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Recent developments

The destruction of the 'animal forests' in the oceans: Towards an over-simplification of the benthic ecosystems

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A R T I C L E I N F O

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A B S T R A C T

The world's oceans are the clearest example of how the common use of resources has led to an intense and unknown degradation of large areas. The lack of a clear responsibility for some practices in coastal and offshore benthic systems, and the difficulty in seeing directly what the direct and indirect impacts are, has profound repercussions for one of the most fragile, biodiverse and biomass generating group of ecosystems: the 'animal forest'. Soft and hard corals, sponges, bryozoans and other animals which are considered eco-engineering species, make up what is known as the animal forests, which are present in shallow and deep waters all over the planet. These sessile three-dimensional living structures are currently under threat from bottom trawling, direct harvesting, pollution and mining, in terms of the direct effects of human intervention. The lack of clear legal rules in the management of coastal, continental platform and deep coral communities is one of the principal problems for these complex communities. The possibility of over-simplifying processes in benthic areas due to a common use of the resources is analysed in this paper, with special emphasis on certain direct impacts all over the world. The real consequences of this over-simplification of the animal forest due to the destruction of these complex, long-lived structures and the potential solutions for a sustainable management are discussed.

1. Introduction

The transformation of the oceans due to direct or indirect human interference is a fact. Over recent decades both the acceleration and expansion of the so-called "ecological footprint" (a measure of human demand on the Earth's ecosystems; Rees, 1992) have increased the need to regulate a complex management system to confront the synergic problems that affect coastal and ocean ecosystems. Some of the perturbations are direct actions that can be regulated, forbidden or transformed into more sustainable models (e.g. bottom trawling, eutrophication, tourism and urban expansion, control of alien species, etc.). Others can be considered "indirect" perturbations that cannot simply be managed at the local and regional level, since they require a global effort to be solved (e.g. global warming and ocean acidification) (Hoegh-Guldberg et al., 2007). These impacts may act synergistically (at the same time) or in an additive way (one after the other), leaving a low chance for community or population recovery in many cases. Additive factors make problematic coastal and ocean management because is difficult to identify only one cause of the deterioration of the habitats (Fig. 1). Among the ocean's ecosystems, coastal areas are the most threatened, and these are the ones that, paradoxically, provide human communities with the most economical, social, and health services (Rossi, 2011).

We are seeing a profound and worldwide ocean transformation process that has become so complex and synergic that it is not perceived as a dramatic occurrence, but as part of our natural adaptation to the present social and economic needs (Bearzi, 2009). Probably the first step towards managing the oceans properly is 'simply' knowing the composition of its community, the population structure of the main benthic organisms or their health status (Sardà et al., 2005, 2012). This first step is completely neglected in our present plans for the future management of the oceans (Sardà et al., 2012). Whereas problems in tropical forests have been identified over the last 100 years, for example, we still lack an understanding of the real problems faced by the seas (Knowlton and Jackson, 2008). In fact, there is a lack of clear information about biodiversity, abundance or even biomass in coastal and offshore areas. Today habitat loss has been identified as the leading problem faced by species and ecosystem conservation in the oceans (Costello et al., 2010), and its poor management is partly due to our ignorance and common use of large areas that are governed by different rules than the land areas.

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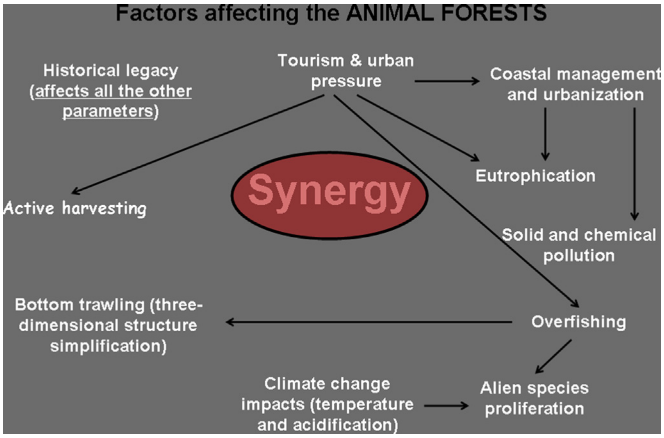

Fig. 1. Synergic effects on the animal forest. The different threats never act alone, being more or less important depending on the location, direct pressure and degree of protection of the coral, gorgonian, sponge, bryozoan, etc. populations. Furthermore, some of them may act in an additive way; arrows indicate consequences of some of these effects on the magnification of some impacts.

One of the main problems is that the baseline of how the benthic ecosystems function is far from being well understood. We lack knowledge about what the real structure of the community is, and the interactions between organisms or the biogeochemical cycles of ancient oceans, and thus it is difficult to evaluate how these systems will evolve in the future (see a good approach to these profound transformations of the marine ecosystems in Jackson, 1997, 2001). Even more dramatic is the fact that our present poor management is largely due to the common use of benthic (and pelagic) resources since ancient times (Knowlton and Jackson, 2008). In 1968, Garrett Hardin made the famous statement that “freedom in a commons brings ruin to all” – the famous tragedy of the commons concept (Hardin, 1968). Hardin argued that the users of a commons are caught in a process that eventually leads to the destruction of the resource upon which they depend, because each individual continues to use the resource until the expected costs of use equals the expected benefits. Since each individual does not consider the costs imposed on others, the accumulated individual decisions result in the overuse of the commons. The present paper attempts to understand what the main threats to the diverse benthic ecosystems are, taking into account a real “tragedy of the commons” concept that has been applied systematically to managing these and other ocean areas.

2. The animal forest concept

The animal forest is a living three-dimensional structure similar to a vegetation forest but composed basically of sponges, cnidarians, bryozoans, ascidians and other sessile animal organisms in the ocean benthos (Rossi et al., 2012). These forests are dominated by ecosystem engineering species, organisms which directly or indirectly modulate the availability of resources to other species, causing changes to the physical condition of biotic or abiotic materials (Jones et al., 1994). These autogenic structuring animals or plants create and maintain these habitats, while other (allogenic) animals may take advantage of these structures to create their own habitats, such as labroid fishes in coral reefs.

These living structures generate and enhance nutrient exchange, as well as capturing and retaining carbon, nitrogen and other elements from plankton in their structures in complex biogeochemical cycles. The animals may be mainly autotrophic (e.g. symbiotic corals or sponges) or completely heterotrophic (e.g. aposymbiotic gorgonians, bryozoans or ascidians). These animals are called benthic suspension feeders because they intercept particles from the water column that will be transformed in biomass and energy (Gili and Coma, 1998). Their self-organising structures allow them to pass from simple to more complex ecosystems, thereby increasing the biomass and biodiversity of other organisms. The more complex animal forests are the result of a long successive history of growth and structuring: the more structured the animal forest, the more capacity to process energy and matter and to retain particles from the more simply organised (and fast-growing) plankton (Gili and Coma, 1998). The more mature animal forests consist of taller and more branched corals, more complex and bigger sponges, etc., structures that can alter major current flows and particle retention, thus concentrating more zooplankton, eggs, larvae, juveniles and adults in their surroundings (Baillon et al., 2012). In contrast, immature animal forests have a smaller surface exposed to the major currents, and therefore their capacity for capturing carbon, nitrogen, phosphorus and other elements (and retaining them) is much lower (Rossi et al., 2012) (as well as recover through the gonadal output, see the example shown in Fig. 2). These mature animal forests are also carbon sinks, retaining part of the ocean productivity in structures that may sequester during very long periods primary and secondary productivity of the oceans (Rossi et al., 2008; Gori et al., 2011).

