algae very exposed to wave action (EUNIS A3.13)

Goods and Services: This biotope is extremely rich as regards both quality and quantity, containing several hundred species. Its production is great and its biomass can attain several kilograms per square meter. Its seasonal dynamics are strong. The trophic network it supports is particularly complex and opens onto other habitats by exporting organisms and organic matter. Infralittoral algae provide significant food source for a great number of fish species either directly, or indirectly, by dispersing vegetal and animal detritus into adjacent areas. Several species of this biotope are characterized by increased nutrient and CO_2 uptakes (Gao & McKinley, 1994), as well as a high capacity for heavy metal biosorption (e.g. Davis *et al.*, 2003), presenting thus a great potential as bioremediators. Exploitation of sea urchins and natural mussel beds also takes place here.

Sensitivity to human activities: This biotope includes associations that are very sensitive to pollution; such is the case of many *Cystoseira* species (e.g. *Cystoseira amentacea stricta*) which are considered to be excellent indicators of seawater quality and their disappearance may often be linked to pollution increase (Orfanidis *et al*., 2003; Ballesteros *et al*., 2007). Associations of this biotope are also quite sensitive to suspended load, the reason being twofold: turbid water decreases photosynthesis and thus affects the algal populations; sedimentation fills in the microcavities in between the algal thalli and eliminates small cryptic fauna. However, sensitivity to these disturbance factors may be influenced or minimized by the naturally increased disturbance regime (i.e. physical disturbance, hydrodynamism). The biotope is subject to the invasion of several introduced species (*Caulerpa taxifolia*, *C. racemosa* v. *cylindracea*, *Stypopodium schimperi*), which may harm or even outcompete native communities. The ichthyofauna that occurs in this biotope is diverse and rich; it is thus subject to heavy pressures from commercial and leisure fishing activities.

Conservation and protection status: Reefs are NATURA-1170 habitat types listed under the EU Habitats Directive 92/43/EC (*hereafter*: Habitats Directive). This biotope is also listed as endangered in the Resolution no. 4, Council of Bern Convention (1996): *Sublittoral rocky seabeds and kelp forests* (code 11.24).

Kelp and red seaweeds (moderate energy infralittoral rock) (EUNIS A3.21)

Goods and Services: Although it contributes much in regulating climatically active gases, the processes involved in providing this service, the rate at which it is delivered, and the spatial scales required, are yet unknown for this particular biotope. The overall estimated value of this service provided by the UK marine environment is between £41 million - £4 billion (Beaumont *et al*., 2006). Nutrient cycling, waste treatment, food provision and biological control are also important services provided by this and other marine biotopes (Paramor & Frid, 2006; Beaumont *et al*., 2006). These services however may be significantly reduced by the removal of kelp, which in some countries (e.g. France) are commercially harvested. The kelp beds provide a physically complex habitat for juvenile fish (Gaines & Roughgarden, 1987; Henriques & Almada, 1998). This biotope is also of importance for recreational divers and anglers, contributing to an estimated value of £11.7 billion for the UK alone (Beaumont *et al*., 2006). The *Laminaria hyperborea* biotope supports diverse and abundant invertebrate communities. The invertebrate fauna supported by NE Atlantic kelps is dominated by crustaceans and molluscs (Christie *et al*., 2003; Moore, 1972; Schultze *et al*., 1990). Invertebrate abundance is particularly high in the kelp holdfasts and associated with epiphytes on the stipes (Norderhaug *et al*., 2002). A study by Christie *et al*. (2003) showed that 56 individual *Laminaria hyperborea* specimens supported 238 species, with an average density of almost 8000 individuals per kelp.

Sensitivity to human activities: This biotope is sensitive to physical disturbance and is likely to be particularly sensitive to activities which may increase the turbidity of the water column. The main threats to the biotope and the biological community it supports include: smothering (e.g. by disposal of dredge spoil), suspended sediment (e.g. run-off, dredging, outfalls), nutrient enrichment (e.g. agricultural run-off, outfalls), organic enrichment (e.g. mariculture, outfalls), introduction of microbial pathogens, introduction of non-native species and translocations, selective extraction of species (e.g. commercial and recreational fishing). Other threats may include substratum loss (e.g. by permanent constructions), selective extraction (e.g. aggregate dredging, entanglement), abrasion (e.g. boating, anchoring), introduction of synthetic compounds (e.g. pesticides, antifoulants, PCBs), and introduction of non-synthetic compounds (e.g. heavy metals, hydrocarbons). Following mass mortalities associated with oil spills, recovery can occur within 1-2 years for wave exposed intertidal rocky reefs and 7-10 years for more sheltered shores (Frid, pers. obs.). Impacts that affect kelp are likely to affect the biotope's functions and goods and services most adversely.

Conservation and protection status: Included in the Annex I of the Habitats Directive under the code 1170 (*Reefs*). The biotope is also listed as endangered in the Resolution no. 4, Council of Bern Convention (1996): *Sublittoral rocky seabeds and kelp forests* (code 11.24).

Mediterranean and Pontic communities of infralittoral algae moderately exposed to wave action (EUNIS A3.23)

Goods and Services: Marine benthic macrophytes are ecosystem engineers, which provide structural base for many coastal habitats and associated food webs (McRoy & Lloyd, 1981; Orfanidis *et al*., 2001). This is especially true for large perennial algae as are species of the order Fucales and Laminariales (Lüning, 1990; Arevalo *et al*., 2007). These communities are known to host a large variety of algal and animal epiphytes, and provide shelter, food and nursery grounds for numerous fish and invertebrate species (Lüning, 1990; Thibaut *et al*., 2005). Coastal macroalgae have been estimated to contribute to about one tenth of the world's marine primary production (Charpy-Roubaud & Sournia, 1990). As sessile organisms they integrate and respond rapidly and predictably to nutrient pollution and other environmental impacts, thus serving as sensitive bioindicators of water quality (Orfanidis *et al*., 2003; Arevalo *et al*., 2007; Ballesteros *et al*., 2007). Moreover, this biotope constitutes a well-defined system, easily accessible and able to express the anthropogenic stress in long-term environmental quality monitoring studies, as foreseen in the Water Framework Directive (Panayotidis *et al*., 2004; Ballesteros *et al*., 2007). Algae have been harvested or cultivated for human and animal food as well as fertilizers for centuries. Much of their economic value however seems yet to lie in their high potential as sources of long- and short-chain chemicals with wide medicinal and industrial uses (Guiry & Blunden, 1991), as well as their high potential for environmental and industrial bioremediation (Davis *et al*., 2003).

Sensitivity to human activities: Many researchers have observed the degradation or complete regression of macroalgal infralittoral communities under various anthropogenic disturbances (Thibaut *et al*., 2005 and references therein). *Cystoseira* populations, in particular, have been often described as especially susceptible to increased pollution levels (Charpy-Roubaud & Sournia, 1990, Panayotidis *et al*., 1999). Water turbidity and habitat destruction due to the proliferation of coastal structures pose also a serious threat to this biotope (Cormaci & Furnari, 1999). Mechanical disturbance, i.e. human trampling in shallow and crowded coastal areas, collection of specimens for scientific purposes, and net fishing in deeper zones can be particularly destructive, especially so for those algal species with long life spans, low recruitment levels, and low growth rates (Thibaut *et al*., 2005 and references therein). Destructive fishing practices, such as date mussel (*Lithophaga lithophaga*) harvesting (conducted by breaking rocky substrata with sledgehammers), cause direct damages to benthic assemblages by eradicating sessile animals and algae, alter biotic interactions, and favour the persistence of rocky barrens (Parravicini *et al*., 2010a; Guidetti, 2011). Similar devastating effects may result from other illegal -yet locally persistent- fishing practices, i.e. blast-fishing and the use of poisons (Guidetti *et al*., 2003). Sea urchin population blooms -as an indirect effect of overfishing - have also been described as a factor contributing to the disappearance of *Cystoseira* assemblages and other canopy-forming algae in the infralittoral zone (Sala *et al*., 1998; Hereu, 2006). Furthermore, similar disappearances were recently ascribed to overgrazing by the herbivorous lessepsian fish species *Siganus* spp. in the Eastern Mediterranean basin (Sala *et al*., 2011).

Conservation and protection status: The algal communities of the upper infralittoral zone are included in the Annex I of the Habitats Directive under the code 1170 (*Reefs*) as well as the Bern Convention under the code 11.24 (*Sublittoral rocky seabeds and kelp forests*). To prevent a large scale degradation of this biotope, the date mussel fishery was banned in the EU and most non-EU Mediterranean countries. However, even within the EU, illegal date mussel fishing is still practiced (Katsanevakis *et al*., 2011b).

Faunal communities on moderate energy infralittoral rock (EUNIS A3.24)

Goods and Services: Mussels can be harvested for food and bait, although this is mostly a recreational, rather than a commercial activity. Natural mussel beds provide seed for mussel culture, which has become a fast-growing industry. Some artisanal and subsistence fishery for gobies take place in this biotope and, locally, small scale harvest for the crab *Eriphia verrucosa* may exist. Potentially, the piddock *Pholas dactylus* and the date mussel *Lithophaga lithophaga* may be harvested or cultured. *Mytilus* beds on infralittoral rock, in particular, constitute an important biotope due to their crucial contribution in the ecosystem's self-cleansing capacity and the benthic-pelagic coupling. The biological production of this biotope can exceed 10 kg m^{-2}, with a complex food web, which links it to several other biotopes (Bacescu *et al*., 1971). They are also important feeding and nursery grounds, as well as refuges for many commercially valuable fish species, and they provide much of the biofiltering capacity essential for maintaining the quality of coastal waters. *Mytilus* is an important food source for demersal fishes (gobbies, flounder), crabs and the predatory alien whelk *Rapana venosa*. Furthermore, mussel eggs and larvae are probably an important food source for pelagic fish larvae and zooplankton.

Sensitivity to human activities: Generally, epifaunal communities are sensitive to substratum loss and displacement, physical disturbance and abrasion. Most of the characteristic species on infralittoral rock are permanently attached and will not re-attach after displacement. Therefore the biotope will not recover through re-attachment but through new settlement. Some *Mytilus* species are capable of re-attaching themselves, however decrease in mussel bed coverage would result in decreased species richness of the associated fauna. Mussel beds can be extremely prone to biological invasions as has been the case for the invasive alien gastropod *R. venosa* which caused complete obliteration of mussels and subsequent loss of the associated community in the Black Sea (Micu & Todorova, 2007). Many *Mytilus* species are rather tolerant to hypoxia, therefore able to thrive in eutrophicated conditions. They are also relatively tolerant to various chemical and hydrocarbon contaminants. *P. dactulus* and *L. lithophaga,* some of the key structuring species of this biotope, are highly intolerant to substratum loss and displacement because once removed from their burrows they cannot excavate a new chamber and are thus unlikely to survive. These species are also intolerant to synthetic compound contamination. *P. dactulus* and *L. lithophaga* are harvested by the use of a hammer and chisel, a practice that has had a devastating impact on this biotope and has now been banned throughout the Mediterranean. However, both species are still harvested and served illegally in many restaurants and fish markets (Katsanevakis *et al*., 2011b).

Conservation and protection status: *Reefs* are NATURA-1170 habitat types listed under the Annex I of the Habitats Directive. *P. dactulus* and *L. lithophaga,* in particular, are protected by the Bern and Barcelona conventions, enforced by local legislations.

Mediterranean submerged fucoids, green or red seaweeds on full salinity infralittoral rock (EUNIS A3.33)

Goods and Services: This biotope is extremely rich both in biodiversity and abundance, hosting several hundreds of species. It is also considered highly productive as its biomass can attain several kilograms per square meter. The biotope is characterized by strong seasonal dynamics and a highly complex trophic network which also supports several other biotopes by dispersion of organisms and organic matter. Comprising various seaweeds and animals, it offers a valuable food source to many commercially and otherwise important fish species. Many algal species that abound in this biotope have been described as highly efficient in removing nutrients, CO_2, and heavy metals from the seawater (Gao & McKinley, 1994; Davis *et al*., 2003).

Sensitivity to human activities: Being directly subject to various human activities, this biotope is especially prone to impacts such as coastal pollution (urban, agricultural, industrial, fish-farming, etc.), coastal zone development (particularly urbanization and uncontrolled coastal infrastructures) and episodic perturbations (i.e. sedimentation, sediment removal and illegal dumping of wreckages), as well as the deliberate or accidental introduction of alien and potentially invasive species.

Conservation and protection status: This biotope is part of the wider *Reef* NATURA-1170 habitat type (Annex I of the Habitats Directive). It is also part of the *Sublittoral rocky seabeds and kelp forests* (code 11.24), listed as endangered in the Resolution no. 4 of the Council of Bern Convention (1996).

Robust faunal cushions and crusts in surge gullies and caves (EUNIS A3.71)

Goods and Services: Apart from some crabs (i.e. *Cancer pagurus*, *Eriphia verrucosa*) and the lobsters (*Palinurus elephas, Homarus gammarus*) that can be taken from deep recesses under overhangs, few other species are likely to be subject to exploitation. Rocky shores features such as caves, overhangs and gullies provide opportunities for recreation and tourism, enjoyment of natural heritage, aesthetic and spiritual experience, inspiration for art, scientific research and cognitive development. The faunal assemblage is dominated by active suspension feeders that transfer pelagic phytoplanktonic primary production to secondary production, and together with other rocky shore habitats contributes for the nutrient cycling and water quality regulation in coastal environments.

Sensitivity to human activities: Substratum loss due to direct destruction by human modifications of the coastline will result in loss of the associated community. Generally, red algae and crustaceans have been shown to be particularly intolerant to various chemical and hydrocarbon contaminants. The existing information is insufficient for the majority of characteristic species to allow for a more detailed assessment.

Conservation and protection status: Submerged or *partially submerged sea caves* (habitat type 8330) and *Reefs* (habitat type 1170) are listed under the Annex I of the Habitats Directive.

Infralittoral fouling seaweed communities (EUNIS A3.72)

Goods and Services: Fouling communities have been traditionally considered a nuisance especially with regards to ships, navigation buoys, cooling towers, pipelines, etc. However, fouling processes are driven by exactly the same biological forces that are commonly regarded as highly beneficiary in the case of mussel and other bivalve cultures. Moreover, fouling communities in ports, sewage outfalls or fish cultures can significantly contribute to the extraction of dissolved and particulate matter from the water column, and due to their high efficiency in mitigating eutrophication impacts and removing metabolic products and vibrios, they have been suggested as potential biofiltration and bioremediation factors (Licciano *et al*., 2005; Cook *et al*., 2006). In the absence of suitable natural substrata, man-made structures, both purpose designed (i.e. artificial reefs) and those of opportunity (e.g. rope lines, mooring buoys, wrecks etc.), may attract various benthic and pelagic species, thus enhancing local biodiversity and fisheries (Collins *et al*., 1994).

Sensitivity to human activities: In the last decades, various alien species have become prominent constituents of fouling communities (Bulleri & Airoldi, 2005; ICES, 2007; Tyrell & Byers, 2007; Shenkar & Loya, 2009). This fact, which may be partially attributed to the considerably low biological competition characterizing the bare or scarcely colonized immersed artificial structures (Bulleri & Airoldi, 2005; Shenkar & Loya, 2009), could render artificial habitats along with their associated fouling communities as suitable early warning indicators for a wide range of biological invasions (Hulme, 2006). Several researchers have emphasized the need to consider limiting coastal artificial structures and destruction of natural hard-substratum as a means to hinder further spread and proliferation of alien species (Bulleri & Airoldi, 2005; Tyrell & Byers, 2007).

Conservation and protection status: To our knowledge, there have been no specific conservation or protection efforts related to this biotope, although fouling communities on artificial reefs may be incidentally protected as part of local fishery management or habitat restoration plans (e.g. Marine Protected Areas, *hereafter* MPA).

