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SYNTHESIS AND REVIEW OF THE BEST AVAILABLE SCIENTIFIC STUDIES ON PRIORITY AREAS FOR BIODIVERSITY CONSERVATION IN MARINE AREAS BEYOND THE LIMITS OF NATIONAL JURISDICTION

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I. Background

In paragraph 44(a) of its decision VIII/24, the Conference of the Parties requested the Executive Secretary to synthesize, with peer review, the best available scientific studies on priority areas for biodiversity conservation in marine areas beyond national jurisdiction, including information on status, trends and threats to biodiversity of these areas as well as distribution of seamounts, cold water coral reefs and other ecosystems, their functioning and the ecology of associated species, and to disseminate this through the clearing-house mechanism. In undertaking this task, the Executive Secretary was asked to work actively with, and to take into account scientific information available from, the range of relevant expertise available in governmental, intergovernmental, non-governmental, regional and scientific institutions, expert scientific processes and workshops, and, indigenous and local communities, where appropriate.

The present document is the first attempt to review and synthesize existing literature for the priority habitats listed in decision VIII/24, which include seamounts, cold water coral reefs, hydrothermal vents and other ecosystems in areas beyond national jurisdiction. The document presents, in synthesized format, information about their distribution, status and trends (where available), as well as about the threats facing these ecosystems. Information about the functioning of these ecosystems and the ecology of associated species is also presented. Finally, the document reviews work that has been undertaken to identify priority conservation areas beyond the limits of national jurisdiction. The document will be peer reviewed prior to distribution.

II. Seamounts

a. Global distribution

Seamounts are isolated islands or island chains beneath the surface of the sea. Seamounts are generally formed over hotspots, which are points of frequent volcanic activity in the earth's crust persisting over millions of years[1]. The sea floor tectonic plates move over the stationary hotspots causing seamounts to form. As one seamount is carried away from the hotspot another forms in its place, meaning that the oldest seamounts are furthest away from the hotspot. The movement of tectonic plates causes seamounts to often form long chains or elongated clusters. Seamounts stay volcanically active while over the hotspot (2 or 3 million years), and their volcanic activity wanes after they are carried away, Because of their volcanic nature, seamounts are found near mid-ocean spreading ridges, over upwelling plumes and in island-arc convergent settings[2]. Studies suggest a connection between the height of the seamount and the age (and thus the strength) of the tectonic plate, and to a lesser extent melt availability and magma driving pressure[3].

Because seamounts do not break the sea surface, our knowledge of their distribution comes primarily from remote sensing. Traditionally, seamounts have been mapped by acoustic echo

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sounders on oceangoing research vessels. However, because of the vastness of the oceans, it is unlikely that this method can be used to comprehensively map seafloor bathymetry. Alternative methods include the use of satellite altimetry or estimated primary productivity to infer seamount locations[4] [5] [6]. Such studies indicate that seamount numbers are difficult to estimate, but, according to the Census of Marine Life, there are potentially up to 100,000 seamounts over 1 km high and many more of smaller elevation[7]. They are found in every ocean basins and most latitudes. Nearly half of the world's seamounts are found in the Pacific Ocean. The rest are mostly found in the Atlantic and Indian Oceans, and overall there is a considerable bias towards the southern hemisphere[8]. Figure 1 presents a map of estimated seamount location.

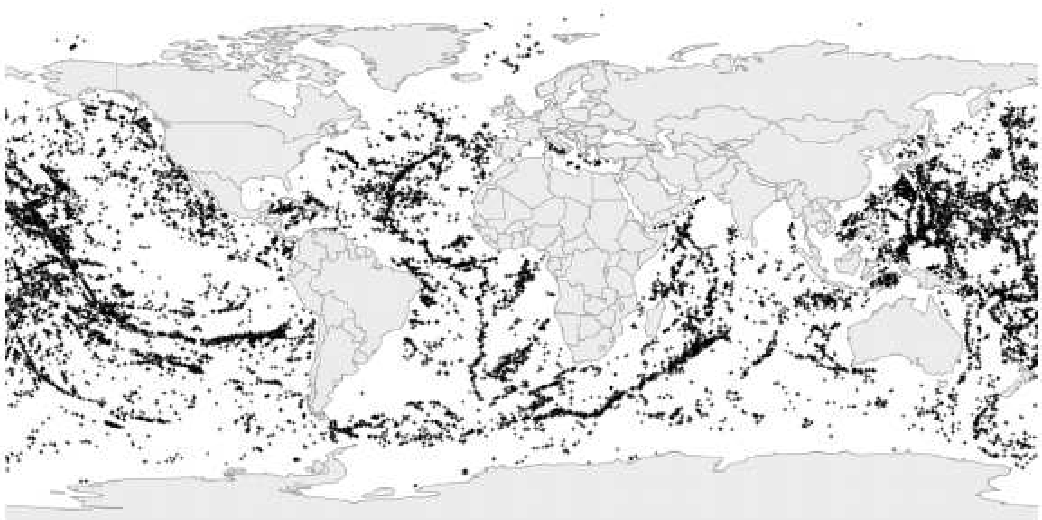


Figure 1: Estimated distribution of large seamounts[9]. This map displays approximately 14,000 particularly well-defined (conical), seamounts. Including a wider range of seamount shape and size could increase their number to 100,000[10].

b. Status and trends

Relatively few seamounts have been studied, with only about 350 having been sampled. Of these, less than 100 have been studied in any detail, many in waters within national jurisdiction. Figure 2 presents a map of studied seamounts as prepared by SeamountsOnline, a global database on seamounts.

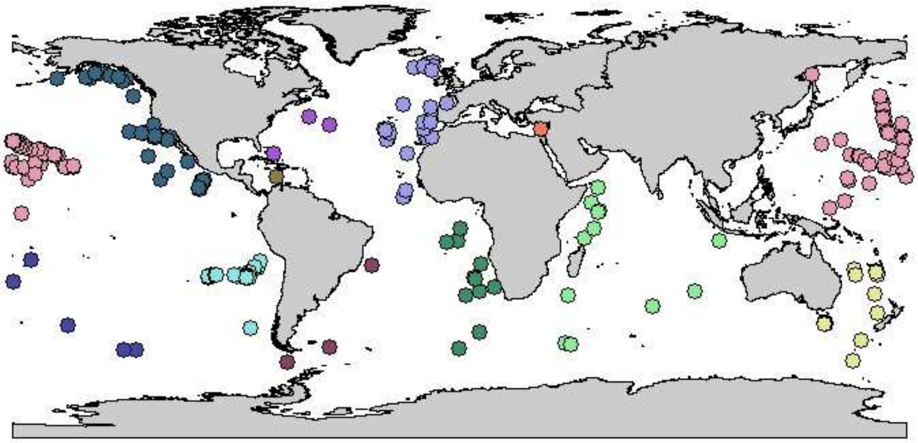


Figure 2: This map shows the seamounts for which SeamountsOnline currently has data. However, in many cases, they only have records of one or a few species - the number of seamounts, which have been well sampled is much smaller. In creating this map, a strict definition of "seamount" was not used - the map includes some features that are less than 1000m tall.[11]

Although seamount biodiversity is still poorly understood on a global scale due to lack of sampling and exploration, available research results suggest that seamounts are often highly productive ecosystems known for their ability to support high biodiversity and special biological communities, including cold water coral reefs as well as abundant fisheries resources, marine mammals and seabirds[12]. There is also evidence of high levels of endemic species[13 14], although these levels may vary between individual seamounts[15]. According to a recent Census of Marine Life Workshop, "seamounts represent important ecosystems for study that have not, to date, received scientific attention consistent with their biological and ecological value"[16] International initiatives such as the Census of Marine Life are attempting to fill key knowledge gaps relating to seamount community structure, diversity, endemism, and the impacts of exploitation on seamount communities. However, due to the large number of seamounts, their widespread distribution, and large variability of physical and biological characteristics, it will take time before all questions can be answered.

Trend-related information is primarily available in regards to seamount fisheries. According to a preliminary assessment of global seamount fisheries[16], estimated catches of primary seamount species such as *oreosomatids* (Oreo), *Hoplostethus atlanticus* (Orange roughy) and *Dissostichus eleginoides* (Patagonian toothfish) remained low at less than 5,000 tonnes from the 1950s to the mid-1970s, but then increased to over 120,000 tonnes in the early 1990s. Catches of secondary seamount species (mainly tunas and mackerels) increased from less than 50,000 tonnes in the 1950s to around 350,000 tonnes in the 2000s. Primary seamount species include those species whose survival depends on seamounts, while secondary seamount species are commonly found on seamounts, but are not exclusive to them[16]. Rapid increase in catches of primary seamount species in the mid-1970s resulted from the availability of technology to find and explore deeper and distant fishing locations such as seamounts[16 17]. Catches of primary species appear to have peaked overall by the early 1990s, by which time it is likely that almost all productive seamounts were accessible to fisheries. It has been suggested that the apparent increase in catch was sustained by serial depletions of previously unexploited and inaccessible stocks[18]. The increased interest of fishing fleets in seamounts beyond national jurisdiction may have been driven by the depletion of many coastal shelf fisheries and the introduction and enforcement of 200 nautical mile exclusive economic zones (EEZs) around most nations' productive inshore waters[19].

c. Threats

Seamount ecosystems are vulnerable because of their geographical isolation[20] and because of the characteristics of their associated species, which include fragile cold water coral reefs, and long-lived, slow growing fish species. The biggest current threat to seamounts comes from fishing activities. Because of their high productivity, seamount ecosystems are often characterized by abundant fisheries resources in comparison to the surrounding open ocean[21]. Seamounts are thought to be targets of recently developed high-technology fisheries[22], with serial depletion and reduced genetic diversity the suggested results of exploitation[23 24 25]. This has made many scientists cautious about the ability of seamount areas to support unlimited exploitation [26 27 28 29]. Watson and Morato (2004)[30] showed that seamount fisheries collapsed faster and recovered more slowly than non-seamount fisheries. Many species associated with seamounts, particularly primary seamount species, such as oreo, orange roughy and Patagonian toothfish, are characterized by slow growth, longevity, late sexual maturity, and restricted distribution, rendering them highly vulnerable to fishing[31 32]. Over-exploitation of the pelagic armorhead over the Pacific seamounts northwest of Hawaii and the serial depletion of orange roughy stocks between southeastern Australia and New Zealand are examples of fishing as a threat to seamount-associated species[33].