Communities dominated by heterotrophic benthic suspension feeders (e.g. deep sea corals) are far more important in terms of bathymetric distribution and biomass than those based in the symbiotic relationship with the micro-algae that make up the animal forests (e.g. on coral reefs), because light (the main driver of photosynthesis) only reaches to a depth of 50–100 m, thereby leaving hundreds of metres free for heterotrophic organisms (Gili and Coma, 1998; Miller et al., 2012). These animal forests can be as diverse as the tropical rainforests even in high latitudes like the Antarctic Ocean (Gili et al., 2001), with coral reefs being probably the most well known animal forest all over the world.

Animal forests are also “nursery” places where many vagile species (e.g. fishes, crustaceans, cephalopods, etc.) spend part or all of their life cycle in its surroundings. The more complex and more mature the structures of the animal forest are, the higher the nursery effect, because the more complex structures provide more places to hide and feed (Marliave et al., 2009; Orejas et al., 2009; Baillon et al., 2012; Miller et al., 2012). It is important to stress that without these complex structures, many species may have not an adequate place to live, feed and shelter. It has been demonstrated that sponge gardens for example may have up to one order of magnitude more species per square metre than the more simple bioherms (Marliave et al., 2009), and a direct relationship of benthic macrofauna diversity-abundance and fish concentration exists in estuarine areas (Wouters and Cabral, 2009).

The animal forest may adapt to changing environmental parameters, overcoming occasional perturbations (Belwood et al., 2004; Hoegh-Guldberg et al., 2007; Rossi et al., 2011), but too frequent or profound perturbations (as a consequence of the direct or indirect effect of human management of benthic ecosystems) such as bottom trawling, over-fishing, eutrophication, pollutant release, excessive tourism, alien species introduction, etc. may be impossible to be overcame by these complex structures, especially when such perturbations act synergically (Belwood et al., 2004; Knowlton and Jackson, 2008; Falkenberg et al., 2010).

3. Indirect impacts on the animal forest

The impacts of climate change exceed the capacity of many organisms to adapt due to their highly rapid onset: Animals and plants can adapt to environmental and biological changes, and

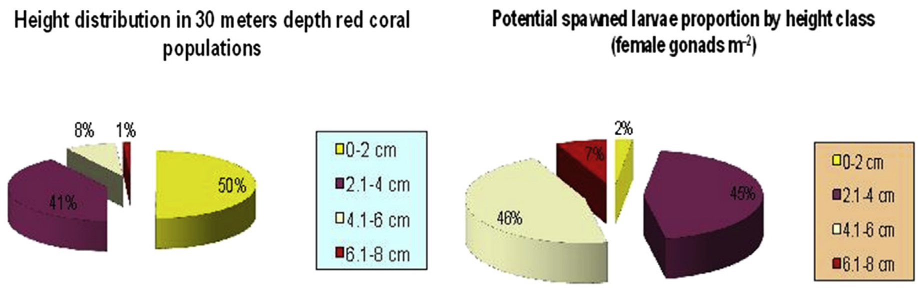

Fig. 2. In Cap de Creus (Spain, North Western Mediterranean), the red coral (*Corallium rubrum*) population is dominated by small colonies (considering the height, on the left). The smaller the colonies, the lower the number of larvae released because the number of polyps is also lower (on the right). It is important to stress that more than 90% of the population (between 0 and 4 cm height) is only capable to spawn 47% of the larvae, whilst the rest of the population (from 4.1 to 8 cm height, 10% of the population) accounts for the 53% of the spawned larvae. Red coral non harvested colonies could reach more than 20 cm height (Rossi et al., 2008), the potential recovery of the species is seriously compromised with the actual harvesting measures. Data from Tsounis et al., (2006a),b.

acclimatise to specific situations, but never in the history of our planet have conditions been changing so fast, and this phenomenon is also true for the components of the animal forest (Hughes et al., 2003). Even if these impacts are not the main target of the present paper, a brief explanation has to be included, because their additive effects also affect the animal forest health and future adaptation.

Briefly, there are three main effects of climate change on the animal forest: warming, ocean acidification and rising sea levels, with all these impacts acting together. For example, coral bleaching has been related to a shift in the sea water temperature in coral reefs all over the world. Over the coming decades coral mortality may reach up to 60% in the areas where corals are present as a fundamental part of the benthic structure of the animal forests (Grottoli et al., 2006). The bleaching phenomena has increased in frequency and strength, but another phenomenon related to sea warming is the intensity of hurricanes, which have increased in strength compared to other decades, affecting the viability of coral reefs in shallower waters (Veron et al., 2009). The bleaching phenomena and the impact of hurricanes are patchy, due to the wide biogeographic differences in the response to climate change, depending on the species composition, the topography and main current regime, as well as the health status of the environment (Belwood et al., 2004). Ocean acidification will also affect the organisms in different ways, with those based on $CaCO_3$ chemistry being the most affected. The animal forests based on hermatypic corals (which seem to be the most affected, Hoegh-Guldberg et al., 2007) are now the most sensitive to the synergic effects of warming, hurricane destruction and ocean acidification, changing their abundance and distribution because of the effects of these climate changes. When we think about the simplification of the animal forest, these effects have to be added to the main direct threats.

4. Bottom trawling

Fishing practices all over the world are the clearest example of how common use of resources has been misinterpreted by human society. The ocean has been considered as an extensive and “never ending” source of protein in which everyone can take as much as they can. This is probably the most paradigmatic issue of the “tragedy of the commons” direct effect. Among fishing practices, bottom trawling has to be considered as the most devastating for animal forests all over the world.

Bottom trawling can be compared with a destruction of a land forest in which all the trees, bushes and other plants are eliminated (and discarded) merely to catch some wild pigs, squirrels, deer or birds (Walting and Norse, 1998). All these three-dimensional terrestrial structures can be compared with forests of corals, seaweeds, gorgonians, sponges or seagrasses. Over the last three decades it has been demonstrated that bottom trawling has had a profound impact on the way ecosystems function in several ways (Thrush and Dayton, 2002). Among these impacts, the destruction of the more long-lived and fragile species, the compacting of the sediments, the impoverishment of the near bottom seston, the simplification of the benthic ecosystems and trophic chains or the interruption of marine biological corridors and shelters for vagile species are the most evident (Pilskaln et al., 1998; Thrush and Dayton, 2002; Coll et al., 2008; Althaus et al., 2009; Clark et al., 2010; among others). In general, it is estimated that some fishing grounds are trawled between 100% and 700% a year, with half of the world’s continental shelves being impacted by bottom trawling each year (Walting and Norse, 1998). This practice can be partly responsible for the depletion of at least two thirds of the top predators, long-lived structures and large animals since the 1950s in our oceans (Christensen et al., 2003). It is outside the scope of this paper to review the real damage caused by bottom trawling, but I would like to demonstrate that this practice has been especially acute because of a “tragedy of the commons” perception maintained by those involved in industrial fishing all over the world.