Vents and seeps in infralittoral rock (EUNIS A3.73)

Goods and Services: Offshore and onshore gas and oil seeps are important sources of greenhouse gas and photochemical pollutants, and they are estimated to be the second most important natural source of atmospheric methane, after wetlands, both on global and European scale (Etiope, 2009). From an exploitation perspective, they are considered as indicators of petroleum or natural gas reservoirs (Sartoni & De Biasi, 1999) as well as sources of elements that can generate oxide, sulphide, and precious metal ore deposits (Prol-Ledesma *et al*., 2005). Moreover, they often indicate the occurrence of a fault or a potential geo-hazard (Etiope, 2009). Contrary to their deep-sea counterparts, vent-obligate taxa seem to be absent or rare in shallow hydrothermal vents (Tarasov *et al*., 2005). So far, the effects of shallow venting on coastal ecosystem processes have not been sufficiently understood and evaluated (Prol-Ledesma *et al*., 2005) and there is even contrasting evidence as to their potential role in determining the associated biodiversity (Bianchi *et al*., 2011 and references therein). Shallow-water hydrothermal vents, and especially those predominated by CO_2 emissions, have lately drawn much scientific attention as natural labs for testing the effects of ocean acidification and rising sea temperatures on shallow marine ecosystems (Tarasov *et al*., 2005; Hall-Spencer *et al*., 2008; Martin *et al*., 2008). Apart from providing insight into upcoming climatic changes, vent-sites are important biological sources of thermophile and hyperthermophile prokaryotes that show a great potential for biotechnological applications (Dando *et al*., 1999). Though extremely difficult to gauge and assess, submarine groundwater discharge in coastal karst aquifers can be larger than river discharge, especially during low stream flow (Moore, 1996; UNSECO, 2004). Freshwater or low-salinity seepage in shallow coastal environments may induce changes in the morphology of substrata and provide particular habitats for fishery stocks (UNESCO, 2004).

Sensitivity to human activities: The elevated sea temperatures in and around hydrothermal vent sites have been suggested to favour thermophilic species, a fact that may render this biotope particularly vulnerable to biological invasions (Dando *et al*., 1999; Sartoni & De Biasi, 1999; De Biasi & Aliani, 2003; Gambi *et al*., 2009). The quality of freshwater seeps is of great concern for coastal management, as groundwater can easily become contaminated with sewage, fertilizers, pathogens, pesticides or industrial wastes, thus diffusing pollution to the marine environment; moreover, reclaiming freshwater seepage from the marine environment is still expensive and ecologically risky as intensive pumping may increase saltwater intrusion in coastal aquifers (UNESCO, 2004).

Conservation and protection status: Vents and seeps that contain substantial carbonate structures may classify as *Submarine structures made by leaking gases* (habitat type 1180) under the Annex I of the Habitats Directive. To our knowledge however, there has been no concerted action to document this biotope's distribution and ensure its protection in European scale.

Mixed faunal turf communities on circalittoral rock (EUNIS A4.13)

Goods and Services: Mixed faunal turf communities are important, very diverse, and considerably aesthetic appealing habitats that enhance the maintenance of biodiversity. The majority of the organisms are filter feeders, depending on suspended material in the water column and providing important water quality regulation and nutrient cycling services (Hartnoll, 1998). Amongst others, sponges, bryozoans, hydroids, ascidians and sea anemones, whose functional roles are of high importance, form these communities. The importance of sponges on substratum, sponge bentho-pelagic coupling, and sponge interactions and associations is described in Bell (2008), where their functional roles as nutrient cyclers (carbon, silicon, nitrogen, etc.), substratum stabilizers, predation protection providers, and primary production providers are enhanced. The bioremediation role in polluted seawaters of some sponge species, such as *Chondrilla nucula* and *Spongia officinalis* var. *adriatica*, has also been corroborated by Milanese *et al.* (2003) and Stabili *et al*. (2006). Slow-growing complex three-dimensional biogenic structures created by hydroids, bryozoans and sponges modify the flow of currents, consolidate sediments and provide a three-dimensional habitat to a multitude of associated species, including many commercially important species (Christiansen, 2009). Furthermore, ascidians, hydrozoans and bryozoans also act as food source for many species of fish, crustaceans, and molluscs like nudibranchs.

Sensitivity to human activities: Organic based effluents such as sewage or intensive fish farming could certainly be a threat especially in enclosed gulfs or embayments, and any new or changed inputs of such type would need careful evaluation. The same considerations would apply to any other effluents originating from a point source, which might contain heavy metals, pesticides, PCBs, or other potential toxins. The effects of eutrophication will include reduced water transparency, affecting light transmission and algal growth, and the toxic effects and deoxygenation induced by algal blooms (Hartnoll, 1998). Commercial diving, recreational diving and recreational angling pose little risk when carried out at current levels following present codes of practice. However, in both cases the incidental damage from anchoring, and excessive concentrations of activity are matters of possible concern (Hartnoll, 1998). Mobile fishing gears such as scallop dredges and rockhopper trawls cause by far the greatest impact both directly through dislodging and flattening animals and indirectly by leaving the surrounding environment smothered with sediment. Strings of crab pots, anchor chains, fishing lines, netting and divers can also damage delicate epifauna, although the level of these impacts is much smaller. Natural fluctuations in abundance of grazers and predators could affect community balance, and need more study (Hartnoll, 1998).

Conservation and protection status: Communities of the circalittoral rock can be classified as *Reefs* (1170) under the Annex I of the Habitats Directive.

Sabellaria reefs on circalittoral rock (EUNIS A4.22)

Goods and Services: Marine biogenic structures that reach a few centimeters into the water column can have a profound effect on the structure and functioning of marine ecosystems. These systems are heavily used by a variety of taxa, including post-settlement juveniles of commercially important fish species (Watling & Norse, 1998). The crusts formed by the sandy tubes of the polychaete worm *Sabellaria spinulosa* may even completely cover the underlying rock, increasing habitat complexity and supporting high diversity and richness of benthic epifauna (Holt *et al*., 1998).

Sensitivity to human activities: In general, anthropogenic influences can strongly modify the engineering community by removing autogenic ecosystem engineers through the use of mobile bottom fishing gear, e.g. bottom trawlers (Bouma *et al*., 2009). The loss of habitat structure generally leads to lower abundance, biomass and often species richness (Airoldi *et al*., 2008). Holt *et al*. (1998) review the impact of bottom fisheries on *S. spinulosa.* The disappearance of the species in some areas in the Wadden Sea has been suggested as a good indicator for fishing intensity. Large areas in the North Sea with *S. spinulosa* reefs have been reported to disappear due to fisheries activities and commercial shrimp fisheries are known to search for *S. spinulosa* upon which they trawl for shrimps (Holt *et al*., 1998 and references therein). Vorberg (2000) found in a one-off experimental disturbance with a shrimp beam trawl that in the short-run, the reef structure itself does not disappear as the natural growth and capacity for repair is such that they can rebuild destroyed parts of their dwellings within a few days. The author indicates, however, that trawling in the medium to long-term can have consequences for the integrity of the reefs in the event of intensive fishing. In addition to fishing activities, *Sabellaria* reefs would suffer, at least in the short term, severe direct damage by extensive aggregate dredging activities (Holt *et al.*, 1998).

Conservation and protection status: *Sabellaria* reefs (either geogenic reef overgrown with *Sabellaria* spp. or biogenic reefs formed on sediments by tube building polychaetes such as *Sabellaria* spp. - EUNIS code A5.61) are included in NATURA-1170 habitat type *Reefs*.

Communities on soft circalittoral rock (EUNIS A4.23)

Goods and Services: This biotope is dominated by the piddock *Pholas dactylus*, a marine rock-boring bivalve mollusc, characterised by its bioluminescence (Katsanevakis *et al*., 2008) as well as the tube-building polychaetes *Polydora* spp. and *Bispira volutacornis*. A similar complex is dominated by the paddock *Barnea parva* and other boring bivalves. Polychaete tubes exert profound effects on near-bed flow, which above a certain threshold abundance lead to sediment stabilization where passive deposition of larvae or juveniles is enhanced (Eckman, 1983; Friedrichs *et al*., 2000). Piddock burrows increase habitat complexity and provide a variety of microhabitats for other species, thereby increasing local assemblage diversity (Pinn *et al*., 2008). Where abundant, pholad borings, which are found in both vertical and horizontal bedrock, can severely compromise the structural stability of the shore, and can result in increased rates of coastal erosion (Trudgill, 1983; Trudgill & Crabtree, 1987). It is estimated that an individual *P. dactylus* could remove 10.1 cm^3 of substratum over a maximum period of 12 years (Pinn *et al*., 2005). Soft rock communities have a nursery function and act as refuges (Houziaux *et al*., 2008). *P. dactylus* has been extensively fished for human consumption and as fishing bait (Katsanevakis *et al*., 2008).

Sensitivity to human activities: P. dactulys was once prevalent across the entire Mediterranean and on the Atlantic coast of Europe, but they have disappeared from most sites due to human collection for food and bait and as a result of pollution (Katsanevakis *et al*., 2008). Various pholad species are still eaten today in parts of Europe and Asia and there has been recent interest in their mariculture (Marasigan & Laureta, 2001; Bombace *et al*., 2000). Epibenthos from soft rock communities is affected by fisheries (Houziaux *et al*., 2008).

Conservation and protection status: Although the species associated with this biotope are not mentioned in the interpretation manual of the Habitats Directive, soft rock habitats can be classified under the definition of NATURA 1170 habitat type *Reefs*. This biotope qualifies for the Oslo-Paris Convention (OSPAR) criteria for the identification and selection of MPA's because of its unique and threatened species (Haelters *et al*., 2007). *P. dactulys* is under strict protection by the Bern Convention (Annex II) and the Protocol for Specially Protected Areas and Biological Diversity in the Mediterranean of the Barcelona Convention (Annex II).

Mussel beds on circalittoral rock (EUNIS A4.24)

Goods and Services: There are mussel fisheries at a number of localities and mussels are often farmed: banks of small overcrowded mussels are moved to more favourable areas where growth is rapid. In many traditional mussel culture areas, new functions have developed, such as recreation and nature conservation, and therefore extension of mussel culture is now also space limited. Expansion of mussel culture in Europe takes place in areas like Spain, Scottish fjords, Ireland and Greece, and is planned in Norway. Further development of sustainable mussel culture in Europe has different requirements for traditional and for new areas (Smaal, 2002). Mussel beds on circalittoral rock support increased biodiversity and high abundances as they provide a structured habitat of increased complexity suitable for many benthic species. Mussels constitute an important food source for many species, including marine mammals, birds, crustaceans, and fish. Mussel beds may alter water flow, which can influence the recruitment of macrofauna including the settlement of larvae as well as redistribution of settled individuals (Commito & Rusignuolo, 2000). Mussel beds induce a significant uptake of total suspended sediments, chlorophyll a, total organic carbon, nitrites and nitrates while there is a significant release of ammonium and orthophosphate (Dame & Dankers, 1988). The potential primary production induced by the nutrient release of the mussel bed is higher than the uptake of phytoplankton by the mussel bed. It is also probable that mussels extract nitrogen from particulate organic material other than phytoplankton. While mussels strongly reduce phytoplankton biomass, mussel beds also have the potential to significantly promote primary production (Asmus & Asmus, 1991).

Sensitivity to human activities: Mussel beds have declined in European waters, mainly due to overexploitation (Dankers *et al*., 2001). The probable role of marine pollution has also been stressed (Herlyn & Millat, 2000).

Conservation and protection status: Within the Habitats Directive, this biotope can be protected under the habitat type 1170. However, the consolidated compact substratum for this biotope is formed by rock rather than by the mussels; it concerns a geogenic reef overgrown with dense mussel aggregations. This is different from biogenic reefs formed by mussel aggregations on soft sedimented areas (see '*Sublittoral mussel beds on sediment*'; EUNIS code A5.62).

Mediterranean coralligenous communities moderately exposed to hydrodynamic action (EUNIS A4.26)

Goods and Services: Coralligenous assemblages are considered the most important hot-spots of species diversity in the Mediterranean, together with *Posidonia oceanica* meadows (UNEP, 2007). According to some recent estimates, the coralligenous is known to host well over 1600 species, but even this large number is thought to be highly underestimated due to the lack of extensive studies (Ballesteros, 2006). Many commercially important species are known to live, feed or reproduce in this biotope among which the precious red coral *Corallium rubrum*, and various species of sharks (e.g. *Scyliorhinus stellaris,* *Mustelus asterias, Mustelus mustelus, Squalus acanthias* and *Squalus blainvillei*) (Ballesteros, 2003 and references therein), many of which are considered vulnerable or endangered (Cavanagh & Gibson, 2007). Moreover, the great variety and abundance of highly productive calcareous organisms render this biotope one of the most important carbon sinks in the Mediterranean circalittoral zone (Ballesteros, 2003). Hydrodynamically exposed coralligenous communities are commonly characterized by spectacular gorgonian facies; such seascapes are widely renowned for their high aesthetic value and feature amongst the most preferred diving spots worldwide.

Sensitivity to human activities: Wastewater dumping, as well as any activities resulting in an increase of water turbidity and sedimentation are known to pose a severe threat to this biotope (UNEP, 2007; Ballesteros, 2006), although active hydrodynamic regimes are likely to mitigate disturbances and accelerate recovery. Because they contain many sessile, long-lived organisms with slow growth dynamics and fragile skeletons, coralligenous communities are extremely prone to mechanical disturbance induced by trawling, fishing nets, anchoring and uncontrolled scuba-diving activities (Garrabou *et al*., 1998; Ballesteros, 2006; UNEP, 2007). In the last decade, several key-species of the Mediterranean coralligenous suffered dramatic mass mortalities, which were attributed to some unusually high summer temperatures, possibly related to global warming (Romano *et al*., 2000; Perez *et al*., 2000; Cerrano *et al*., 2000; Ballesteros, 2003). Currently, three algal invasive species (*Womersleyella setacea, Caulerpa racemosa* v. *cylindracea* and *C. taxifolia*) are threatening coralligenous communities in the Western Mediterranean by forming dense carpets, increasing sedimentation, and smothering indigenous populations (Piazzi *et al.,* 2007;UNEP, 2007). The introduced *Asparagopsis taxiformis* and *Lophocladia lallemandii* are also becoming increasingly abundant in the Balearic Islands (Ballesteros, 2003). Although poorly studied, coralligenous banks of the Eastern Mediterranean basin seem also quite prone to the invasion of the green alga *C. racemosa* var. *cylindracea,* and the brown alga *Stypopodium schimperi* (Bitar *et al*., 2000; Bardamaskos *et al*., 2008). During the last decade, there has been increased awareness on the vulnerability of these ecosystems by the European scientific community, asserting the inclusion of the Mediterranean coralligenous biotope as a priority natural habitat type in the Habitats Directive (UNEP, 2007).

Conservation and protection status: This biotope is included in the NATURA 2000 Habitat Type 1170 (*Reefs*). This bulk category, however, is considered as highly problematic for management purposes, as it comprises a large variety of biogenic natural habitats (Bellan-Santini *et al*., 2002; Relini, 2009; SIBM, 2009; Bianchi *et al*., 2010), which can differ significantly in their ecological and conservation aspects.

*Pontic *Phyllophora* beds on circalittoral bedrock and boulders (EUNIS *A4.28)

Goods and Services: Phyllophora crispa can be commercially exploited as raw material for the production of agar (Sur & Güven, 2002) and iodine-containing compounds (Gazha *et al*., 1983). Potential for cultivation exists (Blinovaa & Trishinaa, 1990). *Phyllophora* beds supply benthic primary production and oxygenation of waters in the circalittoral rocky zone and provide reproduction, nursery and feeding grounds for diverse invertebrate and fish fauna.