Seamount trawl fisheries also have severe impacts on the benthic communities on seamounts, including fragile habitats such as cold water corals and other invertebrates[34]. Comparative surveys of benthic macrofauna community structure at four seamounts found intact coral cover only on the un-fished and very lightly fished seamounts. The substrate of the heavily fished seamounts was predominantly bare rock (>90% at most depths), while the existing coral material was either rubble or sand. Data suggest that virtually all coral aggregate, living or dead, was removed by the fishery, leaving behind bare rock and pulverized coral rubble. The results showed that the impact of trawling on complex seamount reefs appears to be dramatic, with the coral substrate and associated community largely removed from the most heavily fished seamounts. At shallow, heavily fished seamounts, most of the shift in community composition could be ascribed to the impacts of trawling, which effectively removed the dominant colonial coral, *Solenosmilia variabilis*, and its associated fauna[35]. Because so few seamounts have been surveyed, it is not possible to say what percentage of all seamounts globally have already been impacted by fishing and other human activities.

Other threats include the mining of deep water corals associated with seamounts for the jewelry trade, bioprospecting, potential future seabed mining related to mineral resources of ferromanganese crusts, and possible future exploitation of methane gas hydrates found in some deep water sediments as an energy source[36]. Climate change may also present a future threat.

d. Functioning of this ecosystem and ecology of associated species

Upwelling of nutrient-rich water around seamounts make them highly productive ecosystems, capable of supporting substantial biodiversity. Surveys in the Tasman Sea and southeast Coral Sea discovered more than 850 macro- and megafaunal species, of which 29-34% are new to science and potential seamount endemics. The data suggested that seamounts that occur in clusters or are positioned along a ridge system might have highly localized species distributions and high endemism[37]. Other studies have found high polychaete diversity[38] with a decrease in the number of species and the number of individuals with depth[39]. Studies on seamounts off Southern Tasmania found that 60% of near-bottom fish species caught had not been previously recorded in the Australian ichthyofauna, or were undescribed. This indicates a specialized fauna restricted to the seamounts, probably containing many endemic species. Number of fish species appeared to diminish both on the deepest seamounts and on the most heavily fished seamounts. Invertebrate samples taken in the same area found that 26-44% might be new to science, and 35% appeared to be restricted to the seamount habitat. Approximately 48% were endemic to the region[40]. Dense and diverse invertebrate communities are found on Tasmanian seamounts dominated by suspension feeders, including reef-forming and gorgonian corals, hydroids, and sponges. 24-43% of these species are new to science and 16-33% are endemic to the seamount environment[41]. These and other studies support the hypothesis that seamounts are biodiversity hotspots[42].

Marine top predators, such as bigeye tuna (*Thunnus obesus*) and yellowfin tuna (*Thunnus albacares*) in Hawaii, are often found aggregating around seamounts[43]. As indicated in the previous section, several studies have focused on the vulnerability of seamount species to fishing. Seamount aggregating fish are found to be, on average, biologically more vulnerable to fishing than other marine fish. Seamount fish, particularly deepwater demersal fish, are large-sized, slow growing, and late maturing. These life history characteristics render them less able to withstand fishing mortality[44] [45] [46]. Additionally, the localized distribution of many benthic seamount species greatly increases the threat of extinction and may require that conservation and protection of seamount communities be undertaken on a local scale[47].

In addition to acting as feeding grounds for fishes and marine mammals[48], seamounts can also attract seabirds, which feed on prey items concentrated around seamounts. An aggregation of seabirds over Fieberling Guyot, an isolated mid-ocean seamount in the eastern North Pacific Ocean, was found to have seabird density and biomass 2.4 and 8 times higher respectively than the surrounding ocean area. Individual seabird taxa were 2 to 40 times more abundant at the seamount relative to values reported previously from large-scale surveys of deep-ocean regions in the central North Pacific[49].

Seamounts may play an important role in understanding patterns of marine biogeography, as hot spots for the evolution of new species, refuges for ancient species, and stepping-stones for species to spread across ocean basins[50] [51] [52]. The degree to which seamounts are genetically isolated is not well understood. Some studies have suggested that there is limited gene flow between seamounts only for those species with limited dispersal abilities, while species with good dispersal abilities are spread throughout a wider area. Seamounts may be highly productive zones that can support numerous species in small areas by acting as sources of larvae[53]. Patterns of colonization appear to be related to dominant current flows in an area, explaining, for example, similarities between European and African seamount fauna[54]. Cluster analysis can be used to distinguish groups of seamounts with high percentages of similar species[55], potentially leading to the development of biogeographic classification of seamounts in the future.

II. Cold-water corals

a. Global distribution

Cold-water corals include stony corals (Scleractinia), soft corals (Octocorallia), black corals (Antipatharia), and hydrocorals (Stylasteridae). They are widely distributed and have thus far been found in the Atlantic, Mediterranean, Indian and Pacific Oceans. Most of the cold water corals discovered to date appear to be on the edges of the continental shelf or on seamounts[56]. The majority of cold-water coral reefs have been found in the northeast Atlantic Ocean, and are usually dominated by the genus *Lophelia*. The largest reef complex in the world, the Sula Ridge Complex, was found off the Norwegian coast. It is over 14 km long and grows up to 35 metres from the sea bed[57]. The total area covered by cold water coral reefs globally is still unknown, although studies indicate that coverage could equal, or exceed, that of warm-water reefs. A conservative estimate of cold water coral reef coverage is 284,300 km^2 [58].

Cold-water coral reefs and mounds tend to cluster in "provinces" where specific hydrodynamic and food supply conditions favor coral growth. They are largely restricted to oceanic waters and temperatures between 4 and 12 degrees C. They are generally found in shallow waters (~50-1000 m) at high latitudes, and at great depths (up to 4000 m) at low latitudes. There is a strong relationship between the number of cold-water scleractinian coral occurrences and the depth of the aragonite saturation horizon (ASH), which is the depth below which aragonite dissolves readily. Aragonite and calcite are supersaturated in surface ocean waters, and become more soluble with decreasing temperature and increasing pressure (hence depth). The global distribution of cold water coral reefs is not yet well known and new reefs continue to be discovered [59]. A map of known cold water coral reefs can be seen in figure 3.

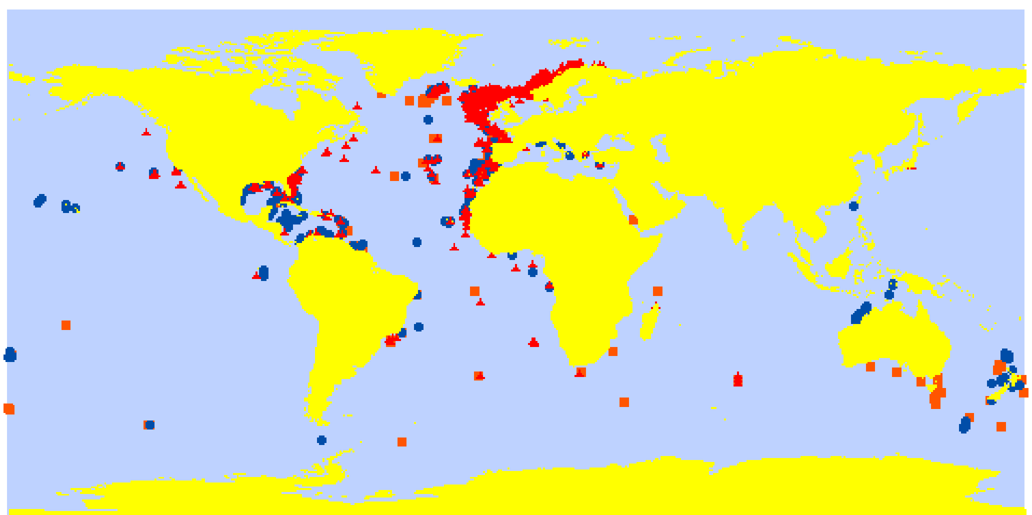


Figure 3: Distribution of known cold-water coral areas based on species distributions, *Lophelia pertusa* (red triangles), *Madrepora oculata* (blue circles) and *Solenosmilia varialilis* (orange squares) (UNEP-WCMC sourced from A. Freiwald from various sources)

Several other factors may contribute to the distribution of cold-water coral reefs. For example, distribution and abundance of corals has been found, in some cases, to be related to large-scale topographic features such as the shelf breaks and ridges, as well as to the types of bottom structure, near-bottom temperature and salinity[60]. It has also been proposed that a steady availability of locally-produced nutrients through seepage from underlying sediments can be the main factor determining the distribution of *Lophelia pertusa* reefs in Norwegian waters. However, based on the available evidence, there is no proof that the Norwegian deep-water coral reefs or any other of the world's deep-water carbonate mounds and coral reefs are directly fuelled by seepage. Various pieces of evidence suggest a link between the location of reef structures and seepage of fluids through the seabed[61]. Similarly, relatively high concentrations of light hydrocarbons have been found in the sediments and the base of the *Lophelia* reef in the Norwegian Sea off mid Norway. It has been proposed that there is an upward seepage of hydrocarbon-charged porewater on which bacteria and other micro-organisms thrive, thus providing suspension-feeders, including the corals, with a substantial and reliable food source[62].