In 1904 an extended study demonstrated the fragility and the impoverishment of the British Isles continental shelf systems due to bottom trawling and over-fishing (Garstang, 1904). This early report alerted to the dangers in the common use of fishing grounds on the continental shelf: there were no clear laws, no clear monitoring or rules, and a belief that the common space shared by fishing boats was in principle “impossible to deplete” because oceans were an infinite source of food and life (Garstang, 1904). The reality of the situation revealed an opposite trend, and within a few decades industrial over-fishing with bottom trawling (and other kinds of fishing) had reduced biodiversity and biomass drastically in the studied area.

The lesson was never learnt in other areas of the world. After the Second World War, bottom trawling experienced its definitive expansion all over the planet. More advanced technology to detect the fish shoals, more powerful ships to fish further afield, and fish kept in cold storage are keys to understanding the success of industrial fishing in general and bottom trawling in particular (Pauly, 2009; Clark et al., 2010). Better terrestrial infrastructure for distributing goods and an efficient chain of cold storage from the fishing boat to the final market helped the product to reach almost every part of the planet, allowing an increase in the amount of protein coming from the sea almost everywhere, especially in the industrialised countries.

Probably the most paradigmatic account of the over-exploitation of fishing grounds, the profound transformation of the animal forest and the collapse of the resource due to misuse and common use of the continental shelf by bottom trawling is the story of the cod in the Georges Banks off the eastern coast of North America (Clover, 2006). This area covers more than 20,000 square kilometres, with a very shallow continental shelf (mostly 30–80 m deep) that is easy to reach by ships from the coast. Though there was growing alarm by the end of the 19th century as a result of the rapid decrease in landings (Rose, 2004), specialists and stakeholders decided to increase the fishing effort of fleets. Very large cod disappeared, but the cod industry was expanding and the cod stocks seemed not to be affected by the numerous fishing vessels. After the great fishing peak of 1929, several marine biologists and fishery specialists produced an extensive report (in fact similar to the published one by Garstang, 1904), in which some concerns were voiced about the possibility of over-fishing in the Georges Banks area (Myers et al., 1996; Kurlansky, 2008). After a period of "forced" cessation of fishing all over the world during the war period, industrial fishing reinforced its structure and became an essential part of some economies. In the 1960s, the Great Banks was the preferred area for bottom trawling for Soviet, Spanish, Portuguese and French fleets. In 1965 the Soviet Union alone had more than 100 very large ships working in the area together with another 425 smaller bottom trawling ships. During this year, the Soviet fleet caught 875,000 tonnes of cod and other fish off the coasts of the US and Canada (Kurlansky, 2006). In 1977, following intense pressure from the fishing industry, the United States and Canada unilaterally established the 200 miles exclusion zone. There was no sense of conservation behind such a measure, only the aim of substituting the foreign fleets with their own fleets. In fact, the 825 US and Canadian ships that worked in the area in 1977 had increased to more than 1400 by 1982. At that time, cod stocks were already collapsing (Myers et al., 1996), and by the end of the 1980s cod landings were only around 20,000 tonnes, almost 10% of the amount captured in the same area in 1929. In 1992 the area was closed to any kind of fishing by bottom trawling to allow stocks to recover, but after almost twenty years cod (as well as other species) fishing is still not allowed because the populations have never recovered from the previous overexploitation (Morissette et al., 2009). It is now accepted that these destructive fishing practices wiped out the benthic animal forests, an essential part of the life cycles of demersal fish such as cod.

This common use and the sensation of impunity fostered by the lack of effective control or proper roles and laws has now extended to remote areas such as deep coral grounds or undersea mountains in international waters, where bottom trawling is being systematically applied (Miller et al., 2012). At least two million tonnes of fish have been taken from the deep sea since 1960 (Clark et al., 2010), being the method for managing the resource is still like the "boom and bust" system practised in the mining industries. It have been suggested that the direct impact of bottom trawling fish exploitation is probably greater than climate change or other perturbations in the animal forests (Jackson et al., 2001). Politicians and stakeholders have always avoided the real problem of bottom trawling management, i.e. the common use of resources with no control and the use of an individual species approach, not an ecosystem-based approach (Pauly, 2009). Even if there has been an increase in the amount of protein for human consumption coming from the ocean's fisheries in the last fifty years (FAO, 2010), the present collapse of ecosystems due to over-fishing shows a delicate point of inflexion in which the recovery of the animal forest can only result from banning bottom trawling and other aggressive fisheries practices.

5. Harvesting of precious corals

Another clear case of a misinterpreted common use of the benthic animal forest is the exploitation of the so-called precious corals. The extraction of colonies by direct harvesting (sponges, gorgonians, precious corals, etc.) is a strong source of perturbation, and the method used is always "boom and bust", depleting entire populations in a way similar to the processes used in mining (Tsounis et al., 2010a). Precious corals have been harvested for centuries because of the value of their hard skeleton, and are used mainly in jewellery. The market for precious corals has extended from the Mediterranean countries to other places (e.g. Tibet, North America, North Africa) for ornamental, religious or spiritual purposes (Tescione, 1976).

Most of the precious corals have been depleted by dredging, using the benthic substrate as a common place that could be used by everyone who had a boat. The Saint Andrew's Cross (a wooden cross-piece with hanging nets used to pick up coral from the rocky bottoms) has been used to collect red coral (*Corallium rubrum*) since the 4th century B.C., and was only definitively banned in 1994 in the Mediterranean. This so-called "ingegno" is trawled along the seabed where red coral (and other suspension feeders of the animal forest) live. It is absolutely non-selective, destroying everything in the benthic system. Hundreds of boats began to dredge systematically along the Italian coast with the Saint Andrew's Cross, with this practice spreading all over the Mediterranean by the beginning of the 19th century.

Scuba diving has delivered the "*coup de grace*" from the 1950s to the present day, reaching the more sheltered patches of coral populations (caves, tunnels, overhangs, crevices) where dredging activities were not capable of reaching the small red "trees" (Tsounis et al., 2009). In this case the areas harvested were also of common use, and divers had only to comply with some kind of rotation discipline in an attempt to avoid the complete collapse of the resource. The deepest patches are still the most difficult to reach, and in some places may be safe from harvesting (Rossi et al., 2008). Sardinia is a typical example of a place where the coral has completely disappeared in the shallow areas due to the sense of it being a common resource that could be harvested by anyone who wanted to dive in its blue waters. In 1956 divers could harvest at a depth of 37 m in Capo Caccia, but by 1964 they needed to go down below 72 m in order to have some coral to sell (Tsounis et al., 2010b). Coral divers from every part of the Mediterranean flocked to the area to harvest red coral, and the first to arrive had the opportunity to collect this long-lived animal with very few legal restrictions. The same scenario was repeated in Trapani (Sicily), Alborán (South of Spain), Cap de Creus (North of Spain) or off the Oran coast (Algeria) (Tsounis et al., 2010a).