Sensitivity to human activities: P. crispa is known to be particularly sensitive to shading by increased phytoplankton due to eutrophication (Zaitsev & Alexandrov, 1998; Zaitsev, 2008; Minicheva *et al*., 2008). Decreased depth of light penetration causes sharp decline in *Phyllophora* beds and degradation of the associated community. Displacement from physical disturbance is not detrimental since *P. crispa* is able to grow and proliferate detached in the water column, and may form dense pelagic accumulations maintained by circular currents in the Black Sea. However extraction may cause major decline not only in the target species but in the associated fauna as well, posing threat to some rare species (Goriup, 2009). As a result of the anthropogenic eutrophication in the Black Sea the depth range of the attached *P. crispa* has decreased by at least 10 m, with the lower boundary having shifted from 30 m in the 1970s to 20 m at present; moreover, the biotope's coverage has diminished from 50-80% to 15-20% and its biomass has dropped from 1.5 - 4 kg m^{-2} to 0.3 - 0.5 kg m^{-2} along the Caucasus and Crimean coasts (Minicheva *et al*., 2008, and references therein). One can now observe only rare small beds but still some have survived.

Conservation and protection status: In 1996 extraction of *Phyllophora* was forbidden in Ukraine due to stock depletion and significant by-catch of species listed in the Red Book (Goriup, 2009). *Phyllophora* meadows may qualify as *Reefs* but they are yet to be included in the NATURA 2000 network of Bulgaria and Romania. A large (402,500 ha) offshore MPA called 'Zernov's *Phyllophora* field' was declared by Ukraine on November 2008 in the northwestern Black Sea, with the aim to preserve "...*Phyllophora* resources and the *Phyllophora* ecosystem as a whole, including the gene pool of rare, exclusive and relic plant and animal species in the region". Kostylev *et al*. (2010) have reported that gradual restoration of the benthic phytocoenosis within the MPA has begun.

Mediterranean coralligenous communities sheltered from hydrodynamic action (EUNIS A4.32)

Goods and Services: Compared to the *Mediterra-*

nean coralligenous communities moderately exposed to hydrodynamic action (EUNIS A4.26) this biotope may present different, yet not least in importance, biodiversity and aesthetic aspects. Sheltered hydrodynamic conditions naturally increase the abundance of active, rather than passive, filter-feeders, favouring thus the dominance of various species of sponges and ascidians (Bo *et al*., 2011); many such species have been shown to contain some of the most bioactive chemicals, providing, thus, useful insight to pharmaceutical research (Uriz *et al*., 1991). Sheltered conditions also increase human access and activities, rendering these communities more popular to recreational and professional fishermen, as well as scuba divers.

Sensitivity to human activities: Sheltered conditions may favour episodic temperature anomalies, eutrophication, sedimentation and bioerosion, which in turn may decrease species richness, eliminate sensitive taxa and even inhibit bioconstruction (Ballesteros, 2003; Balata *et al*., 2005). Other important threats include direct and indirect effects of fishing, as well as uncontrolled anchoring and diving activities (Ballesteros, 2003; Luna-Perez *et al*., 2010) (see also section: *Mediterranean coralligenous communities moderately exposed to hydrodynamic action* - EUNIS A4.26). The invasion by turf-forming, filamentous algae (e.g. *W. setacea*) that further retain sediment and hinder bioconcretion in the lower layer (Ballesteros, 2006 and references therein) may also present an increased threat to coralligenous communities in hydrodynamically sheltered conditions.

Conservation and protection status: This biotope may be classified as *Sublittoral organogenic concretions* (11.25) in the Bern Convention and as *Reefs* (Habitat Type 1170) in the Habitats Directive. All conservation and protection issues may equally apply for both A4.26 and A4.32 EUNIS codes.

Communities of circalittoral caves and overhangs (EUNIS A4.71)

Goods and Services: Marine caves and overhangs may support a rich and at times exceptional biodiversity due to a great and sharp variability of environmental parameters (light, physicochemical water properties, hydrodynamism, etc.), which in turn account for an increased habitat diversification. Due to their high aesthetic value, many submerged Mediterranean marine caves are exploited as diving sites with a rapidly increasing popularity. Studies on marine caves and other crevicular fauna have revealed the existence of unique communities characterized by high endemism, relict species and other unusual characteristics (Sarà, 1976; Hart *et al*., 1985). Moreover, several common features shared between circalittoral caves and deep-sea habitats -such as lack of light, limited food resources and in some cases lack of hydrodynamism (Villora-Moreno, 1996)- provide significant opportunities for studying and understanding deeper environments within the "scuba zone" (Vacelet *et al*., 1994).

Sensitivity to human activities: Submarine caves are unique and vulnerable ecosystems, presenting thus a conservation priority (Sarà, 1976; Parravicini *et al*., 2010b). Organic or industrial contamination may lead to pronounced loss of biodiversity through the disappearance of sensitive species and predominance of ecologically tolerant ones (Calvín Calvo, 1995). Parravicini *et al*. (2010b) highlighted the consequences of seawater temperature anomalies on the sessile communities of a Mediterranean submarine cave system, evidencing the poor resilience of this biotope. Other activities such as uncontrolled scuba diving may adversely affect the biota, either by direct mechanical disturbance or indirectly as a result of sediment resuspension or exhaust air-bubbles (Bellan-Santini *et al*., 1994).

Conservation and protection status: Listed as endangered natural habitat type in the Resolution no. 4 (Council of Bern Convention, 1996): *Sea-caves* (code 12.7). Listed in the Annex I of the Habitats Directive as: *Reefs* (code 1170); *Submerged or partially submerged sea caves* (code 8330).

Infralittoral coarse sediment (EUNIS A5.13)

Goods and Services: Gravelly sediments are generally low in organic carbon levels, and hence the existing epi- and infauna exhibit relatively low diversity and abundance levels (Roche *et al*., 2007). The biotope includes few features that might create microhabitats or localized shelter, and can be important for opportunistic predators on component species (MarLIN, 2004). In some areas and seasons artisanal fishery activities take place on infralittoral coarse biotopes that may also represent nursery grounds for certain fish species.

Sensitivity to human activities: This biotope is directly subjected to anthropogenic activities on the littoral: pollution emissions, turbid water, unsustainable development practices, etc. Sedimentation from watercourses or anthropogenic waste takes place, because the hydrodynamics are usually not strong enough to prevent this type of disturbance. The biotope has a role in maintaining the balance of the adjoining beaches, and could be affected by beach replenishment activities.

Conservation and protection status: Listed as endangered natural habitat type in the Resolution no. 4 (Council of Bern Convention, 1996): *Sublittoral soft seabeds* (code 11.22).

Circalittoral coarse sediment (EUNIS A5.14)

Goods and Services: This biotope includes features that create microhabitats or localized shelter by supporting soft corals, hydroids, encrusting sponges and bryozoans, especially where sediment particles are large. The community is species-rich, mainly dominated by thick-shelled bivalves (e.g. *Pecten maximus*, *Circomphalus casina*, *Ensis arcuatus* and *Clausinella fasciata*), sessile sea cucumbers (*Neopentadactyla mixta*), and sea urchins (e.g. *Psammechinus miliaris* and *Spatangus purpureus*). This biotope provides feeding and nursery ground for various commercially important species like flatfishes. It is also largely exploited as a source of raw construction materials.

Sensitivity to human activities: May be significantly impacted by human activities, particularly those increasing sedimentary load, such as trawl fishing and dredging; gravel habitats are severely modified by aggregate extraction in licensed areas (MESH, 2005-2006). Within the licensed dredged areas, the impact on the seabed can be greater per unit area than that of bottom fishing as both the substrata and fauna are removed, a fact which prolongs the recovery of the habitat and the benthic community. In the past, dumping of solid wastes could trigger pollution incidents, but this is currently prohibited under the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972 (London Convention) and its 1996 Protocol (London Protocol) (*hereafter*: London Convention and Protocol).

Conservation and protection status: Included in the Council of Bern Convention Res. No. 4 1996 as *Sublittoral soft seabed* (code 11.22), and in the Barcelona Convention (1998) as *Biocoenosis of coarse sands and fine gravels under the influence of bottom currents* (code IV.2.4).

Deep circalittoral coarse sediment (EUNIS A5.15)

Goods and Services: This biotope provides natural habitat for shellfish and other food-organisms for several commercially important fish species. It is also becoming progressively considered for exploitation as a source of raw construction materials, along with the development of deep dredging technologies.

Sensitivity to human activities: Can be impacted by offshore human activities, mainly trawl fishing. Because of the stable (non-dynamic) conditions that prevail in deep environments, dredging for gravels may have considerable direct impacts on species diversity, biomass and abundance (Saunders *et al*., 2010). Dumping of solid wastes at sea presented once a considerable threat to this biotope, but this practice is now prohibited under the London Convention and Protocol.

Conservation and protection status: Included in the Council of Bern Convention Res. No. 4 1996 as *Sublittoral soft seabed* (code 11.22).

Infralittoral fine sand (EUNIS A5.23)

Goods and Services: This biotope provides habitat as well as nursery and reproduction grounds for several commercially exploited species (e.g. flatfishes). The epi- and infauna may be rich and diverse, supporting various predatory fish and bird species. Infralittoral sediments play a substantial role in maintaining the balance of sandy beaches. The biotope is utilised for aggregate extraction.

Sensitivity to human activities: This biotope is directly subject to various anthropogenic impacts resulting from urban, industrial, agricultural, aquaculture and other coastal activities. Natural disturbance events, such as storms and waves, may also affect this biotope, and the resulting water movement has been found to be very important in determining resuspension and turbidity regime. Physical disturbance on such biotopes may be caused directly and indirectly by fishing and aggregate dredging activities (MarLIN, 2004). Fishing may affect the physical integrity of the sediment system through, e.g., scraping, digging or ploughing of the seabed, whilst dredging activities, spoil disposal and aggregate extraction would affect the sediment and hydrographic regime through a variety of effects (Elliot *et al.*, 1998). In such high-energy environments the impact of human activities may be considered transitory and negligible.

Conservation and protection status: Listed as endangered natural habitat type in the Resolution no. 4 (Council of Bern Convention, 1996): *Sublittoral soft seabeds* (code 11.22).

Infralittoral muddy sand (EUNIS A5.24)

Goods and Services: Even though this biotope does not generally support communities of high-biodiversity, its benthic fauna may provide food for several commercially important fish species and also host invertebrate populations important to fisheries (e.g. *Chamelea gallina, Tapes* spp.). Such biotopes may provide important feeding and nursery grounds for marine birds and coastal fish (especially Sparidae in the Mediterranean). Small benthic invertebrates of the infauna living in the shallowest parts of this biotope are sometimes collected as bait by recreational fishermen.

Sensitivity to human activities: Infralittoral muddy sands may be severely impacted by numerous coastal human activities, and particularly the ones involving dumping or discharge of solid or liquid wastes at sea. Fishing in general, and the use of bottom-towed fishing gears in particular, may pose ephemeral or permanent threats to this biotope, depending on the relative vulnerability of species present.

Conservation and protection status: Listed as endangered natural habitat type in the Council of Bern Convention Resolution no. 4 (1996): *Sublittoral soft seabeds* (code 11.22).

Circalittoral fine sand (EUNIS A5.25)

Goods and Services: This biotope is a source of sand for beach replenishment and other uses. It also provides habitat, as well as feeding and nursery grounds for several commercially important species (e.g. the great clam *P. maximus* or the stripped mullet *Mullus surmuletus*).

Sensitivity to human activities: Can be impacted from coastal human activities, mainly trawl fishing as well as sand mining activities, which alter seabed structure and biodiversity. In the past, it could be impacted by dumping of solid wastes (currently prohibited under the London Convention and Protocol).

Conservation and protection status: Included also as *Sublittoral sands* in EUNIS, therefore in the Council of Bern Convention Res. No. 4 1996 as *Sublittoral soft seabed* (code 11.22).

Circalittoral muddy sand (EUNIS A5.26)

Goods and Services: The rich epi- and infauna of this biotope make it important in supporting predator communities such as mobile macrofauna and demersal fishes, some of which are commercially targeted by specific fisheries (e.g. shrimp trawling).

Sensitivity to human activities: Sea bed structure of certain circalittoral soft biotopes subject to human activities displayed pronounced changes over the years; macrobenthic communities appeared to be less numerous and more homogeneous. The main factor that can explain these differences is the grain-size of the sediments, which has shown large changes: a strong decrease in the mud fraction and increase in the fine sand fraction. These sedimentary changes were linked with human activities: increase in bottom trawling effort that induces the resuspension of fine mud particles and the homogenization of sediments over large areas, and decrease in terrigenous particulate fluxes due to human activities on the shoreline and in coastal waters (Hily *et al*., 2008).

Conservation and protection status: Listed as endangered natural habitat type in the Council of Bern Convention Resolution no. 4 (1996): *Sublittoral soft seabeds* (code 11.22).

Mediterranean communities of superficial muddy sands in sheltered waters (EUNIS A5.28)

Goods and Services: An environment where birds can feed. Certain facies are exploited either for molluscs (*Paphia aurea* = *Tapes aureus*), whose market value for consumption is great, or for fishing bait (e.g. *Upogebia* spp., *Marphysa* spp., *Arenicola* spp., *Perinereis cultrifera*, etc.). It is a very productive environment, mainly because of very intense phytoplanktonic and microphytobenthic developments. The productive capacity is often exploited by fisheries (mainly fishing for clams and cockles, and bait collection) and aquaculture.

Sensitivity to human activities: This biotope is subject to various threats, among which habitat loss as a result of land reclamation, intense fishing for molluscs or bait causing uncontrolled modification of the sedimentary seabed, and accumulation of detritus and pollutants because of rather slow water-renewal and increased sedimentation rates. Shellfish farming (*M. galloprovincialis*) may result in eutrophication, as well as the physical destruction of the biotope by the elimination of natural or artificial barriers to facilitate water circulation or boat traffic.

Conservation and protection status: Listed as endangered natural habitat type in the Council of Bern Convention Resolution no. 4: *Sublittoral soft seabeds* (code 11.22).

Infralittoral sandy mud (EUNIS A5.33)

Goods and Services: This biotope does not support high-diverse communities, but it can provide food for several commercially important shallow-water species like sea breams, red mullet, flat fishes, prawns and crabs.

Sensitivity to human activities: Infralittoral sandy muds may be severely impacted from coastal human activities, when these involve dumping or discharge of solid or liquid wastes at sea: dredged sediment disposal, industrial plants, agriculture, aquaculture farms, building activities, coastal urban centres can affect directly or indirectly this biotope. Fine sediments can trap pollutants for a long time, especially in sheltered areas.

Conservation and protection status: Listed as endangered natural habitat type in the Council of Bern Convention Resolution no. 4 (1996): *Sublittoral soft seabeds* (code 11.22).

Infralittoral fine mud (EUNIS A5.34)

Goods and Services: The common cockle (*Cerastoderma edule*), which is known to abound in this biotope, is a commercially important species in Europe and also a food source for various fish, crustaceans and birds; the lugworm *Arenicola marina* is commonly collected here by anglers as fishing-bait (Connor *et al*., 2004).

Sensitivity to human activities: Infralittoral fine muds may be severely impacted from coastal human activities, when these involve dumping or discharge of solid or liquid wastes at sea: industrial plants, agriculture, aquaculture, construction and coastal urban centres can directly or indirectly affect this biotope. Fine sediments can trap pollutants for a long time.

Conservation and protection status: Listed as endangered natural habitat type in the Council of Bern Convention Resolution no. 4 (1996): *Sublittoral soft seabeds* (code 11.22).

Circalittoral sandy mud (EUNIS A5.35)

Goods and Services: A variety of species may occur in this biotope, which includes a rich epi- and infauna and species composition at a particular site may relate, to some extent, to the proportions of the major sediment size fractions. Greater quantities of stones and shells on the surface may give rise to more sessile epibenthic species, some of which are important in the diets of many commercially important fish and invertebrate predators (MarLIN, 2004).

Sensitivity to human activities: Circalittoral biotopes may be less susceptible to human impacts related to coastal alteration when they occur at large distances from the shore, and are not subject to aggregate mining. However, due to the relatively stable conditions that characterize this biotope, recovery from disturbances may be particularly slow.

Conservation and protection status: Listed as endangered natural habitat type in the Council of Bern Convention Resolution no. 4 (1996): *Sublittoral soft seabeds* (code 11.22).