Observations show that black corals (antipatharians) and horny corals (gorgonians) are more abundant near peaks of seamounts, compared with mid-slope sites at corresponding depths. The abundance of corals also increases on knobs and pinnacles. Physical models and observations, together with direct measurements, suggest that seamount topography affects the local current regime. Corals appear to benefit from flow acceleration, and some of their patterns of distribution can be explained by current flow conditions[63].

b. Status and trends

There are still large gaps in our understanding of the distribution of cold water coral reefs, their biology and ecology. These gaps are mainly due to the difficulty of researching these remote environments, where observation and sampling requires expensive ship time including sophisticated equipment such as submersibles, remotely operated vehicles, underwater video or other ship-based remote sensing equipment. .Our current knowledge consists of a series of snapshots of well-studied reefs, most of which are located in the higher latitudes. Although cold water coral reefs are known to exist off the coasts of Africa, South America and in the Pacific, these reefs have not generally been subjected to detailed studies and mapping. On-going research projects in a number of countries and the European Community are expected to fill some knowledge gaps[64].

According to currently available knowledge, cold-water corals can exist as small, scattered colonies of no more than a few metres in diameter to vast reef complexes measuring several tens of kilometres across. Radioactive dating techniques have shown that some living banks and reefs are up to 8000 years old and geological records indicate that cold-water coral reefs have existed for millions of years.[65]. About 20 of the 703 known species of deep-sea stony corals build reef structures. Major reef forming species include *Lophelia pertusa* and *Oculina varicosa* (ivory tree coral). It is estimated that more than a hundred deep-sea coral and sponge species live in the North Pacific off Alaska, at least 34 of which are corals. Researchers estimate that roughly 800 species of stony corals alone have yet to be discovered[66].

Cold-water coral reefs support rich and diverse assemblages of marine life, and are home to thousands of other species, in particular animals like sponges, polychaetes (bristle worms), crustaceans (crabs, lobsters), echinoderms (starfish, sea urchins, brittle stars, feather stars), bryozoans (sea moss) and fish[67]. More information about species associated with cold water reefs can be found in section d.

The overall ecological health status of cold water coral reefs is unknown. Most of the reefs studied thus far show physical damage from trawling activities. Only in a few cases has this damage been quantified. The Norwegian Institute of Marine Research estimated that probably between 30 and 50% of the coral reefs known to exist or expected to be found, in Norwegian waters had been partially or totally damaged by bottom trawling activities, which had been on-going since the mid-1980s. Widespread trawling damage has been documented to coral reefs at

840 – 1300 m depth along the West Ireland continental shelf break and at 200m off West Norway[68] From 1990 to 2002, the United States federal fishery observer data indicate that approximately 2,176 648kg of coral and sponge by-catch occurred in the Aleutian Islands, equivalent to 52% of all coral and sponge by-catch in Alaska. Additionally, damage created by trawls and other fishing activities has been documented in many areas, including in the Northeast Atlantic, and in Canadian, United States, New Zealand and Australian waters[69]. Many countries are undertaking measures for protecting cold water coral reefs in their national EEZs, though not in areas beyond national jurisdiction. For example, Norway was the first country to have implemented protection measures in European waters. The rate of regeneration and recovery of once-damaged cold water coral reefs is unknown, but is estimated to be on the scale of decades to centuries for a reef to regain ecological function owing to the very slow growth rate of cold water coral reefs[70].

c. Threats

Major threats to cold-water corals include bottom trawling, hydrocarbon drilling, seabed mining, ocean acidification and direct exploitation. At the present time, bottom trawling is the biggest threat to cold-water coral reefs, causing mechanical breakage of the reef structure. Cold-water corals are also threatened by direct exploitation. For example, the gorgonian coral *Corallium lauuense,* which is found on Hawaiian seamounts, is suffering inbreeding depression (a reduction in fitness and vigor of individuals as a result of increased homozygosity through inbreeding) that might have been caused by exploitation of its skeleton for jewelry making[71].

There is little evidence that hydrocarbon exploitation substantially threatens cold-water coral ecosystems. The greatest concern is the potential for drill cuttings to smother reef fauna, but such effects would be highly localized compared to the disturbance caused by bottom trawling. Mining activities risk causing local extinctions of endemic species of cold-water corals.

Ocean acidification presents a potentially serious future threat. Increase in atmospheric carbon dioxide (CO_2) can increase the acidity of sea water through increased CO_2 dissolution. Current research predicts that tropical coral calcification would be reduced by up to 54% if atmospheric carbon dioxide doubled. There have been no studies to examine the effects of ocean acidification on cold-water corals, but given the lowered carbonate saturation state at higher latitudes and in deeper waters, these species may be even more vulnerable than their tropical counterparts. Also, the depth at which aragonite dissolves could become shallower by several hundred meters, thereby raising the prospect that areas once suitable for cold-water coral growth will become inhospitable in the future[72].

As mentioned in the previous section, widespread trawling damage to cold-water coral reefs has been documented along the West Ireland continental shelf break and off West Norway. Coral by-catch included a diverse array of sessile suspension feeders (e.g., sponges, gorgonians, hydroids, anemones, serpulids, barnacles, bivalves, bryozoans, brachiopods, crinoids and tunicates). The study showed that the deep-water reefs in the Iverryggen and Nordleksa areas of West Norway are especially fragile and easily reduced to rubble by towed fishing gear. Coral by-catches from West Ireland had more diverse coral assemblages than those encountered in Norway[73].

Cold water coral reefs and associated communities occurring on seamounts may be at increased risk from large scale disturbances due to the localized distribution of seamounts and the limited larval phase in plankton of many species[74]. Rich fishery resources associated with seamounts attract fishing efforts and indirectly increase the risk of disturbance to seamount-associated coral reefs.

In addition to the major threats mentioned above, bioprospecting may also be a threat to cold-water coral reefs if unsustainably conducted. Besides their ecological importance, deep-sea coral and sponge communities have potential as pharmaceuticals, nutritional supplements, enzymes, pesticides, cosmetics, and other commercial products[75]. The potential commercial uses of cold-water coral reefs and associated species, if found profitable, may lead to increased scientific sampling and direct exploitation. Such activities, if ineffectively managed, may pose serious threats to cold-water coral reefs and their associated species[76].

d. Functioning of this ecosystem and ecology of associated species

Cold-water coral reefs, like their tropical warm and shallow-water counterparts, are built predominately by stony corals (*Scleractinia*). Unlike tropical reefs, they do not have light-dependent symbiotic algae in their tissues. Because of this, they depend solely on current-transported particulate organic matter and zooplankton (animal plankton) for their food. They grow slowly, at only a tenth of the growth rate of warm-water tropical corals. Many of them produce calcium carbonate skeletons that resemble bushes or trees, and provide habitat for associated animal communities[77].

Reefs develop after an initial settlement of a coral larva on a hard substratum. As a coral grows, polyps in older portions die, and the skeleton becomes increasingly vulnerable to bio-eroders (notably, clionid sponges) and mechanical breakage. Bio-eroded skeletons may break, fall to the seabed, and extend the perimeter of the reef patch. These processes are fundamental in creating the reef framework that, over time, baffles and traps mobile sediment, further building the reef.[78].

There is no doubt that cold-water coral reefs support diverse communities of unique species. Species diversity on cold-water coral mounds has been found to be much higher than in the surrounding sea bottom habitat[79] and cold-water coral reefs are frequently reported on seamounts where their associated species tend to have high endemism[80]. More than 1300 species have been recorded living on or in *L. pertusa* reefs in the northeast Atlantic, a diversity that is three times higher than on surrounding soft bottoms. A study of twenty-five blocks of the coral *Lophelia pertusa* collected from the Faroes, weighing a total of 18.5 kg, found 4,626 individuals belonging to 256 species. Of the 298 species found, 97 were recorded for the first time from the area around the Faroes. When these findings were compared with studies of *Lophelia* banks in Norway and the Bay of Biscay, there were very few overlaps in the associated species, indicating potentially large differences between sites[81] and high endemism of cold-water coral reef-associated assemblages.

Other species associated with cold water coral reefs include economically important rockfish, shrimp and crabs, which often hide among the branches of red tree corals. Crinoids, basket stars, anemones and sponges attach themselves to dead branches so they may better filter food from the currents. Other animals, such as sea stars and snails, feed directly on the corals themselves. Fish often aggregate on deep-sea reefs[82], though the specific functional relationship between species present on a cold-water coral reef and the importance of that reef as fish habitat is not well understood[83]. Most species found on cold-water corals are facultative symbionts (a relationship in which one partner may, but does not have to, live with another in order to survive). Some deep-water coral reefs seem to have richer and more abundant crustacean fauna than similar tropical reefs[84]. Factors affecting the community structure of cold water coral reef associated species include time needed for community development, frequency of external disturbance and variability of nutrient supply.

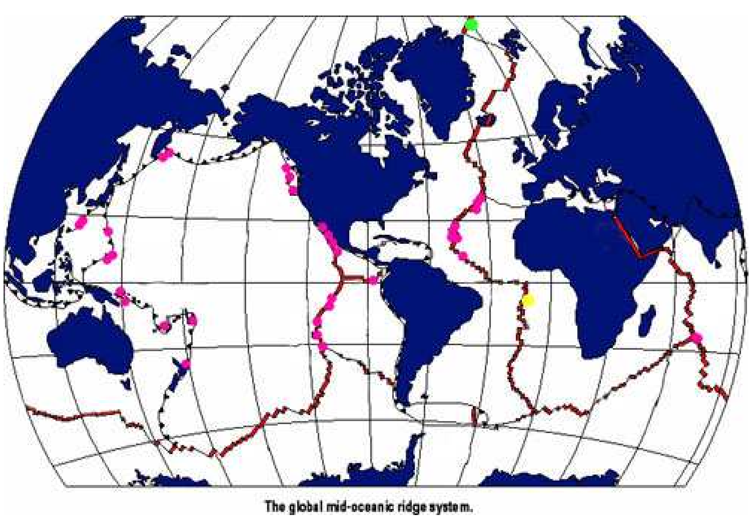
Cold water corals, reefs and mounds generally occur in areas of fast currents and internal waves, where particle flow rates are fast[85]. Given their high species diversity and longevity, and their occurrence in areas of fast current flow, cold-water coral reefs may be major centres of speciation[86].