In some ways, an even worse panorama can be seen today in the Pacific Ocean when other precious corals are considered (e.g. *Corallium elatius*, *Corallium secundum* or *Corallium* sp.). These corals are also an important part of the deep sea animal forests (150–1500 m deep), and have been systematically dredged throughout the last century (Tsounis et al., 2010a). The only way to reach the big colonies in a profitable way is by using tools similar to the Saint Andrew's Cross. The most obvious case of this common use of the resource comes from the Emperor Mountains of the Pacific, in the international waters of the northern part of the Hawaiian archipelago. These undersea mountains had dense populations of coral species, and over a period of only three years (1965–1967) intensive non-controlled dredging harvested more than 1000 tonnes, depleting the area. Russian and Taiwanese ships worked the area intensively, benefiting from the lack of any jurisdiction in international waters. Forty years later this area has still not recovered (Bruckner, 2009; Tsounis et al., 2010a).

Together with a non-based in the biology and ecology of the organisms management rules, poaching and irregular harvesting are probably the most serious problem for the precious coral populations (Tsounis et al., 2013). Poaching is associated with 60% of the red coral biomass loss (Linares et al., 2012). There is a lack of sense of property or good practices in this kind of harvesting, due to a wide ignorance about the resource, since current restriction measures are decided not on the basis of the biology and ecology of the species (the tallest and more branched colonies are those which may produce most new organisms), but on the jewellery interest (the basal diameter of the colonies) (Tsounis et al., 2010a; 2013). Other threats may cause coral populations to become extinct locally. Ocean warming and acidification may act synergistically with harvesting and cause the resource to collapse in several shallow (and even deep) areas (Santangelo et al., 2007; Bramanti et al., 2013), but the current work done by professional divers and ships extracting the coral with no biologically-designed rules in the harvesting plans are not helping the management of this essential part of the animal forest for the near future.

6. Aquaculture

Aquaculture has been presented as the opportunity to make a profound change in the protein resources coming from aquatic environments. The so called Blue Revolution had a specific target: providing the opportunity to enhance the aquaculture industry in less favoured countries in order to provide protein for its own inhabitants or even to sell part of the product to other countries (Stonich and Bailey, 2000; Diana, 2009). Again the problems arose when no respect was shown for the environment and a highly aggressive policy was applied to ensure a rapidly growing business (Queiroz et al., 2013).

Aquaculture may have a positive effect on biodiversity by diminishing bottom trawling and other fishing industrial practices, however intensive aquaculture practices have a direct effect on the benthic populations: direct eutrophication and pollution, introduction of invasive species and profound changes in the trophic chain are some of the consequences. Aquaculture changes the composition of the animal forest, especially in areas where the cages are placed over hard substrate, by eutrophication of water or accumulation of sediments (Borja et al., 2009). This is especially true in the Norwegian or Chilean fjords, where animal forests are currently threatened by salmon cultivating: many authors claim for a better management plans due to the direct impact on the hard bottom-soft bottom communities of these fragile ecosystems (Asche et al., 1999; Häussermann and Försterra, 2007; Ellingsen et al., 2009; Iriarte et al., 2010).

An indirect effect for the animal forest may come when other systems like mangroves are affected. The systematic destruction of mangroves because of the shrimp aquaculture (Polidoro et al., 2010; Queiroz et al., 2013) reduces the possibility of recruiting vagile fauna and providing a nutrient and organic matter load needed in coral reef areas (Mumby et al., 2004). Again aquaculture simplifies the ecosystems and replaces a diverse biomass with a very simple and accelerated monoculture (Pitcher, 2008), and an unclear distribution of the aquaculture structures as a result of a common use of the coastline may be the key to understanding the deterioration of many animal forests all over the world.

7. Mining

Even if bottom trawling has been identified as the most destructive activity for the animal forest all over the world, mining (extraction of fossil fuels or metals) can be also considered a major perturbation for these ecosystems, especially for deep ones (Clark et al., 2010). The main mining extractions are petroleum, gas, magnesium nodules and crusts rich in cobalt and polymetal sulfides, with the submarine mountains having enormous concentrations of these non-renewable resources. The technology to ensure a profitable exploitation of such materials already exists (Sharma, 2007), and the need to look for new places to extract these goods is driving different countries to expand this industry rapidly all over the world.

Mechanical extraction and re-suspended sediment are the more evident threats to the deep coral animal forests (Clark et al., 2010), but there are very few studies dealing with the potential impact of this kind of resource extraction. It is difficult to reach the places in which this kind of mining is carried out and environmental studies are scarce and biased. Another effect is the direct pollution by the leaking of the extracted oil (see the British Petroleum accident in the Gulf of México, the Deepwater Horizon oil spill in 2010). The effect may be more local than bottom trawling, but it is more intense because of the profound transformation of the substrate.

These deep-sea animal forests are in largely unknown zones where active mining practices are not regulated. Again the freedom to reach deep benthic areas, especially in international waters, is devastating these fragile ecosystems. There is a direct overlapping of the most prominent known animal forest and the mining targets all over the world (Clark et al., 2010), with a logical degradation when mining protocols are applied without previous environmental impact studies.

8. Tourism and urban areas impact

Human pressure related to the urban development of coastal areas is also a great concern for animal forest preservation. Among the impacts, those related to the tourism are probably the most contradictory. Even in damaged areas the monetary income from tourism is very high, but it is clear that the more healthy the animal forest, the more tourist will come (White et al., 2000). The tourist wants to pay to see a healthy animal forest, and thus there is an important market related to this business (Asafu-Adjaye and Tapswan, 2008). However, the so-called ecotourism may also negatively impact the animal forests in coasts all over the world. Again, one of the main problems is the common use of the resource and the poor legislation protecting the underwater ecosystems.

Trampling (Liddle, 1991; Hawkins and Roberts, 1993), boat anchors (Ohman et al., 1993; Maynard 2008; Dinsdale and Harriot, 2004) or diving (Sala et al., 1996; Coma et al., 2004) are among the more direct impacts on the animal forests in those places where tourism concentrates to enjoy nature. In the case of anchoring, there is a clear mixture of two types of human behaviour related to the destruction of the three-dimensional structures: the absence of guilt, because the boat owner is not seeing the damage directly, and the lack of an effective ownership of the area where boats can stay. But among the aforementioned direct impacts, diving is one of the more controversial impacting activities. In Belize and Cancun, divers and all the activity related to tourism is damaging the second most extensive coral reef in the world (Dietrich, 2007). In these areas, the people have transferred their economic dependence from fishing to tourism. The people diving is interested in preserving the animal forests, but they do have a direct impact as a result of the diving activity (Arin and Kramer, 2002), destroying the fragile structures of many organisms (Sala et al., 1996; Coma et al., 2004; Luna et al., 2009). In a routine dive every 10 foot a diver touches the fauna and flora of the animal forest, including bryozoans, corals or ascidians, an activity that can collapse sessile animal populations in less than ten years because of the number of times divers frequent a single area (Luna et al., 2009). Damage to the sessile