Circalittoral fine mud (EUNIS A5.36)

Goods and Services: The epi- and infauna of this biotope may be rich and diverse. The relatively stable environmental conditions often lead to the establishment of communities of burrowing megafaunal species; when large populations of species like the Norway lobster (*Nephrops norvegicus*) occur, these sea bottoms become important to trawl fisheries.

Sensitivity to human activities: Circalittoral biotopes may be less susceptible to human impacts when they occur at large distances from the shore. However due to the relatively stable conditions that prevail in this biotope, they may show slow recovery in case of serious disturbance. They are mostly subjected to the effects of trawling and dredging activities.

Conservation and protection status: Listed as endangered natural habitat type in the Council of Bern Convention Resolution no. 4 (1996): *Sublittoral soft seabeds* (code 11.22).

Deep circalittoral mud EUNIS (A5.37)

Goods and Services: The epi- and infauna of this biotope may be rich and diverse and may serve as food for several demersal fish species.

Sensitivity to human activities: Circalittoral biotopes may be less susceptible to human impacts when they occur at large distances from the shore. However due to the relatively stable conditions that prevail in these biotopes, they may show slow recovery in case of serious disturbance. They are commonly subjected to trawling activities.

Conservation and protection status: Listed as endangered natural habitat type in the Council of Bern Convention Resolution no. 4 (1996): *Sublittoral soft seabeds* (code 11.22).

Mediterranean communities of muddy detritic bottoms (EUNIS A5.38)

Goods and Services: Food provision is sustained by several economically important species that are caught in this biotope by trawlers (e.g. the European hake *Merluccius merluccius*). In addition, this biotope makes a substantial contribution to the regional biodiversity because the communities present high spatial variability (Garcia Raso & Manjon-Cabeza, 2002).

Sensitivity to human activities: Characteristic flora and fauna that are highly sensitive to disturbances colonize detritic bottoms in the Mediterranean Sea; coastal areas are exposed to important levels of anthropogenic disturbance, mainly pollution (including changed sedimentation regimes) (Klein & Verlaque, 2009). In cases of high anthropogenic disturbance the general abundance of the macrofauna is decreased. Nevertheless, the community shows high resilience and recuperates relatively fast from mechanical disturbance (Garcia Raso & Manjon-Cabeza, 2002).

Conservation and protection status: Included in the Council of Bern Convention Res. No. 4 1996 as *Sublittoral soft seabed*. Included in the Barcelona Convention (1998) as *Biocoenosis of the muddy detritic bottom* (code IV.2.1).

Mediterranean communities of coastal terrigenous muds (EUNIS A5.39)

Goods and Services: This biotope provides habitat and food for commercially important fish species, notably the red mullet *(M. barbatus)* as well as flatfishes.

Sensitivity to human activities: It is extensively impacted by human activities, mainly trawl-fishing. Recovery may be extremely slow because of the stable (non-dynamic) conditions that prevail in this biotope (Koulouri *et al*., 2006). Dumping of solid wastes may severely modify and pollute this biotope but such practices are currently prohibited under the London Convention and Protocol.

Conservation and protection status: Included in the Council of Bern Convention Res. No. 4 1996 as *Sublittoral soft seabeds*.

Infralittoral mixed sediments (EUNIS A5.43)

Goods and Services: Mixed sediments are often the most diverse among sedimentary habitats, because they support rich communities of both infaunal and epifaunal species such as bivalves, polychaetes, and file shells, which in turn provide food and shelter for several fish species (UKBAP, 2008). This biotope is utilised for aggregate extraction.

Sensitivity to human activities: According to Tyler-Walters *et al*. (2004) this biotope is mostly characterized by communities with intermediate intolerance, moderate to high recoverability and low sensitivity to human activities; however, it may also host communities such as *Limaria hians* beds, which show high intolerance, low recoverability and high sensitivity to human activities. Physical disturbance, such as coastal development and sediment extraction which may alter tidal flow patterns and affect the sedimentary conditions across the seabed, organic enrichment resulting from sewage pollution, and fishing have been reported as potential threats (UKBAP, 2008; Tyler *et al.,* 2009). Trampling damage by beach users and extraction of the worms for angling bait may also have an impact, but consequences may be limited to local scales (UKBAP, 2008). Due to their proximity to coastal areas, this biotope is highly prone to the invasion of non-native species, which may result in outcompeting key species such as oysters (Tyler-Walters, 2008 and references therein). Aggregate extraction may result in drastic degradation of the biotope due to direct removal of organisms and average particle size reduction, which in turn reduces diversity, and particularly that of epifaunal species (Hill *et al*., 2011).

Conservation and protection status: Council of Bern Convention Res. No. 4 1996. *Sublittoral soft seabeds* (code: 11.22)

Circalittoral mixed sediments (EUNIS A5.44)

Goods and Services: The presence of benthic invertebrates in this biotope increases habitat complexity through the creation of tubes and burrows (Aller, 1988; Lenihan & Peterson, 1998; Widdicombe *et al.,* 2000; Callaway, 2006). Few marine sedimentary habitats have been thoroughly sampled and it has been argued that the biological diversity of this biotope is often underrepresented since it appears to support a relatively diverse and abundant benthic fauna (Snelgrove, 1998). Particularly, the high densities of infaunal polychaete and bivalve species that exist here (Connor *et al*., 2004) have been attributed to the relatively low rate of natural physical disturbance and the heterogeneity of the habitat (Etter & Grassle, 1992).

Sensitivity to human activities: Accumulation or loss of sand as a result of shoreline development may have positive or negative effects depending on the nature of the changes. Main threats to this biotope include abrasion, smothering, substratum loss, suspended sediment, nutrient enrichment, organic enrichment and selective extraction of species. However, the severity of these effects are largely determined by the spatial extent and frequency of the impact, as sporadic disturbances over limited spatial and temporal scales are unlikely to affect ecosystem functioning (Paramor & Frid, 2006).

Conservation and protection status: Included in the Council of Bern Convention Res. No. 4 1996 as *Sublittoral soft seabeds*.

Deep circalittoral mixed sediments (EUNIS A5.45)

Goods and Services: The substratum of this biotope is exploited for aggregate resources, which may remove considerable quantities of sediments (Rayment, 2008). The biotope may provide an important source of food for opportunistic predatory fish and benthic scavengers. In the Black Sea, muds with *Modiolula phaseolina*, particularly their upper range, are feeding grounds for the great sturgeon, turbot and whiting (Zaitsev & Alexandrov, 1998).

Sensitivity to human activities: Deep soft bottom sediments are vulnerable to the effects of trawling activities. Moreover, the impact of human-induced eutrophication may be perceptible even in such offshore areas in the Black Sea, as reflected in decreased species richness, decline in *Modiolula* population abundance and biomass and shift of the lower limit of the biotope from 130 m in the 1960s to 100 m in the 1990s (Petranu, 1997).

Conservation and protection status: Included in the Council of Bern Convention Res. No. 4 1996 as *Sublittoral soft seabeds*. Part of this biotope may also be classified as habitat type 1110 under the Habitats Directive.

Mediterranean animal communities of coastal detritic bottoms (EUNIS A5.46)

Goods and Services: These bottoms occupy a considerable portion of the continental shelf throughout the Mediterranean. The pristine biotope is characterized by high species diversity. Influenced by various environmental factors, it may develop multiple facies linked to a – sometimes luxuriant – abundance of particular species. Several commercial fish species (notably the stripped mullet *M. surmulletus*) live and feed in these bottoms, and *Spicara flexuosa* has been observed to dig nests and spawn here (D'Anna & Badalamenti, pers. com.).

Sensitivity to human activities: Subject to threat by human activities that increase mud transport from the coast (mainly untreated urban waste discharge, major construction works in the maritime field, and leaching from soil). Hypersedimentation may eliminate vulnerable facies (e.g. *Lithothamnion* spp., big bryozoans, ascidian beds, etc.), resulting in biotope homogenization and a consequent reduction of the associated biodiversity and the exploitable living resources.

Conservation and protection status: Included in the Council of Bern Convention Res. No. 4 1996 as *Sublittoral soft seabed*. Included in the Barcelona Convention (1998) as *Biocoenosis of the coastal detritic bottom* (code IV.2.2).

Mediterranean communities of shelf-edge detritic bottoms (EUNIS A5.47)

Goods and Services: These communities are present in detritic bottoms with abundance of dead shells, bryozoans and coral skeletons (EUNIS, 2002). The biotope provides habitat and food for several commercially important fish and decapods species, mainly targeted by trawlers. It is also a source of raw materials (lime) for construction, can be enriched with river-borne materials that precipitate in seawater (e.g. phosphorous) and it is locally exploited by the coral-based industry (notably in the Bay of Naples).

Sensitivity to human activities: As recent technologies allow for the exploitation of previously inaccessible oil and gas deposits (Seale & Plus, 2007), the Mediterranean shelf-edge bottoms may become increasingly subjected to drilling, oil and gas exploration and their associated impacts (Howarth & Ingraffea, 2011; Linley 2011). Illegal dumping of solid wastes may also present a threat of yet unknown consequences.

Conservation and protection status: Included in the Council of Bern Convention Res. No. 4 1996 as *Sublittoral soft seabed* (code 11.22). Included in the Barcelona Convention (1998) as *Biocoenosis of shelf-edge detritic bottom* (code IV.2.3).

Maerl beds (EUNIS A5.51)

Goods and Services: Maerl coralline algae are made up of about 80% of calcium carbonate and 10% of magnesium carbonate (Lüning, 1990) and are thus inferred to be some of the largest stores of carbon in the biosphere (Birkett *et al*., 1998). When fossilized, such deposits can be used as stratigraphic markers and palaeoenvironmental indicators (Birkett *et al*., 1998; Foster *et al*., 1997). Live and dead maerl deposits are being heavily and often unsustainably harvested (over 500,000 tons yearly) as a source of lime and trace elements for agricultural use, as water filtration agents, and as a natural remedy for osteoporosis (Lüning, 1990; Birkett *et al*., 1998; Guiry & Blunden, 1991; Blunden *et al*., 1975). The complex nature of this biotope creates a network of exceptional biological and functional diversity, hosting a large variety of associated organisms (Lüning, 1990; Birkett *et al*., 1998; Ballesteros, 2003; Sciberras *et al*., 2010), and providing shelter to many commercially important crustacean, bivalve and fish species, among others (Kamenos *et al.,* 2004 a,b ; Birkett *et al.,* 1998; Georgiadis *et al.,* 2009.

Sensitivity to human activities: Being among the slowest-growing organisms (up to a few mm per year), coralline algae are exceptionally vulnerable to any mechanical disturbance such as dredging, trawling (Birkett *et al*., 1998) and even net fishing (Georgiadis *et al*., 2009; Sciberras *et al*., 2010). Other direct threats include habitat removal through offshore construction activities and the commercial extraction of maerl (Birkett *et al*., 1998). Increased sedimentation and turbidity, as a result of eutrophication, waste discharge, fish farming, construction works and nearby trawling pose also serious threats to both bioconstructors and associated fauna of this biotope (Birkett *et al*., 1998; Hall-Spencer *et al*., 2006; Aguado-Giménez & Ruiz-Fernández, 2012). The alien turf alga *Acrothamnion preissii* has been identified as invasive in maerl beds of the Western Mediterranean basin (Ferrer *et al*., 1994).

Conservation and protection status: Included in the Barcelona Convention as *Biocoenosis of coarse sands and fine gravels mixed by the waves with association with rhodolithes* (III. 3. 1. 1) as well as *Biocoenosis of coastal detritic sands- association with rhodolithes* (III. 3. 2. 2.). Two of the more common maerl-forming species, *Lithothamnion corallioides* and *Phymatolithon calcareum* are included in the Annex V of the Habitats Directive. In the UK, maerl beds are listed as a key habitat type within the Annex I category *Sand banks which are slightly covered by seawater at all times* in the JNCC interpretation of the Habitats Directive, and they are the subject of a Habitat Action Plan under the UK Biodiversity Action Plan. In the Mediterranean, coralligenous and other calcareous bio-concretions (maerl included) became a special subject of an *ad hoc* UNEP-MAP Action Plan (Sciberras *et al*., 2010; Agnesi *et al*., 2009). Destructive fishing was recently prohibited over Mediterranean maerl beds according to the EU Regulation 1967/2006 (EC, 2006). However, the lack of geospatial data on the distribution of these assemblages remains a major impediment for the substantial protection of these biotopes.

Sublittoral seagrass beds (EUNIS A5.53)

Goods and Services: Seagrass ecosystems rank among the most productive biomes on earth (Costanza *et al*., 1997; Duarte & Chiscano, 1999), supporting exceptionally high biomass and an average net production of ca 400 g C m^{-2} yr^{-1} (Costanza *et al*., 1997). Healthy and extensive seagrass meadows provide habitat, shelter, food source and nursery grounds for a large variety and abundance of marine organisms (Marbà *et al*., 2004; Díaz-Almela & Duarte, 2008). Apart from their significant contribution in enhancing local biodiversity, oxygenating waters and sediments and cycling nutrients, seagrasses are also known to constitute important trophic links to their adjacent marine or terrestrial ecosystems by exporting an average 24.3% of their net production (Duarte, 2002). Although seagrass meadows hardly occupy a 0.1% of the ocean surface, they play a significant role as net carbon sinks in the biosphere, directly comparable to that of wetlands, or the Amazonian rain forest (Duarte *et al*., 2010). Seagrass leaf canopies control the transparency of the water column by favouring retention of suspended particles, and protect shorelines by attenuating the wave energy. Shoreline protection is further enhanced by dense networks of rhizomes that stabilize sublittoral sediments, as well as by detached (withered) leaves which cushion beaches from wave erosion (Duarte & Gattuso, 2008; Terrados & Borum, 2004). Due to their slow growth rates, strict ecological requirements and overall sensitivity, seagrasses are generally considered as indicators of environmental quality (e.g. Terrados & Borum, 2004; Montefalcone, 2009). Species with vertical and long lived rhizomes act as long-term logs of environmental information, offering an insight to past episodes of disturbance and levels of persistent contaminants (radioactive and synthetic chemicals, heavy metals, etc.) (Díaz-Almela & Duarte, 2008). Although seagrasses had been quite familiar and directly used by past coastal communities (i.e. dry leaves for packing and filling material, roof insulation and covering, bedding, soil amendment, animal feeding etc.) (Marbà *et al*., 2004), their high ecological value is little comprehended by the public today. According to some estimates, the value of the services provided by these ecosystems rises as high as 15837 € ha^{-1} y^{-1} -two orders of magnitude higher than the estimate obtained for croplands (Costanza *et al*., 1997; Terrados & Borum, 2004).

Sensitivity to human activities: Increasing human population and subsequent urbanization and industrialization of the coastal zone have been widely recognized among the most serious threats that seagrass ecosystems face today (Bianchi & Morri, 2000). Human activities that pose serious direct or indirect threats to seagrasses, are both numerous and multifold, and comprise excess nutrient and organic supplies to coastal waters (domestic, agriculture and aquaculture effluents), mechanical damage from fishing activities, coastal engineering and anchoring, disruption of the sedimentation/erosion balance along the coast, proliferation of invasive species (e.g. *C. racemosa* var. *cylindracea, C. taxifolia*) and human-induced salinity changes (Milchakova, 1999; Duarte, 2002; Marbà *et al*., 2004; Díaz-Almela & Duarte, 2008; Duarte & Gattuso, 2008; Langmead *et al*., 2009; Montefalcone *et al*., 2010). In the course of the last two decades, the estimated loss of seagrass from direct and indirect human impacts amounts to at least 29% of the documented seagrass area, with a global loss rate (≈7% yr^{-1}) faster than that of tropical rainforests (Waycott *et al*., 2009). Given the slow growth rate of all European seagrasses (especially so for *P. oceanica*) such losses may sometimes be irreversible, at least on human-life time scales and within highly urbanized coastal areas (Montefalcone *et al*., 2007; 2009; Díaz-Almela & Duarte, 2008; Duarte & Gattuso, 2008). However, cautious optimism can be drawn from facts such as the slow regrowth of heavily impacted seagrass beds after oil spills or coastal construction works, the observed positive response of rhizome growth to increased atmospheric temperature and, presumably, CO_2 concentration, as well as the more attentive coastal management of the last decades (Peirano *et al*., 2005 and references therein). Nevertheless, paucity of sufficient data on seagrass distribution and quality status hinders the effective implementation of management policies. Moreover, legal protection against seagrass losses is only possible where disturbance derives from proximal causes, while difficulties of assigning responsibility for more diffuse impacts (e.g. eutrophication) constitute major barriers to conservation (Duarte, 2002).