Recent DNA studies have revealed that some cold water corals species, such as *Lophelia*, show high genetic variability across the Atlantic Ocean. Sequences obtained from samples of *Lophelia* from the northeast Atlantic were very different from those obtained from samples collected in the southwest Atlantic. *Lophelia* samples collected in Scandinavian fjords appeared to be genetically different from those distributed along the European continental margin. Results suggest that continental margin reefs might originate from migrants dispersed out of the fjords in the past. Understanding such relationships may be important for the development of conservation and management strategies[87].

IV. Hydrothermal vents

a. Global distribution

The discovery of hydrothermal vents along the Galapagos Rift in the eastern Pacific in 1977 represented arguably one of the most important findings in biological science in the latter quarter of the twentieth century[88]. Hydrothermal vents were the first ecosystem on Earth found to be independent from the sun as an original source of energy, relying instead on chemosynthesis. Hydrothermal vents are now known to occur along all active mid ocean ridges and back-arc spreading centres. The InterRidge Hydrothermal Vent Database currently lists 212 separate vent sites[89], though more are likely to exist. The map in figure 4 has been produced by the ChEss project, which is a global study of the distribution, abundance and diversity of species in deep-water hydrothermal vents, cold seeps and other chemosynthetic ecosystems for the Census of Marine Life initiative.[90]



The global mid-oceanic ridge system.

Figure 4: Global distribution of known hydrothermal vents. The locations of those vents that have already been studied are marked on the map below as pink dots. Two new vent sites were discovered in 2005 - one on the south Mid-Atlantic Ridge (yellow dot) and one on the Arctic Ridge system (green dot). The latter contains the northern most vent fields found in the world to date.

As mentioned above, hydrothermal vents are commonly associated with mid-ocean ridges, where they are formed by interactions between molten rock and seawater as the tectonic plates spread apart. The recent discovery of a new type of hydrothermal vent, a so-called off-axis vent, indicates that ocean-bottom hydrothermal activity may be much more widespread than previously thought. . The off-axis vents have been found up to a few tens of kilometers away from the mid-ocean ridge, on near-ridge seamounts. Instead of being formed by volcanism, the off-axis vents appear to be formed by a heat-generating chemical reaction taking place when the seamount's eroded rocks interact with seawater[91].

It also appears that vents associated with mid-ocean ridges may be more frequent than originally thought. Initially it was hypothesized that vents occurred only in areas where the ridge is spreading at fast rates. However, recent studies have found the presence of vents at ridge locations characterized by a variety of spreading rates, from relatively slow to fast[92].

b. Status and trends

As is evident from the previous section, our knowledge about where hydrothermal vents occur, and how extensive they are, is far from complete. Hydrothermal activity does not take place everywhere along mid-ocean ridge systems. Since the 1990s, there have been large-scale, systematic searches for undiscovered vent sites. Many of these searches rely on inferring the presence of vents from water column observations by measuring optical properties, temperature and particle anomalies, as well as chemical tracers that distinguish hydrothermal plumes from the surrounding seawater. The currently known vent sites reflect historic funding priorities for research, with over half of the known or inferred ridge vent sites occurring on the heavily surveyed eastern Pacific ridges, with only a few locations thus far found in the southern hemisphere[93].

There are also knowledge gaps in regards to the biodiversity and ecology of hydrothermal vent ecosystems, and their interactions with surrounding communities. Generally, biomass of hydrothermal vent communities is high but biodiversity is low[94]. This is typical of habitats with high energy availability and extreme environmental conditions. However, vent sites support exceptionally productive biological communities in the deep sea, and vent fauna range from tiny chemosynthetic bacteria to tube worms, giant clams, and ghostly white crabs. Over 300 new species of animals have been discovered at hydrothermal vents from a number of different animal groups, even though only 10 percent of the ocean ridge system has been explored for hydrothermal activity[95]. It is estimated that the average rate of discovery of new species over the past three decades is approximately two new species per month[96]. Many species are exclusive to these ecosystems and would be unable to exist outside them[97]. These animals are discussed in more detail in section d.

Individual hydrothermal vent sites are intrinsically unstable and ephemeral on geological time scales, lasting only on the order of years to decades[98] Volcanic eruptions, or the ceasing of vent fluids can generate frequent extinctions, re-colonizations and changes in community structure.

This transient nature of vent sites, and its consequences on vent fauna, is discussed further in section d.

Human impacts on hydrothermal vent ecosystems have, to date, been limited to those vent sites subject to intensive scientific studies. Although some human impacts have been documented on heavily visited sites (see section c), the high natural variability of vent systems may make it more difficult to accurately assess the effects of human activities[99].

c. Threats

The major current anthropogenic threat to hydrothermal vent systems is from marine scientific research. Research may entail physical disturbance or disruption, or the introduction of light into an ecosystem that is naturally deprived of it. Some evidence of disturbance caused by scientific research already exists. For example, the use of floodlights of manned submersibles may have irretrievably damaged the eyes of decapod shrimps (family *Bresiliidae*) that dominate the fauna at vents on the Mid-Atlantic Ridge.[100] The scientific community is aware of this threat, and has begun to consider preventive action. InterRidge (a non-profit organization concerned with promoting all aspects of mid-ocean ridge research) has issued in 2006 a statement of commitment to responsible research practices at deep-sea hydrothermal vents. This statement contains guidelines for responsible research practices, which InterRidge encourages scientists to abide by[101]. A Code of Conduct for the Scientific Study of Marine Hydrothermal Vent Sites is under development. It should be noted, though, that both the guidelines and the Code are voluntary measures.

Bioprospecting of hydrothermal vents is already taking place, and may present a threat if sample collection methods cause a disturbance to the vent community. Hydrothermal vent organisms posses novel adaptations that make them capable of surviving in extreme environments. These same adaptations make the organisms of potential use to biotechnology. A number of patents have been filed relating to inventions based on hydrothermal vent organisms, ranging from skin care products to industrial applications[102]. For example, the California-based biotechnology company Diversa has developed the Valley "Ultra-Thin™" product from genes recovered from a deep sea hydrothermal vent organism. This product is currently marketed by Valley Research for use in starch liquefaction for the production of ethanol[103].

Mining of polymetallic sulphide deposits associated with vent systems, high-end tourism and marine scientific research present potential future threats to vent ecosystems. Extraction of polymetallic sulphide deposits can cause direct physical damage and destruction to the vent ecosystem, as well as sedimentation and disruption of water circulation systems. Submarine-based marine tourism and marine scientific research may disturb the fragile vent ecosystem[82], such as the retinal damage to deep sea crustaceans mentioned above[94].

d. Functioning of this ecosystem and ecology of associated species

Hydrothermal vents are found along mid-ocean ridges, where magma from deep parts of the earth emerges. A vent is typically formed when seawater penetrates the crust, is heated by the magma, and surges back into the ocean through a hot vent, bringing with it mineral substances, including sulfide, hydrogen, methane, manganese and metals. Chemoautotrophic bacteria use the sulfur-rich water for primary production. The energy produced by the bacteria supports the nutritional requirements of other organisms in the vent community.[104] For example, giant tubeworms

(*Riftia*), which can reach up to 3m in length, survive only as a result of the symbiotic relationship they have with chemoautotrophic bacteria.

Because of their independence from sunlight as an energy source, hydrothermal vent systems are thought to have played an important role in the development of life on Earth, and the differentiation of a common ancestor into Bacteria and Archaea (an evolutionary branch that is separate from those of Bacteria and Eukarya). There is evidence that life has existed around hydrothermal vents for more than 3 billion years. However, subsequent studies have found limited support for the hypothesis that modern vent fauna are Palaeozoic relics. Instead, molecular evidence suggest that these fauna evolved from relatively recent radiations (or re-radiations) of vent and seep taxa. This implies that deep-sea chemosynthetic environments are not immune from global extinction events affecting diversity in the photic zone.[105] Similarly, the hypothesis that life arose in hydrothermal vents has not been proven[106].

Deep-sea hydrothermal vent communities are characterized by three important environmental attributes which govern community composition, distribution and dynamics: (1) the harsh physical and chemical conditions experienced by the vent fauna, (2) the patchy distribution of vent sites over oceanic ridges, where distances between vents within a given field range from a few metres to hundreds of metres, and the distances between vent fields range from hundreds to thousands of kilometers; and (3) the high temporal variability of hydrothermal activity due to tectonic events and heat convection through the oceanic crust, which induces a high site turnover that may vary in duration from years to decades on fast-spreading ridges. [107]

The first of these attributes has caused hydrothermal vent animals to develop a rich variety of novel biochemical and physiological features that allow them to survive in the extreme environmental conditions within a vent field.[108] The harsh vent environment has also resulted in a high degree of endemism. Studies have shown that vent communities contain remarkable taxonomic novelty, and over 80% of vent species appear to be endemic[109]. Many species found in studies are new to science[110].

Although most of the species diversity at hydrothermal vents can be attributed to taxonomic groups that comprise small, inconspicuous individuals (e.g. polychaete worms, gastropods, copepod crustaceans and nematodes), most of the biomass is formed by a few large and visually striking species. These include vestimentiferan tube worms (*Siboglinidae*), vent clams (*Vesicomyidae*), vent mussels (*Bahtymodiolinae*) and the blind vent shrimp, all of which harbour chemoautotrophic bacterial symbionts. These organisms exploit the reduced chemical compounds in vents either directly, by way of symbiotic chemoautotrophic bacteria, or indirectly, by grazing and filtering free-living chemoautotrophs[111]. The trophic structures seem to be relatively simple, with few steps. Most animals appear to feed directly on microbial production[112].