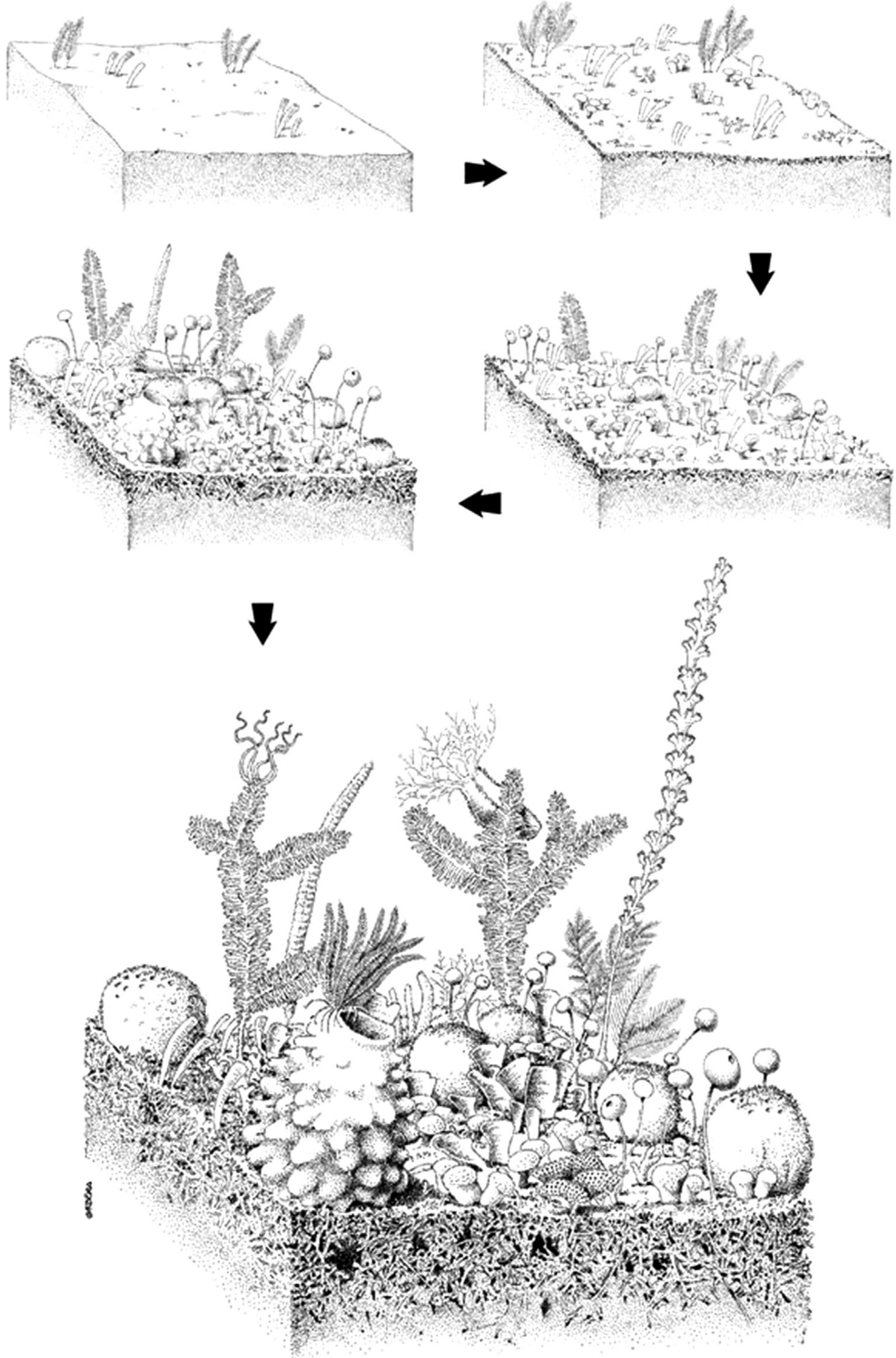

Fig. 3. The animal forest, like the land tree forest, needs time to recover. In this example, different steps after an iceberg (natural) disturbance are considered in one of the more complex animal forest all over the world: the Weddell sea animal forest). The succession time is unknown, but the high complexity probably takes decades or even centuries to conform such biodiverse seascape. Bottom trawling effects may be compared with these disturbances in some way, being too much frequent for the animal forest recovery, and the rising number of icebergs in Antarctica may also impact some zones with an excess of damage to the animal forests in this area of the wolrd. Figure from Gili et al., (2001), with the permission of Gili & Corbera.

suspension feeders (by divers' frequent visits or due to other activities such as artisan fisheries) has a direct repercussion on the capacity of gorgonians to store energy and reproduce, because of the loss of tissue by abrasion and the growth of epibionts (Tsounis et al., 2012). Divers are in fact part of the problem, but can also be part of the solution when they are adequately informed and used as a source of information and awareness for other divers or other people (Bramanti et al., 2011).

Other activities related to the tourism are impacting the animal forest indirectly, but seek the immediate benefit that this group is providing for coastal areas. Souvenirs, aquarology, and especially the practice of blasting with dynamite to provide fish for the hotels and restaurants are currently destroying the source of monetary income because of a common use of extensive areas. The practice of blasting has a direct repercussion on the animal forest, destroying the coral reef structure. It is very lucrative, with only 20 € worth of dynamite the poachers can easily earn up to 500 € selling the fish (Wells, 2009). The main contradiction in this practice is that it not only affects the animal forest but also the tourists, who do not want to stay next to an area where the fishermen are blasting.

Lastly, but also very important, eutrophication and pollution (i.e. plastic debris, oil spills, heavy metals, etc.) is also directly impacting very large areas in many different places due to the concentration of tourism or simply large human populations in coastal areas. The lack of clear rules, the sensation that the sewage or plastics is going into the sea but its repercussions are not being seen directly, the lack of ownership in the underwater coastline and the rapid (and uncontrolled) growth of tourist or city structures are profoundly degrading coral reefs (Bell, 1992; Nyström et al., 2000). This is probably the direct impact related to urban development that most profoundly affects animal forests in shallow (0–30 m depth) coastal areas, and could only be avoided with strict legislation related to marine pollution management. Almost nothing is known in other animal forests like deep coral assemblages or the coralligene, but Orejas et al. (2009) found up to one debris/fishing gear each 5 m at ≈100–300 m depth in the continental platform and the slope of a submarine canyon, and Sardà et al. (2012) demonstrated that near the urban areas the concentration of litter in the bottom between 0 and 70 m depth can be found in more than the 20% of the surveyed surface.

The loss of diversity and biomass, as well as complexity, may impair the capacity for animal forests to recover and as a consequence the quality and quantity of the ecological goods and services they provide. Conserving the capacity of these ecosystems to generate essential services requires them to be managed as components of a larger seascape-landscape of which human activities are seen as an integrated part (Moberg and Folke, 1999). Marine protected areas are part of the solution for all these direct impacts, but a very well planned extension, dynamic management (i.e. adapted to new problems) and good and affective surveillance is needed to be really effective in different parts of the world (Bearzi, 2007).

9. Simplification of the ocean forests and its consequences

As previously explained, suspension feeders are efficient living machines processing the water column seston. The impact on mature animal forest will have consequences in the benthic–pelagic coupling processes, as well as in the retention of organic matter and the capacity to sequester carbon from the plankton (Rossi et al., 2012). The simpler the animal forests (smaller colonies/individuals, less branched structures, lower biomass of long-lived organisms), the less energy they can process and retain. This effect has a positive feedback in which the degradation processes lead to an acceleration of the simplification process towards more immature and less diverse three-dimensional structures. The ecosystems based on the animal forest are still not well understood, especially those questions related to carbon and nitrogen retention and recycling, being an excess of simplification an advantage for simpler organisms (Pitt et al., 2009).