Conservation and protection status: Seagrasses are recognized as priority species and habitat types for conservation efforts in international (i.e. Rio Convention, Barcelona Convention, Bern Convention, EU Habitats Directive, EU Water Framework Directive) and national frameworks (Milchakova & Phillips, 2003; Duarte *et al*., 2004). More recently, the EU Regulation 1967/2006 prohibited trawling (including beach seines) over *Posidonia oceanica* beds in the Mediterranean.

Sublittoral polychaete worm reefs on sediment (EUNIS A5.61)

Goods and Services: Marine biogenic structures that reach a few centimeters into the water column can have a profound effect on the structure and functioning of marine ecosystems. These systems are heavily used by a variety of taxa, including post-settlement juveniles of commercially important fish species (Watling & Norse, 1998). Furthermore, food availability can be an important factor explaining flatfish distribution in the nursery (Beyst *et al*., 1999) and can even override abiotic habitat preferences (Rees *et al*., 2005a). It has been suggested that flatfish species actively select for a tube mat biotope built up by *Chaetopterus* sp. and *Lanice conchilega* (Rees *et al*., 2005b; Shucksmith *et al*., 2006; Rabaut *et al*., 2010) and clusters of *L. conchilega* constitute a large feeding area for 0-group flatfishes like *Pleuronectes platessa* and *Solea solea* (Amara *et al*., 2001).

Sensitivity to human activities: In general, anthropogenic influences can strongly modify the engineering community by removing autogenic ecosystem engineers through e.g. bottom trawling (Bouma *et al*., 2009). The loss of habitat structure generally leads to lower abundance, biomass and species richness (Airoldi *et al*., 2008). Therefore, the impact of fisheries on marine ecosystem engineers is considered as a potentially serious problem because engineering activity influences both biological diversity and ecosystem functioning. Dubois *et al*. (2002) state that degraded areas are more and more widespread in *Sabellaria alveolata* reefs either directly because of destructive manual fishing methods or indirectly through the impact of shellfish aquaculture. The anthropogenic activities cause a reduction in new recruit densities leading to significant damage to both the structure and the associated fauna of the system (Dubois *et al*., 2006; 2007). Holt *et al*. (1998) review the impact of bottom fisheries on *S. spinulosa*. The disappearance of the species in some areas in the Wadden Sea has been suggested as a good indicator for fishing intensity. Large areas in the North Sea with *S. spinulosa* reefs have been reported to disappear due to fisheries activities and commercial shrimp fisheries are known to search for *S. spinulosa* upon which they trawl for shrimps (Holt *et al*., 1998 and references therein). Vorberg (2000) found in a one-off experimental disturbance with a shrimp beam trawl that in the short-run, the reef structure itself does not disappear as the natural growth and capacity for repair is such that they can rebuild destroyed parts of their dwellings within a few days. The author indicates, however, that trawling in the medium to long-term can have consequences for the integrity of the reefs in the event of intensive fishing. For *L. conchilega*, the reef structure itself appears to be relatively resistant to fisheries impact (Rabaut, 2009) while the associated reef fauna experience an immediate impact (Rabaut *et al*., 2008). In the event of intensive beam-trawling, the reef structure will eventually disappear (Rabaut, 2009). As such, beam trawl impacts on subtidal reefs seem to be similar. *S. alveolata* reefs have proven extremely sensitive also to non-fishing impacts. A shallow-water NW Sicily reef appeared and disappeared repeatedly in about 15-year time following the evolution of human pressures (organic and inorganic discharges, building activities, etc.) along the coast (D'Anna *et al*., 1990; Sparla *et al*., 1992). However, for both reef systems there is not enough detailed knowledge on the natural development processes in the reef to interpret the significance of the various abiotic and biotic factors and it is therefore still difficult to predict the recovery capacity (i.e. the resilience) of the different reef systems.

Conservation and protection status: *S. alveolata, S. spinulosa* and *L. conchilega* have all the potential, when occurring in massive densities, to classify as *Reefs* under the Annex I of the Habitats Directive (i.e. habitat type 1170).

Sublittoral mussel beds on sediment (EUNIS A5.62)

Goods and Services: Mussel beds could be used to dissipate wave energy and thereby protecting valuable salt marshes from erosion both in the Wadden Sea and in the Eastern Scheldt estuary. Mussel beds could also increase deposition in these areas by slowing down the flow (Leeuwen, 2008). Moreover, there are fisheries at a number of localities and they are often farmed: banks of small overcrowded mussels are moved to more favourable areas where growth is rapid. This mussel production is based on an extensive culture and depends entirely on natural resources for food, spat and space. In the main culture areas, production with existing techniques seems to have reached the system's carrying capacity. Spat availability can be an additional limiting factor, particularly in bottom culture. In many traditional mussel culture areas (e.g. Galicia, in Spain), new functions have developed, such as recreation and nature conservation, and therefore extension of mussel culture is now also space limited. Expansion of mussel culture in Europe takes place in areas like Scottish fjords, Ireland and Greece, and is planned in Norway. Further development of sustainable mussel culture in Europe has different requirements for traditional and for new areas (Smaal, 2002).

Sensitivity to human activities: Within a year of commencement of fisheries on a sublittoral mussel bed on sediment, a significant change in the species composition of the benthic community occurs with a decrease in the number of species and in the total number of individuals. The abundance of carnivorous and deposit feeding benthic species increased, whilst the mussels outcompeted other benthic filter feeding organisms, preventing the settlement of these organisms by ingestion of the larvae, and removed other benthic organisms by physical smothering (Smith & Shackley, 2004). Mussel dredgers damage this structure by either removing the entire bed or by making the structure more open and exposed to wave action (Nehls & Thiel, 1993). A German study (Herlyn *et al*., 1999; Herlyn & Millat, 2000) on the impact of fisheries on a few mussel beds in Lower-Saxony, indicated that even removal of a small percentage of mussels caused almost complete destruction of the beds within one year after the fisheries took place.

Conservation and protection status: Within the Habitats Directive, this biotope can be protected as *Reefs* (habitat type 1170). Across Europe, wild mussel stock fisheries are subject to various regulations at local (national) scale.

Pontic *Ostrea edulis* biogenic reefs on mixed and rocky seabottom (EUNIS A5.64)

Goods and Services: Oysters along the western Black Sea coast were never commercially fished since the Pontic oyster reefs being massive, towering structures overgrowing rocky and mixed bottoms (Todorova *et al*., 2009) could not be dredged like oyster beds on sediments along the western European coast, the Mediterranean and the eastern Black Sea. Recreational harvest from this particular habitat was probably absent (due to unreachable depth by skin divers) in the past. Therefore, Pontic oyster reefs have never been of significant importance in recreational and commercial fisheries. At present oysters are locally extinct, along with the ecosystem services this biotope provided, i.e. creation of highly-complex biogenic habitats important to biodiversity, benthic-pelagic coupling, and fishery production; nutrient cycling, transferring nutrients from phytoplankton, bacteria, particulate detritus and dissolved organic matter to benthic and fish communities (Tyler-Walters, 2008 and references therein).

Sensitivity to human activities: The causes of *Ostrea edulis* local extinction in the Western Black Sea are currently unclear. In the Western Black Sea the oysters were never commercially fished, and recreational harvest was very limited, so overfishing can be ruled out as a cause of extinction. The possible causes responsible for the oyster's loss could be increased sedimentation and overall ecological degradation during the anthropogenic eutrophication period in the Black Sea in the second half of the last century. Generally, *O. edulis,* being permanently fixed to the substratum and unable to burrow up through the deposited material, is known to be sensitive to smothering by increased sedimentation (Tyler-Walters, 2008 and references therein). Pathogens such as *Bonamia ostreae* that reached Europe via introduction of infected *O. edulis* from North America and brought about disease outbreaks occurring first in France in 1979 and spreading to neighbouring countries over the following decades could have reached and affected the Black Sea oyster populations too (Todorova *et al*., 2009 and references therein). The predatory pressure of the alien whelk *R. venosa* could have contributed as well (Chuhchin, 1984; Pereladov, 2005) although feeding experiments have shown that oysters are not preferred prey for *R. venosa* (Ivanov & Rudenko, 1969). Being unique and important to marine biodiversity and food web maintenance in the coastal ecosystem, Pontic oyster reefs are of high conservation interest and measures for their rehabilitation are needed. However restoration programmes may be futile since recovery of oyster stocks is shown to be complicated and dependent on many factors, such as sufficient spawning stock density to ensure synchronous spawning and larval production, presence of adults and shell material to enhance settlement, hydrodynamic containment in a favorable environment, etc. (Jackson & Wilding, 2009; Kennedy & Roberts, 1999; OSPAR 2009).

Conservation and protection status: Since the 1980s severe decline of oyster populations has been reported for all habitats along the Black Sea coasts – both sedimentary bottoms and rocky reefs (Pereladov, 2005). *O. edulis* is included in the Black Sea Red Data Book (Dumont, 1999) as Endangered. Pontic oyster reefs qualify for NATURA 2000 habitat type 1170 (*Reefs*).

Organically-enriched or anoxic sublittoral habitats (EUNIS A5.72)

Goods and Services: The Global International Waters Assessment (GIWA) regional assessments reported that dead zones have become increasingly common in the world's lakes, estuaries and coastal zones, with serious impacts on local fisheries, biodiversity and ecosystem functions. Extensive dead zones have been observed for many years in the Baltic Sea, Black Sea and Gulf of Mexico (Díaz & Rosenberg, 2008; Rabalais *et al*., 2010). The action of bio-turbation by benthic organisms, mainly through the construction of burrows, plays a significant role in nutrient cycling, the latter being affected by storage, internal cycling, processing and acquisition by marine benthic organisms, for example fish mineralize nitrogen and phosphorous via excretion (Beaumont & Tinch, 2003). Benthic animals from a wide range of phyla have developed different strategies in adapting to exposure to hypoxic or anoxic conditions resulting in survival for many weeks under adverse environmental conditions (Hagerman, 1998).

Sensitivity to human activities: This biotope could suffer from eutrophication problems due to nutrient input from human agricultural and sanitation activities. The biotope is also sensitive to continental-marine organic matter input (Mojtahid *et al*., 2009). High disturbance could be caused by dredging activities or by trawling (Thrush & Dayton, 2002). Megafauna play a significant role in bio-turbation, and as detailed earlier it is these organisms which are most vulnerable to trawling activity. Disturbance by the increasing aquaculture activities increment which leads to the increasing of fouling pests, toxic and noxious microalgae blooms, diseases, etc. (Kaiser *et al*., 1998; Forrest *et al*., 2009).

Conservation and protection status: Included in the Council of Bern Convention Res. No. 4 1996 as *Sublittoral soft seabeds* (code 11.22). There is a need to design more efficient monitoring programs to assess eutrophication effects in estuaries and determine the effectiveness of regulatory or management initiatives to reduce organic over-enrichment of seabeds.

Deep-sea artificial hard substrata (EUNIS A6.12)

Goods and Services: In shallow waters artificial substrata are usually deliberately deployed to protect habitats from trawling destruction, to promote nature conservation, and to enhance fisheries and, to a lesser degree, biofiltration. On the other hand, artificial hard substrata in deeper waters are either intentionally deployed for the reasons mentioned above together with other purposes (such as to provide substantial cost savings for the oil and gas industries in the case of decommissioned rigs), or are accidentally introduced on the seabed (i.e. ship wrecks). Recently, the prospect of such deep-sea substrata is on the increase due to anthropogenic material being deployed for experimental purposes, especially in view of rig-to-reef conversion schemes, when the production of oil fields is either declining or ending (Soldal *et al.,* 2002). According to Macreadie *et al.* (2011)

decommissioned rigs could enhance biological productivity, improve ecological connectivity, and facilitate conservation and restoration of deep-sea benthos (e.g. cold-water corals) by restricting access to trawlers. Preliminary evidence indicates that decommissioned rigs in shallower waters can also help rebuild declining fish stocks. However, potential negative impacts may include physical damage to existing benthic habitats within the "drop zone", undesired changes in marine food webs, facilitation of the spread of invasive species, and release of contaminants as rigs corrode.

Sensitivity to human activities: The main pressure for communities inhabiting deep-sea artificial substrata is overfishing. There is an attraction vs. production debate regarding artificial reefs (Grossman *et al*., 1997; Pickering & Whitmarsh, 1997), where on one hand scientists see such structures as replacing lost habitat by allowing sessile organisms to grow, providing cover, and hence enhancing the production of large fish. On the other hand, some elements of the conservation movement have come to regard artificial reefs with alarm, seeing them as merely fish aggregators that speed up the depletion of vulnerable large fish (Polovina, 1989; Pitcher & Seaman, 2000). This however, like for several other cases, depends largely on the implementation of good fisheries management practices: if inadequate or no management is in place, deep-sea artificial structures may indeed act as fishing lure, making it easier for unmanaged fisheries to deplete fish populations. Furthermore, when artificial substrata such as oil rigs and other infrastructure materials are moved or taken out of the water for servicing, decommissioning or any other reason, the encrusted community will be lost, resulting in the loss of the associated biodiversity, as well as disrupting the equilibrium of the community around these structures. Moreover, when artificial substrata are moved elsewhere in the marine environment, there is an increased possibility of introducing alien species to native communities.

Conservation and protection status: There are no active conservation measures for this biotope.

Deep-sea manganese nodules (EUNIS A6.13)

Goods and Services: Assemblages of manganese nodules provide microhabitats of hard substrata in environments of soft substrata, where the nodules preferentially occur should the requirements for their formation be met. Furthermore, they provide a higher surface area for attachment due to their irregular form with crevices, resulting both in an increase as well as a more diverse biodiversity compared to the bare sediment. Three microhabitats (raised surfaces, depressed surfaces, and nodule sides) and two surface textures (smooth and rough) are recognised. Most of the summit region of the nodules is occupied by raised microhabitats and have a smooth texture. These smooth, raised surfaces are usually the most colonized microhabitat of the nodules (Veillette *et al*., 2007). Manganese concretions can also be considered as natural metal ionic traps "cleaning" near- bottom waters of some toxic elements as the content levels of toxic metals (e.g. Pb, Zn, and Cu), originating from anthropogenic sources (Zhamoida *et al*., 2007). Although ferromanganese nodules have been recommended by some researchers as monitors of metal marine pollution, their utility for monitoring seems to be limited (Szefer, 2002). On average, manganese nodules contain about 25% manganese, but also minor constituents of copper, nickel and cobalt. These valuable metals are an important resource for the future. Already in the 1970s the Federal Institute for Geosciences and Natural Resources took part in the exploration of manganese nodules in the deep-sea. However, involved mining companies soon lost their interest as the prices for the valuable metals contained in manganese nodules rapidly declined, due to new resource findings on land in the 1980's. Today, in view of the depleting land resources and the increasing industrial demand, manganese nodule resources are of interest again. The International Seabed Authority (ISA), which administers the resources of the deep-sea under the UN Law of the Sea, has already given licenses to contract partners from different countries. France, Japan, India, China, Korea, Russia, and Germany have been active in developing mining and processing technologies for deep-sea manganese nodules (Sharma, 2010) but so far no such large-scale mining has started.