Giant tubeworms are perhaps the most spectacular fauna that have adapted to living near hydrothermal vents. The Pompeii worm (*Alvinella pompejana*) inhabits active deep-sea hydrothermal vents, which form thick, heavily channelled structures along the outer walls of the vent 'chimneys' created by an accumulation of metal sulphides. The worm is tolerant of extreme temperatures, inhabiting an environment with temperature gradient of up to 60 degrees C and an absolute temperature of up to 81 degrees C.[113]

The distribution of animals within a vent community exhibits a pattern of zonation, an example of which has been documented at the Broken Spur vent (in the Mid-Atlantic Ridge). *Bresiliid* shrimp were present close to black smokers, brittle stars were found on solid surfaces of chimneys and mounds, peak densities of anemones occurred at the base of sulphide mounds, and peak densities of brachyuran crabs were found at platform structures[114]. However, there are large differences in population structure between vent sites, likely in response to local variations in time of larval supply and/or reproductive activity[115]. A majority of vent species occur at only one site, and none occur at all studied sites[116]. The results tend to support the hypothesis of a lack of consequent long-distance transport of larvae.[117]

Hydrothermal vent sites are ephemeral, and their activity is highly variable due to the dynamic nature of the oceanic crust. As vents wane, organismal associations can be observed slowly transitioning as they gain greater similarity to background communities[118]. Mobile inhabitants may be able to escape from fading vent sites and establish populations on neighboring vents or on new vent sites, but the large aggregations of sessile organisms die if fluids cease to flow[119]. There is a successional pattern following disturbances, as demonstrated by vent-animal colonisation following an eruption on a segment of the Juan de Fuca Ridge, where it took five years for the species pool to reach pre-disturbance characteristics. The environmental unpredictability, transient nature and high biological production of hydrothermal systems also favours continuing reproduction, rapid recruitment, accelerated growth and a tolerance to environmental perturbations. For example, the documented growth rates of the giant tube worm *Riftia pachyptila* were almost 2.5 cm in ten days, which is the fastest rate reported to date for any species of marine invertebrates.[120]

The heat of volcanic processes creates and sustains hydrothermal plumes, formed through the interaction of seawater with rock. These plumes are often black or white with the color coming from mineral particles that precipitate rapidly as hot hydrothermal fluids (with temperatures as high as 340^{o}C) mix with cold seawater (usually about 1-2^{o}C) at or just below the vent orifice. As mentioned in section b, scientists search for evidence of hydrothermal plumes in seawater to discover the presence of hydrothermal activity below. Hydrothermal plumes are likely to be very important for the transport and distribution of marine organisms, especially thermophile or hyperthermophile bacteria that live under the seafloor and have been released into the ocean in plumes resulting from recent volcanic events[121]. The chemosynthetic bacteria, resuspended detritus from the upper ocean, and other biological products carried upward by the plumes also appear to support a wide range of biological activity in the overlying water column, in particular zooplankton communities consisting of both deep- and shallow-water species, though these interactions are not well known. Similarly, the links between hydrothermal vents and surrounding communities are not well understood. Studies at the Endeavour vent field suggest that substantial carnivore biomass outside the vents, including deep sea crabs, octopus and fish may be dependent upon localized production[122].

Studies relating to fish diversity on and around hydrothermal vents found a low specific diversity of fish, but a high degree of endemism. In general, fishes can be separated into two groups: (1) species living within the vent and seep environments, including the so-called vent-endemic species, and (2) species pertaining to the surrounding deep water environment, but recorded from a close proximity to vents and seeps. Their high degree of endemism is demonstrated by a study of the order *Anguilliformes* (comprising eels and other elongated fishes) living inside active vent fields. Of the 21 species found, 11 species (52%) have been described and 5 (24%) were new to science. The remaining 5 (24%) could only be identified to the genus or family level. Vent-living fishes were found at only 20 of some 50 active vent fields discovered at the time of the study. Species diversity in the Atlantic appears to be slightly higher than in the Pacific. This may be partly attributed to the differences in depth range of the vents[123].

The patchiness of vent sites has resulted in the delineation of a number of vent biogeographic provinces. On a large scale, the vent sites at different ocean basins differ somewhat. The vents in the East Pacific are dominated by giant tubeworms (*Riftia*), large white clams (*Calyptogena magnifica*) and mussels (*Bathymodiolus*). The Atlantic vent communities differ considerably from those in the Pacific, notably in the absence of vestimentiferan tube worms.[124] Instead, the Atlantic vents are dominated by dense aggregations of bresilioid shrimp (6 species belonging to 5 genera) and mussel beds. Most of the Indian Ocean vent fauna is related to the animals in the Pacific, presenting evidence in support of a connection between Indian Ocean vents and those in the Pacific. Surprisingly, however, the dominant species in the Indian Ocean is the common shrimp *Rimicaris* from the Atlantic, indicating that there is a connection with the Atlantic, too[125]. Because of these differences, the following biogeographic provinces of hydrothermal vents can be identified: (1) East Pacific Rise and Galápagos Rift; (2) Northeast Pacific; (3) Western Pacific; (4) Atlantic (Azores); (5) Mid-Atlantic ridge between Azores Triple Junction and Equator; (6) South Mid-Atlantic Ridge; and (7) Indian Ocean (Central Indian Ridge)[126 127]. It is likely that the regional species pool affects local vent diversity.[128]

There are differences within these biogeographic provinces, too. A comparison of the fauna between Lucky Strike, Menez Gwen and Rainbow vent fields on the Mid-Atlantic Ridge between the Equator and the Azores archipelago showed that the Lucky Strike and Menez Gwen sites are dominated by mussels (*Bathymodiolus azoricus*) while the Snake Pit and TAG sites are dominated by shrimps (particularly *R. exoculata*). It could be argued that these sites do not belong to a single biogeographic province, but are rather a succession of several distinct biogeographic islands having different associations and habitats. There was also a decrease in the number of non-endemic species with depth[129]. A separate study considered that the Lucky Strike fauna was sufficiently unique to be a separate biogeographic hydrothermal province, in addition to the eastern Pacific (East Pacific Rise and Galapagos Spreading Center), northeastern Pacific (Gorda, Juan de Fuca, Explorer Ridges), western Pacific (Back-Arc) and Mid-Atlantic Ridge (TAG and Snake Pit) provinces.[130] This demonstrates that biogeographic differences exist between sites, but that they are not yet well documented. Table 1 provides a summary of biogeographic provinces of hydrothermal vents and their dominant fauna as proposed by Ramirez-Llodra *et al*. (2007)[131]. Such differences are important for any initiatives to conserve representative areas consisting of hydrothermal vent sites.

Biogeographic Province	**Dominant fauna**
East Pacific Rise and Galápagos Rift	Vestimentiferan tubeworms, bathymodiolid mussels, vesicomyid clams, alvinellid polychaetes, amphipods, and crabs
Northeast Pacific	Vestimentiferan tubeworms (except Riftiidae, polychaetes and gastropods)
Western Pacific	Barnacles, limpets, bathymodiolid mussels, “hairy” gastropod, vesicomyid clams, and shrimp.
Atlantic (Azores)	Bathymodiolid mussels, amphipods, and caridean shrimp
Mid-Atlantic ridge between Azores Triple Junction and Equator	Caridean shrimp and bathymodiolid mussels
South Mid-Atlantic Ridge	Caridean shrimp, bathymodiolid mussels and clams
Indian Ocean (Central Indian Ridge)	Caridean shrimp and mussels, gastropods and anemones

Table 1. Main biogeographical provinces of hydrothermal vents and their dominant fauna[132]

IV. Other ecosystems in marine areas beyond the limits of national jurisdiction

Other ecosystems of note in marine areas beyond the limits of national jurisdiction include continental slopes and abyssal plains, trenches, canyons, sponge reefs and fields, and cold seeps. In addition, the pelagic (open water) realm provides an important habitat for many species. Each of these ecosystems is briefly discussed in the following text.

A. Abyssal plains

Abyssal plains cover almost 50% of the deep seabed, and are comprised mainly of mud flats. There is a relatively high diversity of animals living in and on deep sea sediments, including bottom-dwelling fishes, sea cucumbers, star fishes, brittle stars, anemones, glass sponges, sea pens, stalked barnacles, mollusks, worms and small crustaceans[133]. However, despite the large number of rare animals, a few species make up the individuals in deep sea samples. The most diverse species are macrofauna, small animals of up to 1mm in size[134].

Not all areas of the abyssal plain have similar species diversity. Species diversity of both macro- and megafauna increases with depth below the continental shelf, reaching a maximum at mid to lower bathyal regions (bathyal regions correspond to the continental slope, between the depths of 200 and 2000 meters). Diversity also decreases with increasing distance seaward on the abyssal plain. While deep-sea benthic fauna is less patchily distributed than shallow water fauna, significant aggregations of different taxa have been detected on scales ranging from centimeters to meters and kilometers. The most pronounced depth-related change in faunal composition occurs at the transition from continental shelf to continental slope (shelf-slope transition), and is probably due to differential adaptation by species to increasing environmental predictability on the upper slope. Rates of species replacement are more gradual below the shelf-slope break. The rate of environmental change is high at bathyal depths and lessens at abyssal depths[135].

Some large scale biogeographic patterns of species diversity can also be found. Local species richness in the central equatorial Pacific abyss was found to be higher than that recorded at abyssal depths in the North Atlantic[136]. Moreover, species diversity appears to decrease toward the poles[137].. For instance, deep-sea isopods, gastropods, and bivalves in the North Atlantic exhibit poleward decreases in species richness. It has been suggested that the decreased diversity at the poles may be due to greater seasonality in these regions, which produces seasonal pulses in phytoplankton production and thus in nutrients sinking to the deep sea[138]. However, a recent study has found high levels of biodiversity new to science in the deep benthos of the Southern Ocean, challenging the suggestion that deep sea biodiversity is depressed in these areas[139].