In fact, we are destroyers of diversity and complexity, replacing nature's complex structures and interactions with our own complexity, passing from "animal forests" to "grassland" seascapes (Rossi et al., 2008). We have a poor understanding of the concepts governing the resilience of the main contributors of these complex structures, being far from a good understanding of the metabolic, physiological, reproductive or the simply distributive processes and patterns. Thus, we need to change both locally and globally perceptions of these ecosystems to avoid the collapse of the animal forests all over the world. Because we are still far from a real comprehension of the system functioning in the oceans, especially with respect to what the animal forests need to survive, there is an urgent need to cope with a more holistic vision of these systems everywhere.

Can we identify the limits of degradation in the animal forest? Can we know when a certain limit is surpassed and there is a point of no return for recovery on a human timescale? As in the tropical rainforest, the way to return to similar complex structures prior to degradation is very difficult and not well understood (Knowlton and Jackson, 2008) (see a succession example toward a more complex community of polar seas in Fig. 3). We need thus to provide solutions in which the final consumer is able to realise the damage to the animal forests caused by the various direct and indirect impacts he is making in different benthic systems. In a land system people are used to seeing direct cause and effect, while in the marine system both indirect and direct affects are practically unperceived. Living in big cities makes the task of understanding the potential damage to the complexity of the systems more difficult. We are currently blinded by the neo-liberal policies and economic theories based on the idea that progress has to be continuous, and especially that technology will save us from the collapse (Garrity, 2012). It is impossible to maintain a first world economic and social model in its current form, since ecosystems like the animal forest cannot withstand this accelerated degradation. We are replacing top predators, highly resilient ecosystems and complex structures with our own model of complexity but without a solid base of adaptation (Jackson, 2008). Therefore there is an urgent need to understand what we are doing, changing the ocean management if we wish to recover the animal forests all over the world.

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References

Althaus, F., Williams, A., Schlacher, T.A., Kloser, R.J., Green, M.A., Barker, B.A., Bax, N.J., Brodie, P., Schlacher-Hoenlinger, M.A., 2009. Impacts of bottom trawling on deep-coral ecosystems of seamounts are long-lasting. Marine Ecology Progress Series 397, 279–294.

Arin, T., Kramer, R.A., 2002. Divers' willingness to pay to visit marine sanctuaries: an exploratory study. Ocean and Coastal Management 45, 171–183.

Asafu-Adjaye, A., Tapsuwan, S., 2008. A contingent valuation study of scuba diving benefits: case study in Mu Ko Similan marine national park, Thailand. Tourism Management 29, 1122–1130.

Asche, F., Guttormsen, A.G., Tveterås, R., 1999. Environmental problems, productivity and innovations in Norwegian salmon aquaculture. Aquaculture Economics and Management 3, 19–29.

Baillon, S., Hamen, J.F., Wareham, V.E., Mercier, A., 2012. Deep cold-water corals as nurseries for fish larvae. Frontiers in Ecology and the Environment. http://dx.doi.org/10.1890/120022.

Bearzi, G., 2007. Marine conservation on paper. Conservation Biology 21, 1–3.

Bearzi, G., 2009. When swordfish conservation biologists eat swordfish. Conservation Biology 23, 1–2.

Bell, P.R.F., 1992. Eutrophication and coral reefs: some examples in the Great Barrier Reef lagoon. Water Research 26, 553–568.