Sensitivity to human activities: The main threat to assemblages associated with deep-sea manganese nodules is nodule mining. The most direct effect of manganese-nodule mining will be on the bottom-dwelling communities, especially on fauna attached to the nodules, which will be destroyed (Thiel *et al*., 1991; 1993). Other effects include the partial covering of surrounding epifauna by sediment blanketing, biochemical changes resulting in biotic responses, and changes in the existing depositional and decompositional biota-sediment processes (Raghukumar *et al*., 2001; Ingole *et al*., 2001 and references therein). However, the impact of the mining itself is very likely to be small compared with the potential environmental impact of processing nodules at sea, or in the coastal zone.

Conservation and protection status: Mining of manganese nodules is regulated by the Mining Code, which refers to the whole of the comprehensive set of rules, regulations and procedures issued by the ISA to regulate prospecting, exploration and exploitation of marine minerals in the international seabed area (defined as the seabed and subsoil beyond the limits of national jurisdiction). It states that prospecting shall not be undertaken if substantial evidence indicates the risk of serious harm to the marine environment.

Communities of bathyal detritic sands with *Gryphus vitreus* (EUNIS A6.31)

Goods and Services: Bathyal detritic sands with *Gryphus vitreus* (BDS) offer a high species richness and abundance when compared to the deep-sea silt zones (SZ) and detritic sands (DS): BDS contains double the number of species and four times the number of individuals supported by SZ, and three times more species and 5 times more individuals than DS (Laubier & Emig, 1993). *G. vitreus* might serve as prey for economically important species, especially when molluscs, which are more difficult to open, are scarce. Known predators of the brachiopod in the Mediterranean are polychaetes, naticid gastropods and decapods, especially the spiny lobster *Palinurus mauritanicus* which is of economical importance (Delance & Emig, 2004).

Sensitivity to human activities: The main threat to communities of bathyal detritic sands with *G. vitreus* is trawling and dredging. As in any other biotope where members of the community act as a secondary substratum (i.e. providing hard habitat islands where such a substratum is scarce) bottom fishing with towed gears will definitely have a detrimental effect. Silting due to towed fishing gears affects this biotope and can cause its replacement by bathyal muds, which always occur below the former. Silting and the consequent decline of BDS may substantially affect lobster fisheries (Emig, 1989).

Conservation and protection status: Communities of bathyal detritic sands with *G. vitreus* are currently not protected by any legislation or regulation.

Communities of deep-sea corals (EUNIS A6.61)

Goods and Services: Deep-sea coral communities are considered as biodiversity hotspots, representing patches of high diversity in a low diversity environment (Henry & Roberts, 2007; Carlier *et al*., 2009; Mastrototaro *et al*., 2010). It is hypothesized that reefs may function as centres of spreading for associated fauna (Fosså *et al*., 2002). Deep-sea coral reefs are important for fisheries: fish aggregate on deep-sea reefs as they provide protection from currents and predators, nurseries for young fish, and feeding, breeding and spawning areas for numerous fish and shellfish species (Freiwald *et al*., 2004), including crustacea and fish species of economic interest, such as *Aristaeomorpha foliacea* and *Helicolenus dactylopterus* (Tursi *et al*., 2004). Furthermore, coral and sponge communities are a largely untapped resource of natural products with enormous potential as pharmaceuticals, nutritional supplements, enzymes, pesticides, cosmetics, and other commercial products (Freiwald *et al*., 2004). Bathyal cold-water corals are being increasingly studied for paleoceanographic purposes, since their aragonitic skeletons serve as geochemical archives, providing useful insights into past water properties and circulation patterns (Lopez Correa *et al*., 2010 and references within). Deep-sea coral reef communities also have what is known as a high existence value. This is the benefit of simply knowing marine biodiversity exists even if it is never utilized or experienced (Loomis & White, 1996).

Sensitivity to human activities: Documented and potential sources of threats to cold water corals are (1) commercial bottom trawling and other bottom fishing; (2) hydrocarbon exploration and production; (3) cable and pipeline placement; (4) bioprospecting and destructive scientific sampling; (5) other pollution; (6) waste disposal and dumping and (7) coral exploitation and trade (Freiwald *et al*., 2004).

The biggest human threat to deep-sea coral reefs is destructive fishing; bottom trawling in particular has pulverized these communities and ripped many of them from the seabed. Trawling directly kills the corals, breaks up the reef structure, and buries corals through increased sedimentation. Wounds in coral tissue and infection cause additional deaths in those that are not killed outright. Furthermore, bottom trawl activity alters the hydrodynamic and sedimentary conditions (Tursi *et al*., 2004). Another impact of trawling activity on the white coral reef is due to the suspension of sediments; in fact, coral species, like all suspension feeders, are particularly vulnerable to the effects of increased sedimentation (Rogers, 1999). Other fishing gears such as bottom longlines and gillnets can also cause substantial damage to these communities (Freiwald *et al*., 2004). However, Mediterranean deep-coral banks are not targeted and therefore are not deliberately impacted by any commercial fishing. On the contrary, they represent a type of bottom that trawlers try carefully to avoid in order not to damage their nets. Fishing-boat echo-sounders are capable of indicating the likely presence of coral mounds. The experience gained by the accidental entangling of nets with coral colonies has greatly reduced such accidents among commercial fishermen (Remia & Taviani, 2005). Drilling, oil and gas exploration, seabed extraction and mining directly crush and damage corals, and can affect their living conditions by increasing the amount of sand and grit in the water and altering essential currents and nutrient flows. Drilling muds and cuttings from oil and gas exploration can be toxic to corals, and are known to cause death and alter feeding behaviour in shallow water varieties. Drill cuttings also settle and build up into piles directly underneath oil platforms and can smother and kill corals, sponges and other animals that filter the seawater for food (Freiwald *et al*., 2004).

Conservation and protection status: Resolution 58/240 of the United Nations General Assembly, approved in December 2003, called for the urgent management of risks to the marine biodiversity of vulnerable marine ecosystems (VMEs), including cold waters coral reefs, and invited the relevant regional bodies to also address the conservation of VMEs in areas beyond national jurisdiction (WWF/IUCN, 2004). In 2007, the United Nations General Assembly (UNGA) resolution 61/105 called for States and Regional Fisheries Management Organisations (RFMOs) to assess impacts, and avoid significant adverse impacts on VMEs from destructive fishing practices in managed international waters. Similarly, the FAO's International Guidelines for the management of deep-sea fisheries in high seas (FAO, 2009), call for the need to operate on a precautionary basis with regards to VMEs, including deep-water corals. Cold water corals are also included in the list of VMEs, in a recent regulation issued by the Council of the European Union on the protection of vulnerable marine ecosystems in the high seas from the adverse impacts of bottom fishing gears (EC, 2008). This Regulation puts restrictions on fishing activities, requires special fishing permits and impact assessments, and contains provisions on unforeseen encounters with vulnerable marine ecosystems, area closures and an observer scheme for all vessels which have been issued a special fishing permit. Freiwald *et al*. (2004) have made several recommendations regarding the conservation and sustainable management of deep-sea coral communities and stressed the need for proper information management and research, monitoring and assessment, specific regulations and measures, and international coordination and awareness. Since 1999, the Norwegian Ministry of Fisheries has banned trawl-fisheries on eight deep-sea coral sites, namely the Sula Reef (1999), Iverryggen Reef (2000), the Røst Reef (2003), Tisler and Fjellknausene Reefs (2003), and Trænarevene, Breisunddjupet and an area northwest of Sørøya in Finnmark (2009). Similar measures were taken by the EU at the Darwin Mounds, off Scotland in 2004, and three more coral sites off Iceland in 2006, whereas numerous other sites around the Azores, Madeira and the Canary Islands have been proposed as candidates for protection (Tudela *et al*., 2004; Hourigan, 2008). In 2006, the General Fisheries Commission for the Mediterranean has created the new legal category of "Deep-sea fisheries restricted area", and recommended the banning of demersal fishery practices over the coral reef off Cape Santa Maria de Leuca (Italy) and the Eratosthenes Seamount (Cyprus) (Tudela *et al*., 2004). Following the General Fishery Commission for the Mediterranean (GFCM) recommendation, the EU prohibited the use of towed dredges and trawlers at depths beyond 1,000 m (GFCM, 2005; EC, 2006), which potentially protects part of the Mediterranean deep-sea coral communities.

Deep-sea sponge aggregations (EUNIS A6.62)

Goods and Services: Deep-sea sponge aggregations are directly related to increased abundance and richness of the macrofauna. Deep-sea sponges provide a structured habitat of increased complexity suitable for many invertebrates; they provide shelter to small epifauna, within the oscula and canal system, and an elevated perch for many species, such as brittlestars (Konnecker, 2002). Deep sponge aggregations constitute an essential fish habitat, providing shelter and prey for both juvenile and adult fish (OSPAR, 2010). Dense spicule mats deposited by sponges may have several effects on the benthic community, e.g. by providing a hard substratum that is suitable for colonisation by many epibenthic species, and support increased biomass of macrofaunal species (Bett & Rice, 1992). Furthermore, sponge communities are a largely untapped resource of natural products with enormous potential as pharmaceuticals, nutritional supplements, enzymes, pesticides, cosmetics, and other commercial products (Freiwald *et al*., 2004); many compounds obtained from deep-sea sponges are being tested in clinical trials for anti-cancer, anti-inflammatory, and other medical properties (Maxwell *et al*., 2005).

Sensitivity to human activities: Having similar habitat preferences to cold-water corals, thus often being found in the same location (Gubbay, 2002), deep-sea sponge aggregations suffer from the same threats that deep-sea corals do (see the previous section on 'Communities of deep-sea corals – EUNIS A6.61' for more details). Deep-sea sponges are long-lived and slow-growing, and deep-sea sponge communities are likely to take many years to recover if damaged. Recovery of sponge aggregations is much slower in deep waters than it is in shallower, warmer waters (Freese, 2001). Physical disturbance to the seabed, particularly by bottom trawling, is the greatest threat. A recent evaluation of the status of this habitat in the OSPAR area concluded that it is considered 'currently threatened as the likely rate of decline linked directly to human activity exceeds that which can be expected to regrow' (OSPAR, 2010).

Conservation and protection status: Deep-sea sponge aggregations are one of the five deep-sea habitats listed by OSPAR as threatened or declining. Within the Habitats Directive, this biotope can be protected under the habitat type 1170. In the UK, '*deep-sea sponge aggregations*' is a priority habitat for conservation action (UKBAP, 2008). Deep-sea sponge aggregations are often offered the same protection that deep-sea coral reef communities benefit from, because these two community types are very often mentioned together in regulations and directives (e.g. EC, 2008) as they both benefit from the same conservation measures (see the previous section on 'Communities of deep-sea corals – EUNIS A6.61').

Seamounts, knolls and banks (EUNIS A6.72)

Goods and Services: Seamounts are hotspots of biodiversity in deep waters as their distinctive environment provides habitat for a great variety of benthic and pelagic species. Especially deep cold-water coral reefs or gorgonian and antipatharian beds associated with seamounts provide microhabitats of high biodiversity similar to the shallow-water tropical coral reefs. There is a high rate of speciation and endemism amongst seamount fauna (Richer De Forges *et al*., 2000; Rogers, 2004; Gad, 2009). Seamounts provide appropriate environmental conditions for the reproduction of many pelagic or demersal fish species. Orange roughy (*Hoplostethus atlanticus*), roundnose grenadier (*Coryphaenoides rupestris*), splendid alfonsino (*Beryx splendens*) and bulls-eye (*Epigonus telescopus*) are known to form spawning aggregations over NE Atlantic seamounts (Gubbay, 2003; Menezes *et al*., 2009). Seamounts often maintain high standing stocks of demersal and pelagic fishes providing habitat, feeding grounds and sites of reproduction. The high abundance of commercially valuable fish and shellfish around seamounts has caused their intensive exploitation with long-lines, mid-water and deep bottom trawlers and static nets. Black scabbard fish (*Aphanopus carbo*), anglerfish (*Lophius piscatorius*), redfish (*Sebastes* spp.), slickhead (*Alepocephalus bairdii*), roundnose grenadier (*Coryphaenoides rupestrius*), various species of sharks, and also large pelagics such as tunas and swordfish are among the target species of commercial fisheries on seamounts in the NE Atlantic (Gubbay, 2003; Menezes *et al*., 2009).

Sensitivity to human activities: Fishing is by far the most significant threat to the biodiversity of seamounts. Seamounts are especially vulnerable to bottom trawling, which is highly destructive for the fragile habitat forming taxa such as corals and sponge aggregations (Koslow *et al*., 2001; Clark & Rowden, 2009) (see also section: Communities of deep-sea corals - EUNIS A6.61). Strong differences in faunal composition have been reported between trawled and untrawled seamounts; the coral cover has been almost completely removed from the fished seamounts (Koslow *et al*., 2001; Clark & Rowden, 2009). Many species of fish living around seamounts have a life history of slow growth and maturation rates and high longevity (e.g. orange roughy has a longevity of >100 years and matures at an age of ~20-30 years). These species may not withstand intensive fishing, which has already led to the collapse of many seamount fish stocks (Gubbay, 2003). Many fish species are known to form spawning aggregations around seamounts and are therefore easily targeted by trawlers. Trawl fisheries around seamounts have a high proportion of discards. Mining activities on seamounts, especially targeting hydrogenous ferromanganese crusts and polymetallic sulphides, which could be exploited for base metals, such as copper, zinc, and lead, or for precious and high-tech metals is likely in the near future (Hein *et al*., 2010), as such exploratory mineral mining has already been conducted. Mining activities will be destructive in the impacted area (habitat loss or degradation of habitat quality; connectivity and biodiversity loss; reducing biodiversity; local, regional, or global extinction of rare taxa; loss of potential biological resources) but will also affect the benthic fauna (and especially suspension feeders) in the surrounding seamount areas by substantially increasing the sediment load and water turbidity (Gubbay, 2003; Rogers, 2004; Shank, 2010). However, Hein *et al*. (2010) consider the effects of mining to be substantially less than those of deep-sea trawling.

Conservation and protection status: Seamounts are extremely vulnerable to destructive fishing activities (i.e. bottom-trawling) and the habitats and biocommunities of many of them have already been seriously degraded. Seamounts have become a priority biotope under the OSPAR Convention and are included in the network of MPAs promoted by OSPAR. The United Nations General Assembly adopted in 2006 resolution 61/105 that calls for a precautionary approach and required sufficient conservation and management measures to be established at all known and suspected vulnerable ecosystems, including seamounts, to prevent significant adverse impacts of bottom fishing. Such measures should have been established by 31 December 2008 or else all bottom fishing activities should be seized. Seamounts are also likely to form part of the NATURA 2000 network under the 1170 code (*Reefs*). In European territorial waters there are currently only few seamounts managed as MPAs or for which management plans have been developed (Santos *et al*., 2009). A number of high seas areas are now closed to bottom fisheries, by Regional Fishery Management Organizations (RFMOs), in accordance with the United Nations General Assembly resolution 61/105. The 2010 OSPAR Ministerial Meeting took the significant step of adopting OSPAR Decisions establishing six MPAs in areas beyond national jurisdiction, including several seamounts, and OSPAR Recommendations on their initial management. However, outside the European territorial waters and Exclusive Economic Zones no adequate mechanisms exist yet for the effective surveillance and protection of these areas. In addition there are several issues that complicate the management of these areas: (1) the seabed and water column in these areas may be subject to different jurisdiction; in four of these MPAs Portugal manages the seabed as part of an outer limit continental extension defined by the United Nations Convention on the Law of the Sea (UNCLOS); (2) OSPAR has no authority to control fishing activities, which are controlled by the North East Atlantic Fisheries Commission (NEAFC); (3) OSPAR has no control on mining, which is covered by the ISA; (4) OSPAR has no control on shipping, ruled by by the International Maritime Organization (IMO). OSPAR continues its liaison with other international competent authorities and relevant bodies to further develop the management framework for these sites. Following the GFCM recommendation, the EU prohibited the use of towed dredges and trawlers at depths beyond 1,000 m (GFCM, 2005; EC, 2006), which potentially protects parts of the Mediterranean seamount biotope.