B. Trenches

There are 37 trenches, mostly distributed around the periphery of the world's oceans. Approximately 700 deep-sea species have been recorded inhabiting trenches below 6000 metres in depth. Interestingly, recent studies have suggested high density and biomass of meiofauna in the Atacama Trench, eastern South Pacific Ocean[140]. Species diversity declines with depth, especially below 8500 metres[141]. Disposal of human waste is a major potential threat to biodiversity in deepsea trenches[142].

C. Canyons

Canyons dissect continental margins in many places. They are biologically productive because they are recipients of organic matter from the continental shelf, and are characterized by currents driven by internal waves and upwelling. Canyons can be rich in species, and differ from the surrounding continental slope. The biological communities are variable in composition. An abundance of predators, such as cetaceans, are attracted to these locations[143 144 145].

D. Sponge reefs and fields

Sponge reefs, which are formed by glass sponges with three-dimensional silica skeletons, are built in a manner similar to coral reefs, by new generations growing on previous ones. Although glass sponges are found throughout the world's oceans between the depths of 500 and 3000 meters, reef-forming species occur mainly in cold, northern Pacific waters. The reefs grow at a rate of 2 to 7 cm per year and are long-lived. A 5-meter thick sponge reef in the Queen Charlotte Sound of British Columbia, Canada, is estimated to be nearly 6000 years old[146].

The three-dimensional structure of sponge aggregations provides habitat for many species, including invertebrates and commercially important fish[147 148]. Stalks of sponges offer vertical living space, extending several tens of centimeters above the sediment surface into the turbulent benthic boundary layer flow with its drifting food particles. Studies off the coast of California found that the most abundant taxa living on glass sponges included the calcareous foraminiferan *Cibicides lobatulus*, followed by the most abundant metazoan, the serpulid polychaete *Bathyvermilia* sp.[149]. The number of taxa in sponge stalk communities ranged from four to forty four per stalk, with a mean of twenty two taxa and 272 individuals. Sponge stalk communities appear to be based on detritus collected on stalk branches, which supports detritivores such as copepods and polychaetes. Mobile predators may feed on the detritivores, or on the cnidarian colonies present in the stalk communities. . Vertical species zonation can be found on stalks, with large suspension feeders, such as cnidarian colonies, living at the top, and smaller solitary epifauna and encrusting faraminifera living at the base of the stalks. This vertical zonation appears to be controlled by biological interactions among species. Sponges both in shallow and deep water are considered islands for cryptofauna, organisms dwelling in cavities[150].

Like cold-water coral reefs, sponge reefs are threatened by bottom trawling activities.

E. Cold seeps

Cold seeps are deep soft-bottom areas where oil or gases seep out of the sediments. "Seepage" encompasses everything from vigorous bubbling of gas from the seabed to the small-scale emanation of microscopic bubbles or hydrocarbon compounds in solution. Seep fluids contain a high concentration of methane. This methane can have a biological origin from the decomposition of organic matter by microbial activity in anoxic sediments, or a thermogenic origin from fast transformation of organic matter caused by high temperatures. Another important factor in some cold seeps is a high concentration of sulfide in the sediments, produced by the reduction of sulfates. Both, methane and sulfide play a major role in sustaining highly productive cold seep communities.

Cold seeps support abundant biological populations, fuelled by chemosynthesis. The chemoautotrophic bacteria of cold seeps are found both free living and in symbiotic associations with invertebrates such as tube worms, mussels and clams. For example, the ecosystem-structuring, extremely slow-growing vestimentiferan tubeworm, *Lamellibrachia* sp., were found around hydrocarbon seeps on the Louisiana continental slope. The fauna are highly specialized, of relatively low diversity, but high endemism. For instance, of the approximately twenty known cold-seeps, only four revealed the presence of seep-living fishes, which had low diversity and high endemism[151]. The large majority of seep fauna are endemic to single seep sites and to the seep ecosystem. Of the 211 species reported thus far, only 13 occur at both seeps and hydrothermal vents[152]. Although the seeps ecosystem support communities that are phylogenetically and physiologically quite similar to those at the hydrothermal vents, the latter experience rapidly fluctuating and ephemeral environments that stimulate their biological growth and development at rates far exceeding those of other deep-sea communities[153].

F. Pelagic habitats

The pelagic realm can be divided into three parts based on depth: the epipelagic zone (surface to approximately 150-200 metres), the mesopelagic zone and (approximately 200 metres to 1000 metres) the bathypelagic zone (1000 metres to the bottom of the sea). The epipelagic zone has sufficient light for photosynthesis, with the highest overall species diversity in the subtropics, followed by the equatorial belt. Deep-water production depends on this thin photosynthetic layer at the surface. The mesopelagic zone is home to communities of animals that undergo daily migrations to the surface at night to feed, returning to deeper water during the day to avoid predators. The bathypelagic zone is the least studied and least understood part of the pelagic realm. The animals differ from those in the mesopelagic zone, but are not well studied[154].

Areas of highest species richness seem to be associated with mobile boundary regions between water masses, where different faunal assemblages are mixed together. High species richness tends to be correlated with low productivity and low latitude. Regardless of latitude, the maximum species richness occurs at depths of around 1000m[155].

Numerous species of conservation concerns inhabit the open ocean. These species include marine turtles, marine mammals, seabirds, and pelagic fish predators such as sharks and tunas. These species are not evenly distributed across the open ocean, but may be concentrated temporally or spatially for feeding, reproduction or migration. Many of these species are threatened directly or indirectly by commercial fishing. Biomass of large pelagic fish predators such as sharks and tunas may have declined by over 90% in fifty years[156] although the magnitude of the decline is still being debated[157]. Deep sea fish species exploited at depths of over 600 m, such as orange roughy (*Hoplostethus atlanticus*), oreos (e.g. *Allocyttus niger, Pseudocyttus maculatus*), and macrourid rattails (e.g. *Coryphaenoides rupestris, Macrourus berglax*) have slow growth rates and high longevity compared to traditional commercial species from the continental shelf. They have low levels of sustainable yields, are vulnerable to overfishing, and have slow recovery rates[158].Moreover, seabirds, cetaceans, and marine turtle populations are often caught as by-catch, particularly by pelagic longline fisheries.

V. Priority areas for conservation

A. Some considerations relating to identifying priority areas for conservation

The method for identifying priority areas for conservation in marine areas beyond the limits of national jurisdiction will depend on the objectives of that conservation action (for example, biodiversity conservation or the rehabilitation of populations of endangered species). Once those objectives have been determined, criteria for site selection can be developed. Commonly-used criteria in national waters include (i) areas of high biodiversity (so-called “hot spots”); (ii) representative areas; and (iii) areas of critical importance for survival or recovery of endangered, threatened, rare or endemic species (or areas with significant assemblages of such species)[159]. Of these approaches, the identification of areas that are highly biodiverse, and areas that contain threatened or endemic species, are likely to be relatively expedient given that a considerable, though not exhaustive, amount of data and information already exists on species distribution.

Using the representative areas approach would first require the development of a biogeographic classification of marine areas beyond national jurisdiction. An agreed-upon classification does not exist as of yet, though it is being contemplated at the CBD and at other fora. Much still remains to be known about the biogeography of various marine ecosystems beyond national jurisdiction, though as the above text demonstrates, work in this regard has been undertaken for hydrothermal vents, and, to a lesser extent, seamounts. The recent Scientific Experts’ Workshop on Biogeographic Classification Systems in Open Ocean and Deep Seabed Areas beyond National Jurisdiction, which was held at the National University of Mexico (UNAM) in Mexico City, Mexico, from 22 to 24 January 2007, has already made considerable progress on this topic. Similar efforts are underway in some regions, for example in regards to the Southern Ocean.

The data and information available globally on the distribution of ecosystems, habitats and species of the deep sea and open ocean is improving. Large-scale initiatives, such as the Census of Marine Life will result in an improved informational basis for conservation action. At the present time, the following databases contain information about the global distribution of ecosystems and species in marine areas beyond the limits of national jurisdiction:

- The Ocean Biogeographic Information System (OBIS), which was developed as part of the Census of Marine Life. The database focuses on marine biodiversity (see http://www.iobis.org/)
- The *Sea Around Us Project* database, which provides fisheries and biodiversity information by area (see http://www.seaaroundus.org/)
- SeamountsOnline, which is an information system for seamount biology (see http://seamounts.sdsc.edu/)
- The InterRidge databases, which provide information about the known (i.e. ground-truthed) and suspected (i.e. plumes observed, vents not yet ground-truthed) vents, and about taxonomical, biological, ecological and distributional data of all species described from deep-water chemosynthetic ecosystems (see http://www.interridge.org/)
- OBIS-SEAMAP (Ocean Biogeographic Information System - Spatial Ecological Analysis of Megavertebrate Populations), which provides spatially referenced data about the distribution of marine mammals, seabirds and sea turtles (see http://seamap.env.duke.edu/)
- FishBase, which is a global information database on fishes (see http://www.fishbase.org/home.htm)
- CephBase, which is a database-driven web site on all living cephalopods (octopus, squid, cuttlefish and nautilus) (see http://www.cephbase.utmb.edu/)
- Sealifebase, which is a global information database and portal on all marine organism (see http://www.sealifebase.org)

The three types of criteria for site selection described above are not mutually exclusive. In fact, any systematic approach to identify and protect priority areas beyond national jurisdiction may include highly biodiverse areas, representative areas, areas to protect threatened species, as well as sites selected by the application of other specific criteria. These issues will be further discussed in the CBD "Expert Workshop on ecological criteria and biogeographic classification systems for marine areas in need of protection", which is scheduled to be held from 2 to 4 October 2007 in the Azores.

The text below will review previous and ongoing efforts to identify priority areas for conservation in marine areas beyond the limits of national jurisdiction applying the three above-mentioned criteria for site selection: (i) areas of high biodiversity; (ii) representative areas; and (iii) areas with high concentrations of endangered, threatened, rare and endemic species.