Belwood, D.R., Hughes, T.P., Folke, C., Nyström, M., 2004. Confronting the coral reef crisis. Nature 429, 827–833.
Borja, A., Rodríguez, J.G., Black, K., Bodoy, A., Emblow, C., Fernandes, T.F., Forte, J., Karakassis, I., Muxika, I., Nickell, T.D., Papageorgiou, N., Pranovi, F., Sevastou, K., Tomassetti, P., Angel, D., 2009. Assessing the suitability of a range of benthic indices in the evaluation of environmental impact of fin and shellfish aquaculture located in sites across Europe. Aquaculture 293, 231–240.
Bramanti, L., Vielmini, I., Rossi, S., Stolfa, S., Santangelo, G., 2011. Approaching recreational scuba divers to emblematic species conservation: the case of red coral (*Corallium rubrum*). Journal for Nature Conservation 19, 312–318.
Bramanti, L., Movilla, J., Guron, M., Calvo, E., Gori, A., Dominguez-Carrio, C., Grinyo, J., Lopez-Sanz, A., Martinez-Quintana, A., Pelejero, C., Ziveri, P., Rossi, S., 2013. Detrimental effects of ocean acidification on the economically important Mediterranean red coral (*Corallium rubrum*). Global Change Biology. http://dx.doi.org/10.1111/gcb.12171.
Bruckner, A.W., 2009. Rate and extent of decline in *Corallium* (pink and red coral) populations: existing data meet the requirements for a CITES Appendix II listing. Marine Ecology Progress Series 397, 319–332.
Christensen, V., Guenette, S., Heymans, J.J., Walters, C.J., Watson, R., Zeller, D., Pauly, D., 2003. Hundred-year decline of North Atlantic predatory fishes. Fish and Fisheries 4, 1–24.
Clark, M.R., Rowden, A.A., Schlacher, T., Williams, A., Consalvey, M., Stocks, K.I., Rogers, A.D., O'Hara, T.D., White, M., Shank, T.M., Hall-Spencer, J., 2010. The ecology of seamounts: structure, function, and human impacts. Annual Review of Marine Sciences 2, 253–278.
Clover, C., 2006. The End of the Line. University of California Press, California, US.
Coll, M., Palomera, I., Tudela, S., Dowd, M., 2008. Food-web dynamics in the South Catalan Sea ecosystem (NW Mediterranean) for 1978–2003. Ecological Modelling 217, 95–116.
Coma, R., Pola, E., Ribes, M., Zabala, M., 2004. Long-term assessment of temperate octocoral mortality patterns, protected vs. unprotected areas. Ecological Applications 14, 1466–1478.
Costello, M.J., Coll, M., Danovaro, R., Halpin, P., Ojaveer, H., Miloslavich, P., 2010. A census of marine biodiversity knowledge, resources, and future challenges. PLoS ONE 5 (8), e12110.
Diana, J.M., 2009. Aquaculture production and biodiversity conservation. BioScience 59, 27–38.
Dietrich, A., 2007. The impacts of tourism on coral reef conservation awareness and support in coastal communities in Belize. Coral Reefs 26, 985–996.
Dinsdale, E.A., Harriot, V.J., 2004. Assessing anchor damage on coral reefs: a case study in selection of environmental indicators. Environmental Management 33, 126–139.
Ellingsen, H., Olaussen, J.O., Utne, I.B., 2009. Environmental analysis of the Norwegian fishery and aquaculture industry IA preliminary study focusing on farmed salmon. Marine Policy 33, 479–488.
Falkenberg, L.J., Burnell, O.W., Connell, S.D., Russell, B.D., 2010. Sustainability in near-shore marine systems: promoting natural resilience. Sustainability, 2593–2600.
FAO, 2010. The State of World Fisheries and Aquaculture 2009. FAO Fisheries Department, Rome, Italy.
Garrity, E.J., 2012. Tragedy of the commons, business growth and the fundamental sustainability problem. Sustainability 4, 2443–2471.
Garstang, W., 1904. The impoverishment of the sea. Journal of the Marine Biological Association of the UK 6 (1), 1–57.
Gili, J.M., Coma, R., 1998. Benthic suspension feeders: their paramount role in littoral marine food webs. Trends in Ecology and Evolution 13, 316–321.
Gili, J.M., Coma, R., Orejas, C., López-González, P.J., Zabala, M., 2001. Are Antarctic suspension-feeding communities different from those elsewhere in the world? Polar Biology 24, 473–485.
Gori, A., Rossi, S., Berganzo-González, E., Pretus, J.L., Dale, M.R.T., Gili, J.M., 2011. Spatial distribution, abundance and relationship with environmental variables of the gorgonians *Eunicella singularis, Paramuricea clavata* and *Leptogorgia sarmentosa* (Cape of Creus, Northwestern Mediterranean Sea). Marine Biology 158, 143–158.
Grottoli, A.G., Rodrigues, L.J., Palardy, J.E., 2006. Heterotrophic plasticity and resilience in bleached Corals. Nature 440, 1186–1189.
Hardin, G., 1968. Tragedy of the Commons. Science 162, 1243–1248.
Häussermann, V., Försterra, G., 2007. Large assemblages of cold-water corals in Chile: a summary of recent findings and potential impacts. Bulletin of Marine Science 81, 195–208.
Hawkins, J.P., Roberts, C.,M., 1993. Effects of recreational scuba diving on coral reefs: trampling on reef-flat communities. Journal of Applied Ecology 30, 25–30.
Hoegh-Guldberg, O., Mumby, P.J., Hooten, A.J., Steneck, R.S., Greenfield, P., Gomez, E., Harvell, C.D., Sale, P.F., Edwards, A.J., Caldeira, K., Knowlton, N., Eakin, C.M., Iglesias-Prieto, R., Muthiga, N., Bradbury, R.H., Dubi, A., Hatziolos, M.E., 2007. Coral reefs under rapid climate change and ocean acidification. Science 318, 1737–1742.
Hughes, T.P., Baird, A.H., Bellwood, D.R., Card, M., Connolly, S.R., Folke, C., Grosberg, R., Hoegh-Guldberg, O., Jackson, J.B.C., Kleypas, J., Lough, J.M., Marshall, P., Nyström, M., Palumbi, S.R., Pandolfi, J.M., Rosen, B., Roughgarden, J., 2003. Climate change, human impacts, and the resilience of coral reefs. Science 301, 929–933.
Iriarte, J.L., González, H.E., Nahuelhual, L., 2010. Patagonian fjord ecosystems in southern Chile as a highly vulnerable region: problems and needs. AMBIO 39, 463–466.
Jackson, J.B.C., 1997. Reefs since Columbus. Coral Reefs 16, S23–S32.
Jackson, J.B.C., 2001. What was natural in the coastal oceans? Proceedings of the Natural Academy of Sciences 98, 5411–5418.
Jackson, J.B.C., Kirby, M.X., Berger, W.H., Bjorndal, K.A., Botsford, L.W., Bourque, B.J., Bradbury, R.H., Cooke, R., Erlandson, J., Estes, J.A., Hughes, T.P., Kidwell, S., Lange, C.B., Lenihan, H.S., Pandol, J.M., Peterson, C.H., Steneck, R.S., Tegner, M.J., Warner, R.R., 2001. Historical overfishing and the recent collapse of coastal ecosystems. Science 293, 629–638.
Jackson, J.B.C., 2008. Ecological extinction and evolution in the brave new ocean. Proceedings of the Natural Academy of Sciences 105, 11458–11465.
Jones, C.J., Lawton, J.H., Shachak, M., 1994. Organisms as ecosystem engineers. Oikos 69, 373–386.
Knowlton, N., Jackson, J.B.C., 2008. Shifting baselines, local impacts, and global change on coral reefs. Plos Biology 6 (e54), 215–220.
Kurlansky, M., 2006. Cod. Penguin Books Ltd., England.
Kurlansky, M., 2008. The Last Fish Tale. Penguin Books Ltd., England.
Liddle, M.J., 1991. Recreation ecology: effects of trampling on plants and corals. Trends in Ecology and Evolution 6, 13–17.
Linares, C., Garrabou, J., Hereu, B., Diaz, D., Marschal, C., Sala, E., Zabala, M., 2012. Assessing the effectiveness of marine reserves on unsustainably harvested long-lived sessile invertebrates. Conservation Biology 26, 88–96.
Luna, B., Valle Pérez, C., Sánchez-Lizaso, J.L., 2009. Benthic impacts of recreational divers in a Mediterranean marine protected area. ICES Journal of Marine Science 66, 517–523.
Marliave, J.B., Conway, K.W., Gibbs, D.M., Lamb, A., Gibbs, C., 2009. Biodiversity and rockfish recruitment in sponge gardens and bioherms of southern British Columbia, Canada. Marine Biology 156, 2247–2254.
Maynard, J.A., 2008. Severe anchor damage to *Lobophyllia variegata* colonies on the Fujikawa Maru, Truk Lagoon, Micronesia. Coral Reefs 27, 273.
Miller, R.J., Hocevar, J., Stone, R.P., Fedorov, D.V., 2012. Structure-forming corals and sponges and their use as fish habitat in Bering sea submarine canyons. PLoS ONE 7 (3), e33885.
Moberg, F., Folke, A., 1999. Ecological goods and services of coral reef ecosystems. Ecological Economics 29, 215–233.
Morissette, L., Pedersen, T., Nilsen, M., 2009. Comparing pristine and depleted ecosystems: the Sørfjord, Norway versus the Gulf of St. Lawrence, Canada. Effects of intense fisheries on marine ecosystems. Progress in Oceanography 81, 174–187.
Mumby, P.J., Edwards, A.J., Arias-Gonzalez, J.E., Lindeman, K.C., 2004. Mangroves enhance the biomass of coral reef fish communities in the Caribbean. Nature 427, 533–536.
Myers, R.A., Hutchings, J.A., Barrowman, N.J., 1996. Hypothesis for the decline of cod in the North Atlantic. Marine Ecology Progress Series 138, 293–308.
Nyström, M., Folke, C., Moberg, F., 2000. Coral reef disturbance and resilience in a human-dominated environment. Trends in Ecology and Evolution 15, 13–17.
Ohman, M.C., Rajasuriya, A., Lindén, O., 1993. Human disturbances on coral reefs in Sri Lanka: a case study. AMBIO 22, 474–480.
Orejas, C., Gori, A., Lo Iacono, C., Puig, P., Gili, J.M., Dale, M.R.T., 2009. Cold-water corals in the Cap de Creus canyon, northwestern Mediterranean: spatial distribution, density and anthropogenic impact. Marine Ecology Progress Series 397, 37–51.
Pauly, D., 2009. Beyond duplicity and ignorance in global fisheries. Scientia Marina 73, 215–224.
Pilskaln, C.H., Churchill, J.H., Mayer, L.M., 1998. Resuspension of sediment by bottom trawling in the Gulf of Maine and potential geochemical consequences. Conservation Biology 12, 1223–1229.
Pitcher, T.J., 2008. The sea ahead: challenges to marine biology from seafood Sustainability. Hydrobiologia 606, 161–185.
Pitt, K.A., Welsh, D.T., Condon, R.H., 2009. Influence of jellyfish blooms on carbon, nitrogen and phosphorus cycling and plankton production. Hydrobiologia 616, 133–149.
Polidoro, B.A., Carpenter, K.E., Collins, L., Duke, N.C., Ellison, A.M., Farnsworth, E.J., Fernando, E.S., Kalthiresan, K., Koedam, N.E., Livingstone, S.R., 2010. The loss of species: mangrove extinction risk and geographic areas of global concern. PLoS One 5, e10095.
Queiroz, L., Rossi, S., Meireles, J., Coelho, J., 2013. Shrimp aquaculture in the state of Cearà during the period 1970–2012: trends of the privatization of mangrove forest in Brazil. Ocean and Coastal Management 73, 54–62.
Rees, W.E., 1992. Ecological footprints and appropriated carrying capacity: what urban economics leaves out. Environment and Urbanisation 4 (2), 121–130.
Rose, G.A., 2004. Reconciling overfishing and climate change with stock dynamics of Atlantic cod (*Gadus morhua*) over 500 years. Canadian Journal of Fisheries and Aquatic Sciences 61, 1553–1557.
Rossi, S., 2011. El planeta azul: un universo en extinción. Debate editorial, Barcelona, p. 428.
Rossi, S., Tsounis, G., Orejas, C., Padrón, T., Gili, J.M., Bramanti, L., Teixidó, N., Gutt, J., 2008. Survey of deep-dwelling red coral (*Corallium rubrum*) populations at Cap de Creus (NW Mediterranean). Marine Biology 154, 533–545.
Rossi, S., Gili, J.M., Garrofé, X., 2011. Net negative growth detected in a population of *Leptogorgia sarmentosa*: quantifying the biomass loss in a benthic soft bottom-gravel gorgonian. Marine Biology 158, 1631–1643.
Rossi, S., Bramanti, L., Broglio, E., Gili, J.M., 2012. Trophic impact of long-lived species indicated by population dynamics in a short-lived hydrozoan, *Eudendrium racemosum*. Marine Ecology Progress Series 467, 97–111.
Sala, E., Garrabou, J., Zabala, M., 1996. Effects of diver frecuentation on Mediterranean sublitoral populations of the bryozoan *Pentapora fascialis*. Marine Biology 126, 451–459.