Oceanic ridges (EUNIS A6.73)

Goods and Services: Biological productivity is generally enhanced at ridges compared to the adjacent oligotrophic ocean basins, often because of local upwelling. Aggregations of zooplankton and nekton have been observed in several locations of the Mid-Atlantic Ridge (MAR) region (Opdal *et al*., 2008; Gaard *et al*., 2008). Aggregation of feeding cetaceans may be associated with the enhanced secondary production of oceanic ridges. In several locations of the MAR, aggregations of sperm (*Physeter macrocephalus*) and sei (*Balaenoptera borealis*) whales and other cetaceans capitalize on secondary production maintained by enhanced primary production associated with the frontal processes in the upper part of the water column (Skov *et al*., 2008; Doksæter *et al*., 2008). Oceanic ridges provide important and diverse habitats for many deep-water fish (such as the orange roughy) and shark species. The rough topography of oceanic ridges with available hard bottoms and the elevated currents provide favourable conditions for sessile suspension feeders such as corals, hydroids, and sponges, which may occur in great abundance along oceanic ridges. In the MAR there is a high species richness of corals with at least 40 taxa, with *Lophelia pertusa* and *Anthomastus* sp. being the most common (Mortensen *et al*., 2008).

Sensitivity to human activities: The main human activities conducted in the areas of oceanic ridges are fishing, shipping and the laying of communication cables. Fishing activities have the biggest impact on marine biodiversity around oceanic ridges (Mortensen *et al*., 2008). High Seas fishing has been conducted in the area of MAR since the 1970s and has led to overexploitation of several demersal deep-sea fish species and extended damage to the biotope because of bottom trawling (Dotinga & Molenaar, 2008).

Conservation and protection status: The areas beyond national jurisdiction of the North East Atlantic, including MAR, are covered by a regional seas agreement (the OSPAR convention) and by three regional fisheries management organisations: NEAFC, North Atlantic Salmon Conservation Organization (NASCO), and International Commission for the Conservation of Atlantic Tunas (ICCAT). Regional fisheries management organisations are recognized as the primary international vehicles for high seas fisheries governance in accordance with the UNCLOS and the United Nations Fish Stocks Agreement (UNSFA). Their formal mandates extend solely to the regulation of fisheries, including wider environmental concerns (NEAFC) or more narrowly focused on the conservation and sustainable utilization of the target species involved (NASCO and ICCAT) (Dotinga & Molenaar, 2008). The OSPAR commission pursues the establishment of a network of MPAs in the NE Atlantic with a broader scope that also applies to the MAR. The 2010 OSPAR Ministerial Meeting took the significant step of establishing six MPAs in areas beyond national jurisdiction including sections of the MAR. However, there are several complications for the management of these MPAs (see previous section on 'Seamounts, knolls and banks - EUNIS A6.72'). Following the GFCM recommendation, the EU prohibited the use of towed dredges and trawlers at depths beyond 1,000 m (GFCM, 2005; EC, 2006), which potentially protects part of the Mediterranean oceanic ridges.

Abyssal hills (EUNIS A6.74)

Goods and Services: There is a lack of relevant knowledge. Although this is the most common marine biotope, it is the least explored and we know very little on the goods and services it provides or may provide in the future. Further research is needed especially on the role of abyssal hills to climate regulation, water quality regulation and the maintenance of deep-water biodiversity.

Sensitivity to human activities: There are no documented threats to abyssal hills due to human activities.

Conservation and protection status: There are no conservation or protection measures so far for this biotope.

Cold-water coral carbonate mounds (EUNIS A6.75)

Goods and Services: Carbonate mounds are important palaeoclimatic archives due to their longevity over geological scales, cosmopolitan distribution, and banded skeletal structure (Murray Roberts *et al*., 2006). Fossil records from carbonate mounds allow us to estimate past seawater temperatures and follow the ventilation history of the ocean and shifts in deep-ocean circulation patterns (Goldstein *et al*., 2001; Schröder *et al*., 2003; Murray Roberts *et al*., 2006). Active carbonate mounds are complex high diversity habitats in the deep ocean, providing niche for a great variety of species and great abundance of suspension feeders, grazers, scavengers and predators (Murray Roberts *et al*., 2006). Carbonate mounds represent patches of high diversity in an environment of low diversity (Fosså *et al*., 2002). Their biodiversity may be comparable to that found on tropical shallow-water coral reefs, while there is evidence of high endemism (Murray Roberts *et al*., 2006). Carbonate mounds provide fish habitat and are considered good fishing places for net and long-line fisheries.

Sensitivity to human activities: Bottom trawling is the most significant threat to carbonate mounds. Severe physical damage to the coral cover of carbonate mounds, from which recovery would take hundreds or thousands of years, has been reported in many areas (Hall-Spencer *et al*., 2002; Fosså *et al*., 2002; Wheeler *et al*., 2005). Global climate change is a serious potential threat for the cold-water coral ecosystems of carbonate mounds due to the acidification of the oceans, rising of seawater temperature and alteration of deep-water circulation (Orr *et al*., 2005; Murray Roberts *et al*., 2006; Weaver *et al*., 2009). Modelling studies predict that depth of the aragonite saturation horizon will move shallower by several hundred meters, thereby turning current carbonate mound areas inhospitable for coral formation in the future (Orr *et al*., 2005; Murray Roberts *et al*., 2006). See also section: Communities of deep-sea corals (EUNIS A6.61).

Conservation and protection status: Carbonate mounds are extremely vulnerable to destructive fishing activities (i.e. bottom trawling) and many of them have already been seriously damaged. Carbonate mounds are included in the OSPAR List of Threatened or Declining Species and Habitats and are included in the network of MPAs promoted by OSPAR. The United Nations General Assembly adopted in 2006 resolution 61/105 that calls for a precautionary approach and required sufficient conservation and management measures to be established at all known and suspected vulnerable ecosystems, including cold-water corals, to prevent significant adverse impacts of bottom fishing. Such measures should have been established by 31 December 2008 or else all bottom fishing activities should be seized. Several nations worldwide such as Canada, Norway, UK and USA have closed areas with cold-water corals to bottom fishing.

Submarine canyons on the continental slope (EUNIS A6.81)

Goods and Services: Submarine canyons can sustain high biomass of infaunal megabenthic invertebrates over large areas (De Leo *et al*., 2010). Fish abundance is enhanced in canyons (Stefanescu *et al*., 1994; Vetter & Dayton, 1999; Brodeur, 2001; Vetter *et al*., 2010), which are therefore regularly targeted by commercial and recreational fishermen exploiting bottom fish and invertebrates (Vetter *et al*., 2010). Some of the deep-water shrimp fishing grounds are located on the margin of submarine canyons (Sardá *et al*., 2004). Canyons may also focus the deposition of nekton carcasses, concentrating scavengers (Vetter, 1995) and thus be hotspots of scavenger-based ecosystem services and enhanced fishery yields (Vetter *et al*., 2010). Canyons may serve as important nursery grounds for some fish and invertebrate species possibly due to increased structural diversity compared to adjacent slope areas (e.g. rock walls, boulders, and detritus patches) and increased availability of benthic or planktonic prey (Vetter & Dayton, 1999; Vetter *et al*., 2010). Enhanced availability of food in canyons may be especially important for allowing demersal fish and benthic invertebrates to reproduce in otherwise oligotrophic regions (Vetter *et al*., 2010). Submarine canyons may harbour source populations in a 'source-sink system' providing larvae out to the surrounding slope and enhancing local and regional species density (Vetter *et al*., 2010). Submarine canyons play a crucial role in the redistribution of carbon and anthropogenic materials derived from marine primary production and terrestrial runoff (Weaver *et al*., 2004). They are considered major pathways for the transportation and burial of organic carbon, acting as buffers for carbon storage; burial of organic carbon in marine sediments moderates atmospheric CO_2 levels on geological time scales (Masson *et al*., 2010).

Sensitivity to human activities: Marine pollution seems to be an important threat to submarine canyons. Canyons receive anthropogenic materials derived from terrestrial runoff and have been considered as potential waste disposal sites (Weaver *et al*., 2004). For example, the Cassidaigne canyon near Marseilles has been used by the aluminum industry for damping its wastes ("red mud"). Marine litter (defined as any manufactured or processed solid waste material that enters the marine environment from any source) has been found to accumulate in high densities in submarine canyons (Galgani *et al*., 2000) with significant impact to benthic fauna. Bottom fishing, especially trawling, might be an important threat to the biocommunities of some submarine canyons.

Conservation and protection status: There are no specific conservation or protection measures so far for submarine canyons. Following the GFCM recommendation, the EU prohibited the use of towed dredges and trawlers at depths beyond 1,000 m (GFCM, 2005; EC, 2006), which potentially partly protects the deeper part of some Mediterranean submarine canyons.

Deep-sea trenches (A6.82)

Goods and Services: Deep-sea trenches are the deepest areas of the ocean typically extending 3 to 4 km below the level of the surrounding oceanic floor. A diverse array of metazoan species of fish, holothurians, polychaetes, bivalves, isopods, actinians, amphipods and gastropods have been recorded in deep-sea trenches, with many of them considered as exclusive to this biotope (Jamieson *et al*., 2010). The deep-sea environment is also a source of unique microorganisms with great potential for biotechnological exploitation. Piezophilic (i.e. pressure loving) bacteria living in the deep sea have special features that allow them to live in this extreme environment, and it seems likely that further studies of these organisms will provide important insights into the origin of life and its evolution (Horikoshi, 1998). Research on piezophiles is expected to progress in two directions: (1) the exploration of high-pressure adaptation mechanisms of deep-sea organisms; and (2) the biotechnological applications of deep-sea organisms, as in the case of other extremophiles (Abe & Horikoshi, 2001).

Sensitivity to human activities: There are no documented threats to deep-sea trenches due to human activities.

Conservation and protection status: There are no conservation or protection measures so far for deep-sea trenches.

Deep-sea hydrothermal vents (A6.94)

Goods and Services: Hydrothermal vents have a unique biodiversity differing from the surrounding deep-sea areas. They contain a high diversity of chemoautotrophic bacteria, which form the core of the trophic structure around the vent. Other small or large animals (tubeworms, bivalves, limpets, barnacles, shrimp, crabs, gastropods) live off the chemosynthetic bacteria either eating them directly or harbouring them in their bodies (endosymbiotic or episymbiotic relationships) living off the organic compounds the bacteria produce (Lutz & Kennish, 1993). It takes a high level of specialisation to live in such extreme biotopes and thus many of the species recorded in hydrothermal vents are exclusive to this biotope (Van Dover, 2000; Tarasov *et al*., 2005). Hundreds of species have been discovered at the hydrothermal vents and the fauna varies widely between regions due to discontinuities of the ridges and hydrological barriers (Bachraty *et al*., 2009). Deep-sea hydrothermal vents are important biological sources of thermophile and hyperthermophile bacteria that show a great potential for biotechnological applications (Guezennec, 2002; Mancuso Nichols *et al*., 2005). Microbial polysaccharides represent a class of important products of growing interest for many sectors of industry. Some bacteria originating from hydrothermal deep-sea vents were shown to biosynthesize innovative exopolysaccharides under laboratory conditions that are expected to find many applications in the near future due to their specific properties (Guezennec, 2002). Extremophilic microorganisms from hydrothermal vents will provide a valuable resource not only for exploitation in novel biotechnological processes but also as models for investigating how biomolecules are stabilized when subjected to extreme conditions (Guezennec, 2002; Mancuso Nichols *et al*., 2005). Proposed uses for polymers produced exopolysaccharides from deep-sea hydrothermal vents include water treatment and removal of heavy metal pollutants, food-thickening agents, and clinical applications in the area of cardiovascular diseases and bone healing (Mancuso Nichols *et al*., 2005). The relatively uniform reactions between seawater and seafloor basalt are considered to constitute a geochemical "flywheel" that stabilizes the ocean's composition against variations in river input caused by long-term climatic and tectonic changes (Edmond & Von Damm, 1992). Some hypotheses about the origin of life on Earth centre on hydrothermal vents and their chemosynthetic based communities. Several important features of hydrothermal vents make it a good candidate for abiogenesis (Martin & Russel, 2003; Howe, 2008). Such theories have important implications for extraterrestrial life, as similar conditions to those at deep-sea hydrothermal vents are expected to prevail on certain planets (Howe, 2008). Thus, hydrothermal vents are natural laboratories that provide valuable information for our understanding of the origin of life.

Sensitivity to human activities: The main documented threat to hydrothermal vents is bottom fishing. Hydrothermal vents spew metal-rich fluids that settle out to form mineral-laden sediment beds. There is an ongoing discussion on mining the metalliferous deposits around hydrothermal vents and arguments that such mining can be environmental friendly and sustainable (Ellis, 2008); however the consequences to this biotope are unknown. Scientific research and sampling can pose a threat to hydrothermal vents and their associated communities, especially to the most visited systems (Glowka, 2003). Therefore, several international agencies have called for a formal code of conduct for scientific research in hydrothermal vents (see e.g. Devey *et al*., 2007; Godet *et al*., 2011).

Conservation and protection status: The United Nations General Assembly adopted in 2006 resolution 61/105 that calls for a precautionary approach and required sufficient conservation and management measures to be established at all known and suspected vulnerable ecosystems, including hydrothermal vents, to prevent significant adverse impacts of bottom fishing. Such measures should have been established by 31 December 2008 or else all bottom fishing activities should be seized. The 2010 OSPAR Ministerial Meeting took the significant step of establishing six MPAs in areas beyond national jurisdiction to protect parts of the MAR, some of which comprising hydrothermal vents. However, there are several complications for the management of these MPAs (see previous section on 'Seamounts, knolls and banks - EUNIS A6.72').

Pontic anoxic H_2S black muds of the slope and abyssal plain with anaerobic sulphate reducing bacteria and nematodes (EUNIS A6.95)

Goods and Services: Deep anoxic Black Sea sediments are inhabited by anaerobic bacteria, which are believed to be more active and diverse than anywhere else in the ocean. The most abundant bacterial population in the Black Sea belongs to the sulphate - reducing bacteria from *Desulfosarcina – Desulfococcus* group. Other functional groups include methane oxidizing archaea, ammonium-oxidizing (anammox) bacteria, chemoautotrophic sulphur-oxidizing bacteria, and photosynthetic purple and green sulphur bacteria. The Black Sea harbours vast quantities of hydrogen sulphide. This noxious gas could be used as a renewable source of hydrogen gas to fuel a future carbon-free economy (Op Den Camp, 2006; Haklidir *et al*., 2009). Total hydrogen sulphide production in the sediments of the Black sea is estimated at about 10,000 tons per day and this equates to potentially well over 500 tons of daily hydrogen gas production using various different decomposition methods (Haklidir *et al*., 2009). The anammox bacteria were estimated to contribute up to 50% of oceanic nitrogen loss (Op Den Camp, 2006). The anammox process is currently implemented in water treatment for the low-cost removal of ammonia from high-strength waste streams (Op Den Camp, 2006). The major part of methane (>90%) that is produced in ocean sediments is consumed by microbes before it reaches the atmosphere. Therefore anaerobic oxidation of methane has a significant impact on climate regulation as methane is a 30 times stronger greenhouse gas compared to carbon dioxide (Treude *et al*., 2005).

Sensitivity to human activities: Insufficient information.

Conservation and protection status: Deep-sea biotopes in the Black Sea are not addressed by any legal provisions or management aimed at their conservation.

***Pontic anaerobic microbial biogenic reefs above methane seeps (EUNIS *A6.96)**

Goods and Services: Carbonate structures with methanogenic origin, associated with several centimetres thick microbial mats, occur in the Black Sea above methane seeps. Microbes consume the major part of methane produced in the ocean sediments, preventing it from reaching the atmosphere, and thus playing a significant role in climate regulation (Treude *et al.,* 2005). The microbial reefs discovered in the Black Sea suggest how ancient oceans might have looked when oxygen was a trace element in the atmosphere, long before the onset of metazoan evolution, and provide a unique opportunity for scientific knowledge development regarding the biological cycling of carbon in an anoxic biosphere.