B. Areas of high biodiversity

It can be argued that conserving areas of high biodiversity provides the greatest benefits for the most species when resources are limited. Areas of open ocean and deep sea commonly identified as "hot spots" include seamounts and their associated biological communities[160]. They also include biologically rich and productive oceanic fronts, which attract marine life[161]. A study of worldwide patterns of tuna and billfish diversity over the past 50 years revealed distinct subtropical "hot spots" that appeared to hold generally for other predators and zooplankton. Diversity was positively correlated with thermal fronts and dissolved oxygen and a nonlinear function of temperature (~25°C optimum). Diversity in the past 50 years has declined between 10 and 50% in all oceans, a trend that coincided with increased fishing pressure and a strong El Niño–Southern Oscillation–driven variability across the Pacific. The study concluded that predator diversity shows a predictable yet eroding pattern signaling ecosystem-wide changes linked to climate and fishing[162].

Work to identify areas of high biodiversity in the open ocean and deep sea has also been undertaken in the context of the CBD. In preparation for the first meeting of the Ad Hoc Open-ended Working Group on Protected Areas, which took place in Montecatini, Italy, from 13 to 17 June 2005, the CBD Secretariat, with generous funding from the European Union, commissioned a map-based analysis of biodiversity in marine areas beyond national jurisdiction. This analysis was carried out by the *Sea Around Us Project* of the University of British Columbia in Canada. The results of the analysis are available in CBD Technical Series No. 20[163], while a policy summary can be found in document UNEP/CBD/WG-PA/1/INF/1 (Scientific Information on Biodiversity in Marine Areas beyond the Limits of National Jurisdiction)[164].

The study resulted in a comprehensive set of geographic information systems (GIS) maps of known cold-water coral and seamount areas, as well as maps of species richness of invertebrate and vertebrate groups (including exploited invertebrates and fishes, reptiles, birds and marine mammal species). Threats to biodiversity in marine areas beyond national jurisdiction were explored through maps of distribution of red-listed non-fish vertebrates. Together, these maps provide an analysis of patterns of biodiversity in marine areas beyond national jurisdiction, which were used to identify a preliminary set of priority sites for conservation as follows:

(a) Marine areas beyond national jurisdiction of the Indo-Pacific region, specifically centred on South-East Asia, northern Australia and the Tasman Sea;
(b) Seamounts beyond national jurisdiction in the north and south Atlantic, and the Southern Ocean convergence zone;

(c) Marine areas beyond national jurisdiction adjacent to islands in the southern ocean; and

(d) Small shelf areas beyond national jurisdiction in the North-East and North-West Atlantic.

Figures 5 and 6 show the results of the GIS analysis for all analyzed species (figure 5) and for marine fish and higher vertebrates (figure 6).

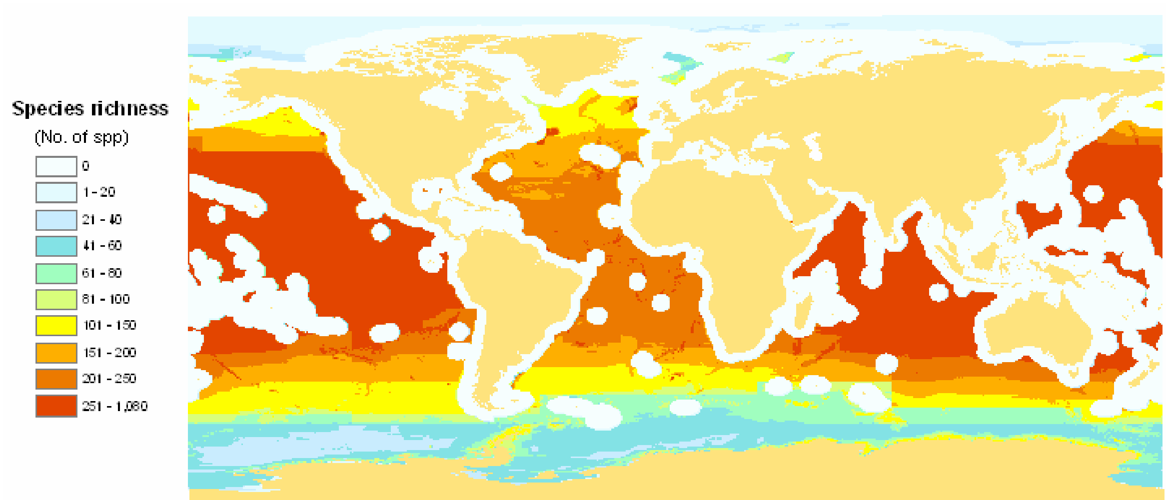


Figure 5: Map of marine species richness in areas beyond the limits of national jurisdiction (based on the ranges of exploited invertebrates and fish, and of reptiles, birds, and marine mammal species).

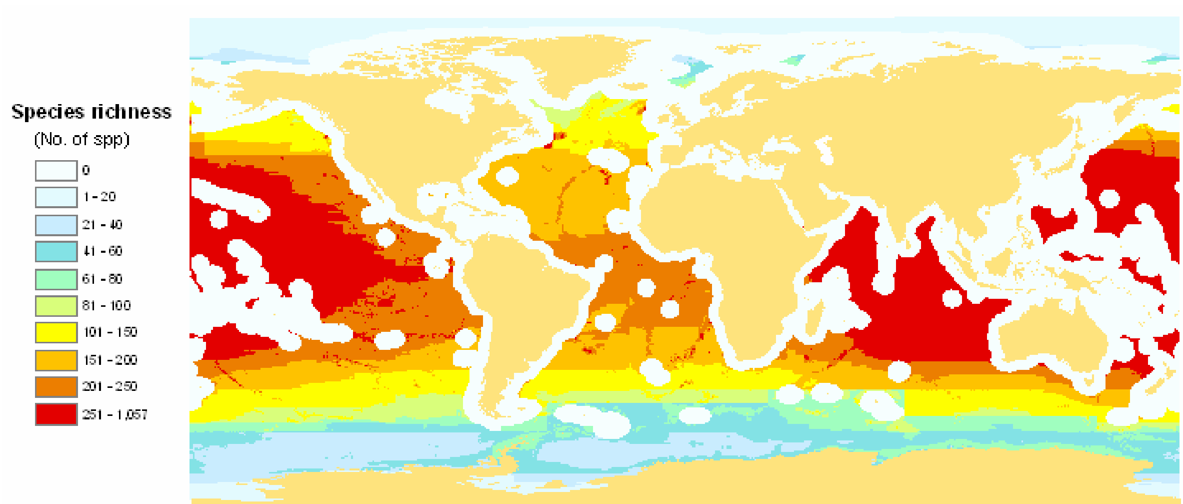


Figure 6: Map of marine fish and higher vertebrates' species richness in the high seas. Note the relatively high species richness of seamounts in the Atlantic.

C. Representative areas

Protecting examples of the entire range of ecosystems, habitats and species found in marine areas beyond the limits of national jurisdiction aims to maintain the health and resilience of these ocean areas in their entirety in the long term.

One study[165] divided the open ocean into three categories of habitats according to their predictability and dynamics as follows:

> (1) Static bathymetric features, which include reefs, shelf breaks, submarine canyons, seamounts and the lee (downstream) of islands, where primary production is often enhanced and many pelagic predators aggregate for foraging.
> (2) Persistent hydrographic features, which include currents and frontal systems. These features are recognized as regions of elevated biological activity, where seabirds, marine mammals and tunas aggregate to exploit prey concentrations. Frontal zones with their high productivity represent vital foraging habitat and migratory routes for many species including salmonids, albacore tuna, albatrosses, shearwaters, sharks and turtles.
> (3) The Ephemeral hydrographic features, which are defined by short-lived gradients in water properties. Highly mobile pelagic species find and exploit these ephemeral fronts while they persist (e.g. west coast of North America where large volumes of upwelled water are transported offshore by high-speed jets of cool and productive water).

Based on these categories, identified candidate areas for protection included the Gully, a submarine canyon in the Nova Scotian shelf with diverse cetacean assemblages; the North Pacific Transition Domain (a narrow (40^o - 44^o) region of strong temperature and salinity gradients); and the mid-section of the currents forming the North Pacific gyre[166].

Work undertaken by Greenpeace sought to identify a comprehensive and representative system of marine protected areas, which also takes into account areas with high intrinsic biological value. The data layers included in their GIS analysis were oceanographic features (upwellings and downwellings, sea surface temperature gradients), physical features (bathymetry, bathymetric complexity, seamounts, bottom sediments, ocean trenches), biological features (at sea movements of albatrosses, turtles, pinnipeds and penguins; biodiversity distribution of cetaceans; billfish and tuna species richness; billfish and tuna species density; and marine biomes). Twelve marine biogeographic zones were used. The goal was to protect 40% of all habitats in marine areas beyond the limits of national jurisdiction. The 40% figure was selected due to the large scales of oceanic processes and species movements. The set of priority sites was generated using Marxan, the most commonly applied computer programme for developing networks of marine protected areas, originally developed and applied for the rezoning process of the Great Barrier Reef Marine Park. The resulting map can be seen in Figure 7 below[167].