Santangelo, G., Bramanti, L., Iannelli, M., 2007. Population dynamics and conservation biology of the over-exploited Mediterranean Red coral. Journal of Theoretical Biology 244, 416–423.
Sardà, R., Avila, C., Mora, J., 2005. A methodological approach to be used in integrated coastal zone management process: the case of the Catalan Coast (Catalonia, Spain). Estuarine, Coastal and Shelf Science 62, 427–439.
Sardà, R., Rossi, S., Martí, X., Gili, J.M., 2012. Marine benthic cartography of the NE Catalan coast (Mediterranean sea). Scientia Marina 76 (1), 159–171.
Sharma, R., 2007. Proposed exploration and mining technologies for cobalt-rich ferromanganese crusts deposits. In: Proceedings of the International Seabed Authority's Workshop, pp. 87–100 ch. 4.
Stonich, S.C., Bailey, C., 2000. Resisting the Blue Revolution: contending coalitions surrounding industrial shrimp farming. Human Organization 59, 23–36.
Tescione, G., 1976. The Italians and Their Coral Fishing. Fausto Fiorentino, Naples.
Thrush, S.F., Dayton, P.K., 2002. Disturbance to marine habitats by trawling and dredging: implications for marine biodiversity. Annual Review Ecology and Systematics 33, 449–473.
Tsounis, G., Rossi, S., Aranguren, M., Gili, J.M., Arntz, W., 2006a. Effects of spatial variability and colony size on the reproductive output and gonadal development cycle of the Mediterranean red coral (*Corallium rubrum* L.). Marine Biology 148, 513–527.
Tsounis, G., Rossi, S., Gili, J.M., Arntz, W., 2006b. Population structure of an exploited benthic cnidarian: the red coral case study. Marine Biology 149, 1059–1070.
Tsounis, G., Rossi, S., Gili, J.M., 2009. Fishery management of the Mediterranean red coral: a call for a paradigm shift. In: Bruckner, A.W., Roberts, G.G. (Eds.), Proceedings of the First International Workshop on Corallium Science, Management and Trade, pp. 123–143. NOAA Technical Memorandum NMFS-OPR-43 and CRCP-8, Silver Spring, MD.
Tsounis, G., Rossi, S., Grigg, R., Santangelo, G., Bramanti, L., Gili, J.M., 2010a. The exploitation and conservation of precious corals. Oceanography and Marine Biology: An Annual Review 48, 161–212.
Tsounis, G., Rossi, S., Gili, J.M., 2010b. Identifying population decline in *Corallium rubrum* by using historical information. In: Bussoletti, E., Cottingham, D., Bruckner, A., Roberts, G. (Eds.), Proceedings of the International Workshop on Red Coral Science, Management, and Trade: Lessons from the Mediterranean. Napoli, September 23–26, 2009, pp. 33–39.
Tsounis, G., Martínez, L., Bramanti, L., Viladrich, N., Martínez, A., Gili, J.M., Rossi, S., 2012. Effects of human impact on the reproductive effort and allocation of energy reserves in the Mediterranean octocoral *Paramuricea clavata*. Marine Ecology Progress Series 449, 161–172.
Tsounis, G., Rossi, S., Bramanti, L., Santangelo, G., 2013. Management hurdles in the sustainable harvesting plans of *Corallium rubrum*. Marine Policy 39, 361–364.
Veron, J.E.N., Hoegh-Guldberg, O., Lenton, T.M., Lough, J.M., Obura, D.O., Pearce-Kelly, L., Sheppard, P.C.R.C., Spalding, M., Stafford-Smith, M.G., Rogers, A.D., 2009. The coral reef crisis: the critical importance of <350 ppm CO_2. Marine Pollution Bulletin 58, 1428–1436.
Walting, L., Norse, E.A., 1998. Disturbance of the seabed by mobile fishing gear: a comparison to forest clearcutting. Conservation Biology 12, 1180–1197.
Wells, S., 2009. Dynamite fishing in northern Tanzania-Pervasive, problematic and yet preventable. Marine Pollution Bulletin 58, 20–23.
White, A.T., Vogt, H.P., Arin, T., 2000. Philippine coral reefs under threat: the economic losses caused by reef destruction. Marine Pollution Bulletin 40, 598–605.
Wouters, N., Cabral, H.N., 2009. Are flatfish nursery grounds richer in benthic prey? Estuarine, Coastal and Shelf Science 83, 613–620.