Sensitivity to human activities: Available data remain insufficient but gas and oil drilling and extraction of gas-hydrates may lead to the physical destruction of this biotope.

Conservation and protection status: Microbial 'bubbling reefs' are a subtype of NATURA 2000 habitat type 1180 *Submarine structures made by leaking gases* listed under the Habitats Directive. These should receive adequate attention and Special Areas of Conservation should be designated in the Black Sea aimed at the conservation of this extraordinary natural biotope. The initial list of sites of Community importance for the Black Sea biogeographical region adopted by Commission Decision of 12 December 2008 does not include site with 'bubbling reefs' over methane seeps.

Overview – Concluding remarks

Goods and services provided by each seabed biotope, as assessed in the present review, are summarized in Table 1.

Our oceans, and coastal areas in particular, have been and continue to be affected by a heavy burden of anthropogenic pressures. There is widespread degradation of marine biotopes, depletion of resources and loss of biodiversity. Evidently, the major drivers of change, degradation or loss of marine and coastal ecosystem goods and services are anthropogenic in nature (MEA, 2005). Many of the assessed European biotopes are quite vulnerable to many human activities and have been facing substantial deterioration. This leads to an urgent need for further protection measures. Fishing activities, especially by benthic trawls, and marine pollution are the main threats to a large number of European seabed biotopes (Fig. 1). Many other human-related threats such as increased turbidity of the seawater, dredged sediment disposal, coastal constructions, mining, extraction of raw materials, biological invasions (assisted by global change, shipping, aquaculture, and fishing activities), shipping-related activities, hydrocarbon exploration, tourism, and even some practices of scientific research, also exert substantial pressure to many seabed biotopes (Fig. 1). This is aggravated by the fact that climate change will influence the structure and functioning of marine ecosystems and the use of coastal zones (IPCC, 2007; Rosenzweig *et al.,* 2008; EEA, 2010; Coll *et al.,* 2010).

Although many steps have been taken towards the protection of European marine ecosystems through European, national and international legislation and agreements, there is still a need of further measures to effectively protect all biotopes and ensure the sustainability of the goods and services they provide. Many scientists argue that the future of the European oceans and coasts depends on the successful implementation of a comprehensive governance framework that moves away from a sectoral management approach to an integrated approach (Foley *et al*., 2010; Katsanevakis *et al*., 2011). Through EB-MSM, the assessment of the impacts of human activities and their spatial reallocation to achieve ecological, economic, and social objectives appears to be the only effective way towards sustainable development.

Keeping human uses at sustainable levels must be supported with a better understanding and quantification of the goods and services provided by marine ecosystems (Rice *et al*., 2010). The assignment of values to biophysical features of the marine environment will allow the direct assessment of related management choices and may assist EB-MSM by achieving the widest possible consensus and reducing the need for difficult and costly enforcement in the future (Katsanevakis *et al*., 2011).

The Marine Strategy Framework Directive (MSFD) is the environmental pillar of the European Integrated Maritime Policy and constitutes the general basis for implementing EB-MSM in the European Seas. A better knowledge of the seafloor biotopes will lead to a more accurate assessment of the European Seas environmental status within the MSFD (Borja *et al*., 2010; 2011).

Table 1. Summary of Goods and Services provided by each seabed biotope, as assessed in the present catalogue: the three major evaluation classes (*"High", "Low", "Negligible / Irrelevant / Unknown"*) are given in dark blue, light blue and white respectively.

Biotope	Food provision	Raw materials	Air quality and climate regulation	Disturbance and natural hazard prevention	Water quality regulation / Bioremediation of waste	Cognitive benefits	Leisure, recreation and cultural inspiration	Feel good or warm glow	Photosynthesis, chemosynthesis, and primary production	Nutrient cycling	Reproduction and nursery areas	Maintenance of biodiversity
Mediterranean and Pontic communities of infralittoral algae very exposed to wave action	High		High		High	Low	High	High	High	Low	High	High
Kelp and red seaweeds (moderate energy infralittoral rock)	High	High	High	High	High	Low	High		High	High	High	High
Mediterranean and Pontic communities of infralittoral algae moderately exposed to wave action	Low	High	High		High	High	Low	Low	High	High	High	High
Faunal communities on moderate energy infralittoral rock	High	Low	Low	Low	High	High	High	High	Low	High	High	High
Mediterranean submerged fucoids, green or red seaweeds on full salinity infralittoral rock	High	High	High		High	High	High	Low	High	High	High	High
Robust faunal cushions and crusts in surge gullies and caves	Low				Low	High	High	High	Low	Low	Low	Low
Infralittoral fouling seaweed communities	Low				High	High			Low	Low	Low	
Vents and seeps in infralittoral rock		High				High	Low		High			
Mixed faunal turf communities on circalittoral rock	High	High	Low	High	High	High	High	Low	High	High	High	High
Sabellaria reefs on circalittoral rock					High	Low				High	High	High
Communities on soft circalittoral rock	High								High	High	High	High
Mussel beds on circalittoral rock	High		Low	High	High				High	High	High	High
Mediterranean coralligenous communities moderately exposed to hydrodynamic action	High	Low	High		High	High	High	High	Low	High	High	High
Pontic *Phyllophora crispa* beds on circalittoral bedrock and boulders	Low	High	Low		High	High	High	High	High	High	High	High
Mediterranean coralligenous communities sheltered from hydrodynamic action	High	Low	High		High	High	High	High	Low	High	High	High
Communities of circalittoral caves and overhangs						High	High	Low			Low	High
Infralittoral coarse sediment	High	High					Low	Low		Low	High	
Circalittoral coarse sediment	High	High								Low	Low	Low
Deep circalittoral coarse sediment	High	Low								Low		Low
Infralittoral fine sand	High	Low					Low	Low		Low	High	Low
Infralittoral muddy sand	High	Low			Low				Low	Low	High	Low
Circalittoral fine sand	High	Low								Low	High	Low
Circalittoral muddy sand	High	Low			Low					Low	Low	Low
Mediterranean communities of superficial muddy sands in sheltered waters	High				Low					Low	High	Low
Infralittoral sandy mud	High				Low					Low	Low	Low
Infralittoral fine mud	Low				Low					Low		Low
Circalittoral sandy mud	High				Low					Low	Low	Low
Circalittoral fine mud	High				Low					Low	Low	Low
Deep circalittoral mud	High				Low					Low	Low	Low

(continued)

Table 1 (continued). Summary of Goods and Services provided by each seabed biotope, as assessed in the present catalogue: the three major evaluation classes ("High", "Low", "Negligible / Irrelevant / Unknown") are given in dark blue, light blue and white respectively.

Biotope	Food provision	Raw materials	Air quality and climate regulation	Disturbance and natural hazard prevention	Water quality regulation / Bioremediation of waste	Cognitive benefits	Leisure, recreation and cultural inspiration	Feel good or warm glow	Photosynthesis, chemosynthesis, and primary production	Nutrient cycling	Reproduction and nursery areas	Maintenance of biodiversity
Mediterranean communities of muddy detritic bottoms	Low				Low					Low		Low
Mediterranean communities of coastal terrigenous muds	High				Low					Low	Low	Low
Infralittoral mixed sediments	High	Low			Low					Low	Low	High
Circalittoral mixed sediments	High	Low			Low					Low	Low	High
Deep circalittoral mixed sediments	High	Low			Low					Low	Low	High
Mediterranean animal communities of coastal detritic bottoms	High				Low					Low	Low	High
Mediterranean communities of shelf-edge detritic bottoms	High				Low					Low		Low
Maerl beds	High	High	High			High	Low		High	Low	High	High
Sublittoral seagrass beds	High	Low	High	High	High	High	High	High	High	High	High	High
Sublittoral polychaete worm reefs on sediment	High				High		Low	Low	Low	High	High	High
Sublittoral mussel beds on sediment	High	Low		High	High		Low	Low		High	High	High
Pontic *Ostrea edulis* reefs	High		Low		High	High	High	High	Low	High	High	High
Organically-enriched or anoxic sublittoral habitats	High	Low	Low	Low	Low				Low	High	Low	Low
Deep-sea artificial hard substrata												
Deep-sea manganese nodules		High	Low		Low							High
Communities of bathyal detritic sands with *Gryphus vitreus*	Low							High				High
Communities of deep-sea corals	High					High		High			High	High
Deep-sea sponge aggregations	Low					High	Low	Low		High	Low	High
Seamounts, knolls and banks	High				Low	Low		High		Low	High	High
Oceanic ridges	High							Low	Low	Low	Low	High
Abyssal hills												
Cold-water coral carbonate mounds	High				Low	High		High		Low	High	High
Submarine canyons on the continental slope	High				Low					High	High	Low
Deep-sea trenches		Low				Low		Low				Low
Deep-sea hydrothermal vents		High			High	High		High	High	Low		Low
Pontic anoxic H2S black muds of the slope and abyssal plain		High	High	High	High	High			High	High		
Pontic anaerobic microbial biogenic reefs above methane seeps		High	High	High		High		Low	High	High		Low

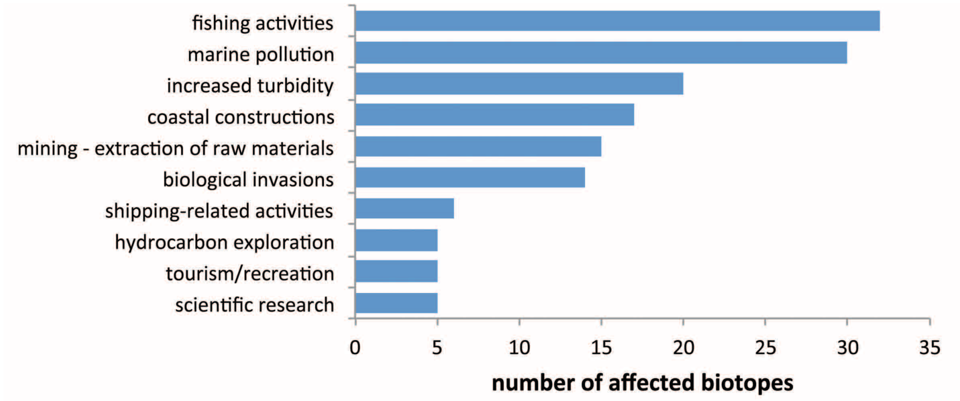

Fig. 1: Main human-related threats of European seabed biotopes.

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ANNEX 1
Goods and services categories adapted from MEA (2003) and Beaumont *et al.* (2007).

Food provision: The extraction of marine organisms for human consumption. Plants and animals derived directly from marine biodiversity provide a significant part of the human diet. Fisheries in particular, and the accompanying employment, provide a significant example of the importance of this function.

Raw materials: The extraction of marine organisms for all purposes, except human consumption. A wide variety of raw materials are provided by marine biodiversity for a variety of different uses, for example, seaweed for industry and fertilizer, fishmeal for aquaculture and farming, pharmaceuticals, biochemicals, natural medicines, and ornamental goods such as shells. This category also includes dredge materials or aggregates.

Air quality and climate regulation: The balance and maintenance of the chemical composition of the atmosphere and climate regulation by sequestering green house gases by marine living organisms. The chemical composition of the atmosphere is maintained through a series of biogeochemical processes, such as the regulation of the volatile organic halides, ozone, oxygen and dimethyl sulphide, and the exchange and regulation of carbon, by marine living organisms. Organisms in the marine environment play a significant role in climate control through their regulation of carbon fluxes, by acting as a reserve or sink for CO_2 in living tissue and by facilitating burial of carbon in sea bed sediments.

Disturbance and natural hazard prevention [regulating service]: The dampening of environmental disturbances by biogenic structures. Living marine flora and fauna can play a valuable role in the defense of coastal regions. The presence of organisms in the front line of sea defense can dampen and prevent the impact of tidal surges, storms and floods. This disturbance alleviation service is provided mainly by a diverse range of species which bind and stabilize sediments and create natural sea defenses, for example salt marshes, mangrove forests and seagrass beds (Huxley, 1992; Davison & Hughes, 1998). Specific biotopes play an important role in sediment retention and the prevention of coastal erosion or underwater sediment slides.

Water quality regulation and bioremediation of waste: Removal of pollutants through storage, burial and recycling. A significant amount of human waste is deposited in the marine environment. Through either direct or indirect activity, marine living organisms store, bury and transform many waste materials through assimilation and chemical de- and re-composition. These detoxification and purification process are of critical importance to the health of the marine environment. Water quality regulation refers to the maintenance of the physical, chemical and biological characteristics of marine waters through the biological and ecosystem processes such as biofiltration, trophic control, nutrient and substance cycling; primary, secondary and tertiary production; sedimentation; bioaccumulation.

Cognitive benefits: Cognitive development, including education and research, resulting from marine organisms. Marine living organisms provide stimulus for cognitive development, including education and research. Information ‘held’ in the natural environment can be adapted, harnessed or mimicked by humans, for technological and medicinal purposes. In addition, marine biodiversity can provide a long term environmental record of environmental resilience and stress. The fossil record can provide an insight into how the environment has changed in the past, enabling us to determine how it will change in the future. This is of particular relevance to current concerns about climate change. Bio-indicators, such as changes in biodiversity, community composition and ecosystem functioning, are also beneficial for assessing and monitoring changes in the marine environment caused by human impact. Ecophysiological responses of marine organisms to the changes in their environment, defined as biomarkers, can provide significant information for development of early warning systems for environmental degradation (Walker *et al*., 2001).

Leisure, recreation and cultural inspiration: The refreshment and stimulation of the human body and mind through the perusal and study of, and engagement with marine habitats and living marine organisms in their natural environment. Marine ecosystems and biodiversity provide the basis for a wide range of recreational activities including ecotourism, swimming, sport fishing, snorkelling, recreational diving, (sea) bird watching, rock pooling, beachcombing, and whale-watching. The provision of this service results in significant employment opportunities (tourism industry, diving industry, recreational fishing industry). Cultural inspiration refers to the opportunity provided by ecosystems for enjoying aesthetic and spiritual experience, inspiration for art and design.

Feel good or warm glow (non-use benefits): Benefit which is derived from marine organisms without using them. The current generation places value on ensuring the availability of biodiversity and ecosystem functioning to future generations (bequest value). It indicates a perception of benefit from the knowledge that resources and opportunities are being passed to descendants. There is also a benefit, often reflected as a sense of well being, of simply knowing marine biodiversity exists, even if it is never utilised or experienced, people simply derive benefit from the knowledge of its existence (Hageman, 1985; Loomis & White,1996).

Photosynthesis, chemosynthesis, and primary production: The production of oxygen by photosynthesis and the assimilation or accumulation of energy and nutrients by organisms or the biological conversion of one or more carbon molecules (usually carbon dioxide or methane) and nutrients into organic matter using the oxidation of inorganic molecules or methane as a source of energy (chemosynthesis). Many marine habitats substantially contribute to the global production of oxygen and the production of organic compounds from aquatic carbon dioxide, methane, hydrogen sulphide or other inorganic molecules.

Nutrient cycling: The storage, cycling and maintenance of nutrients by living marine organisms. The storage, cycling and maintenance of a supply of essential nutrients (i.e. nitrogen, phosphorus, sulphur and metals) are crucial for life. Nutrient cycling encourages productivity, including fisheries productivity, by making the necessary nutrients available to all levels of the food chains and webs.

Reproduction and nursery areas: The provision of the appropriate environmental conditions for reproduction and growing during the early stages of marine species. Some biotopes may constitute areas where most individuals of a species aggregate to reproduce or where juveniles find food and safe shelter. Such biotopes are essential for the viability of some marine populations and the fitness of such populations is closely related to the status of these biotopes.

Maintenance of biodiversity: An ecosystem function resulting from the complex organization (ecosystem structure) and operation of ecosystems (ecosystem processes) that allows for the continuation and diversification of the variability among living organisms (within species and between species) over time.

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