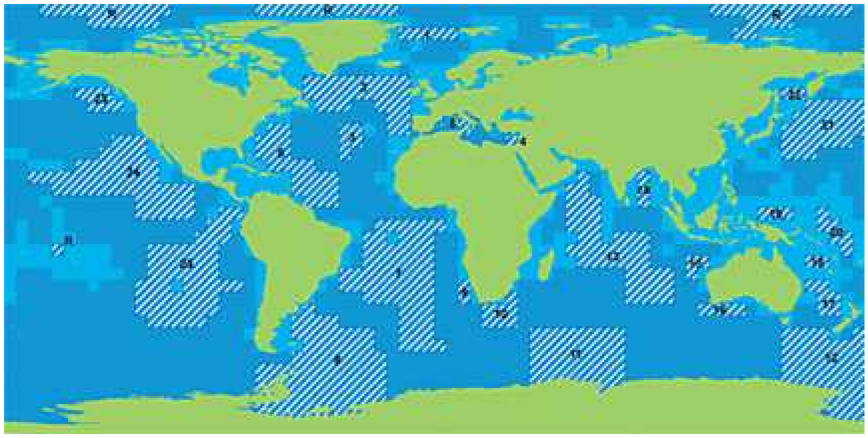


Figure 7: A proposal for a global network of marine reserves, which incorporates the following priority areas: (1) Greenland Sea (2) North Atlantic (3) Azores/Mid-Atlantic Ridge (4) Eastern Mediterranean (5) Central Mediterranean (6) Sargasso Sea/Western Atlantic (7) South-Central Atlantic (8) Antarctic-Patagonia (9) Vema Seamount-Benguela (10) South Africa - Agulhas Current (11) Southern Ocean (12) Southern Ocean - Australia/New Zealand (13) Central Indian Ocean - Arabian Sea (14) Bay of Bengal (15) Northwestern Australia (16) South Australia (17) Lord Howe Rise and Norfolk Ridge (18) Coral Sea (19) Northern New Guinea (20) Western Pacific (21) Kuroshi-Oyashio Confluence (22) Sea of Okhotsk (23) Gulf of Alaska (24) Northeastern Pacific (25) Southeastern Pacific (R) Representative Areas.

D. Areas with high concentrations of endangered, threatened, rare and endemic species

Conserving areas with high concentrations of endangered, threatened, rare and endemic species will ideally prevent such species from declining, and where decline has occurred, will assist in restoring their populations. The review of existing scientific literature above concludes that biological communities associated with seamounts and cold-water coral reefs contain rare and threatened species. The degree of endemism in these ecosystems is also thought to be high[168]. In addition, hydrothermal vents have a high degree of endemism due to the extreme environmental conditions under which organisms in these areas have evolved. Each of these ecosystem types would therefore qualify as priority areas for protection under these criteria. Moreover, protection of migratory routes, feeding or breeding grounds of endangered species such as cetaceans and marine turtles are important to effective conservation of these species.

Work to comprehensively map threatened and declining species in the North-East Atlantic has been undertaken by the OSPAR Commission. In 2003, the OSPAR Commission adopted an initial list of threatened and/or declining species and habitats, with further species and habitats added in 2004. At its Biodiversity Committee (BDC) meeting in 2003, OSPAR agreed to proceed with a programme to collate existing data on the distribution of the fourteen habitats on this list, as part of a wider programme to develop measures for their protection and conservation. Each OSPAR Contracting Party agreed to compile the relevant data for its own marine waters and submit these to the lead country (UK) for collation into composite maps on the distribution of each habitat type across the whole OSPAR area. The work has been coordinated by the Joint Nature Conservation Committee (JNCC). A web-mapping application has been developed to disseminate the data collated through the OSPAR mapping programme. The data available to date provide an initial indication of the distribution of each OSPAR priority habitat type; further data will be added as it becomes available. The maps are not yet considered to be comprehensive for the OSPAR area as a whole and may not be comprehensive within any given Contracting Party's waters. Figure 8 shows a map of seamount habitat data in the OSPAR area, while Figure 9 shows *Lophelia Pertusa* cold-water coral reefs. Other habitat types covered by the OSPAR maps include carbonate mounds, deep sea sponge aggregations, intertidal mudflats, intertidal *Mytilus edulis* beds, littoral chalk communities, maerl beds, *Modiolus modiolus* horse mussel beds, oceanic ridges with hydrothermal vents/fields, *Ostrea edulis* beds, *Sabellaria spinulosa* reefs, seapens and burrowing megafauna communities, and *Zostera* beds[169].

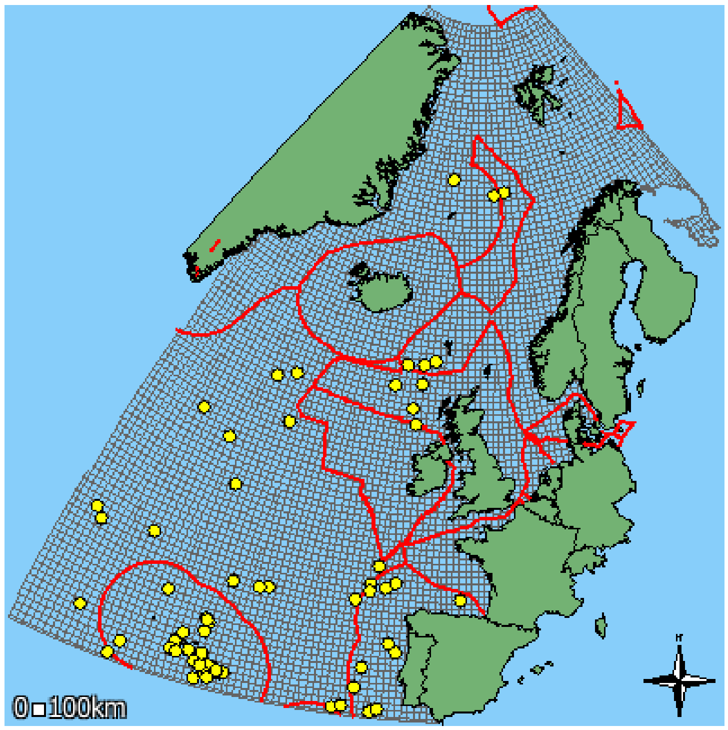


Figure 8: The distribution of seamounts in the OSPAR area (yellow dots). National maritime boundaries can be seen in red.

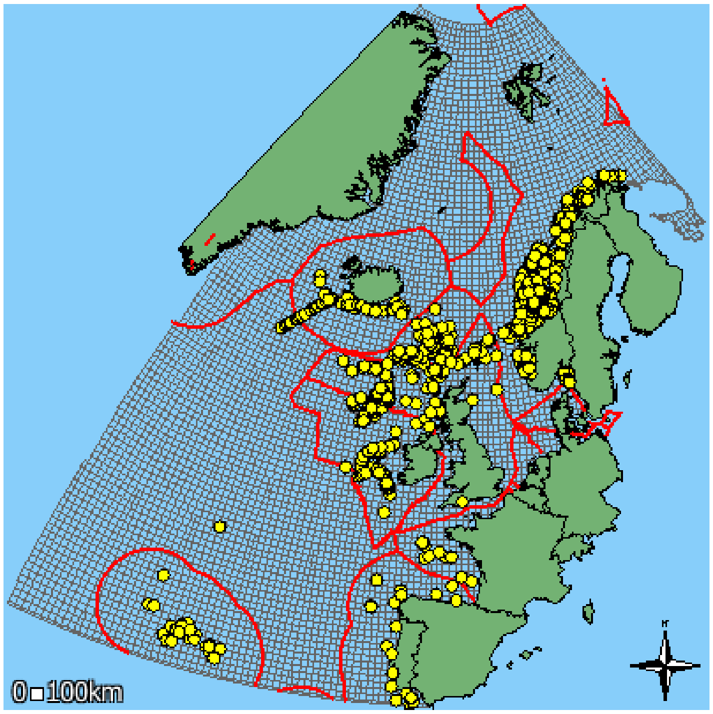


Figure 9: The distribution of *Lophelia pertusa* reefs in the OSPAR area (yellow dots). Country maritime boundaries are seen in red.

E. Some conclusions

There is clear evidence of detrimental human impacts to cold water coral reefs, sponge reefs, seamounts and pelagic habitats, supporting the need for undertaking conservation action even if our scientific understanding of these ecosystems is still imperfect. Major existing and future anthropogenic threats include fishing, notably bottom trawling, as well as climate change, mining and bioprospecting. Knowledge gaps exist in regards to our understanding of these ecosystems. These gaps include basic information about their extent and global distribution. Improved maps of the coverage of cold water coral reefs, sponge reefs, seamounts and hydrothermal vents, as well as pelagic species and processes, would greatly assist in the design of management regimes, including marine protected areas. Additionally, better knowledge of the biogeography, reproductive strategies and vulnerabilities of these ecosystems, as well as the life history and ecology of their associated species would assist in making such management regimes more effective.

All of the literature reviewed here indicates that seamounts and cold water coral reefs fit each of the three selection criteria for priority conservation areas discussed in this section by being (1) highly biodiverse, (2) representative, and (3) home to rare, endemic and threatened species. Human impacts to these ecosystems are large. Hydrothermal vent communities also score highly in both rarity and endemism. Regardless of the type of biogegraphic classification system used for marine areas beyond the limits of national jurisdiction, it is clear that it would need to include categories for each of these ecosystem types.

The studies to identify priority conservation areas discussed here also had some commonalities. All three studies included seamounts as priority areas, while both the CBD and OSPAR studies also included cold-water coral reefs. Because cold-water coral reefs in areas beyond the limits of national jurisdiction are generally associated with seamounts, the Greenpeace study also implicitly considered them amongst its priority areas. Both of the global studies (CBD and Greenpeace) included as common priorities areas in the Southern Ocean, Pacific and North Atlantic. Not surprisingly, the OSPAR work also identified seamount areas in the North Atlantic as conservation priority areas. In addition, the OSPAR work selected deep water sponge beds and hydrothermal vents amongst its priorities.

Besides benthic habitats, such as seamounts and coral reefs, some pelagic habitats and oceanographic features are also identified by scientists to be priority conservation areas. These areas include feeding grounds of pelagic predators such as tunas, sharks, seabirds and cetaceans, and their migration routines. These areas are important to the survival of these species – many of which are currently endangered or vulnerable to extinction.

A number of options to deliver on conservation objectives exist for each priority area. Such options include marine protected areas[170], applied in the context of the ecosystem approach, as well as limitations on specific activities and gear types.

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