Chapter 52. Synthesis of Part VI: Marine Biological Diversity and Habitats

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1. Biodiversity itself

Biodiversity has natural patterns globally, at all levels from phytoplankton to top predators, including fish, marine reptiles, seabirds, and marine mammals. Main factors that underlie these patterns include depth and proximity to coastline, latitude, habitat complexity and primary productivity, temperature and substrate (Chapter 34). These patterns occur on many scales from meters to full ocean basins; the mosaic structure of seafloor benthic biodiversity is often particularly strong. Some types of species are particularly widespread and/or have specialized life history characteristics, making them even more vulnerable to threats and pressures than most other species. They receive special attention in both characterizing the factors that determine their patterns of distribution and in assessing their trends and the associated pressures.

Chapter 35 highlights that although many such patterns are well documented, the ocean's diversity of species, communities and habitats is far from completely sampled. As research continues, new species, new patterns of distribution, and new relationships between components of biodiversity and natural and anthropogenic drivers are being discovered. The incompleteness of our knowledge of biodiversity and the factors that affect it means that decision-making about potential impacts will be subject to high uncertainty, and the application of precaution is appropriate. Nevertheless, as documented below, a central message from Part VI is that detrimental trends in biodiversity on many scales can be at least mitigated, and sometimes eliminated, even when knowledge is incomplete, if the available knowledge is enough to use in choosing appropriate measures and the capacity for implementation of the measures is available.

1.1 Biodiversity hotspots

Although nearly all parts of the ocean support marine life, biodiversity hotspots exist where the number of species and the abundance and/or concentration of biota are consistently high relative to adjacent areas. Some are sub-regional, like the coral triangle in the Pacific (Chapter 36D.2.3) and coral reefs in the Caribbean (Chapter 43), cold-water corals in the Mediterranean Sea (Chapter 36A) the deep seas (Chapter 36F) and the Sargasso Sea (Chapter 51). Some are more local and associated with specific physical conditions, such as biodiversity-rich habitat types. This Assessment has several chapters on these types of special habitats, such as hydrothermal vents (Chapter 45), cold-water (Chapter 42) and warm-water (chapter 43) corals, seamounts and related deep-sea habitats (chapter 51), and the sea-ice zone (Chapter 46), that highlight some of the main factors making an area richer in biodiversity than adjacent areas. Key drivers of biodiversity are complex three-dimensional physical structures that create a diversity of physical habitats (e.g., Chapters 42, 43 on corals, 44 on hydrothermal vents, 51 on seamounts) , dynamic oceanographic conditions causing higher bottom-up productivity (e.g., the North Pacific Transition Zone discussed in Chapter 36C, the eastern boundary currents discussed in Chapter 36B.1 [Benguela Current] and 36D.1 [Humboldt Current], and the ice front of the Southern Ocean (Chapter 36H.2.1), as well as the special seasonality of production in the Southern Ocean benthic communities (Chapter 36H2.4)), effects of land-based inputs extending far out to sea (36B1 [Congo, Plata and Amazon Rivers]) and special vegetation features creating unique and productive habitats nearshore (e.g., kelp forests, Chapter 47; mangroves, Chapter 48; salt marshes, Chapter 49; and offshore (Sargasso Sea, Chapter 50).

2. Bridge to trends and impacts

These habitat-based hotpots are of double concern for the following reasons. As hotspots they support high absolute and relative levels of biodiversity, unique species adapted to their special features, and often serve as centres for essential life history processes of species with wider distributions (e.g., lagoons and spawning beaches for sea turtles, Chapter 39.4.1; upwelling and similar high-productivity centres for foraging seabirds, Chapter 38.3; haul-out sites for pinnipeds, Chapter 37.3.3.2); mangroves (Chapter 48); seagrasses (Chapter 47); estuaries (Chapter 44); and cold-water corals (Chapter 42): all harbour juvenile fish which are important for fisheries in adjacent areas.

Sometimes because of the special physical features that contribute to high biodiversity, and sometimes because of the concentration of biodiversity itself, these hotspots are often magnets for human activities; therefore, many societies and industries are most active in the areas that are also biodiversity hotspots. As on land, humanity has found the greatest social and economic benefits in the places in the ocean that are highly productive and structurally complex. For example, of the 32 largest cities in the world, 22 are located in estuaries (Chapter 44), mangroves and coral reefs support small-scale (artisanal) fisheries in developing countries (Chapter 36.D.2.3, Chapters 43, 48), and commercial fishing targets fish aggregations over seamounts (Chapter 51).

These hotspots are also recognized in the scientific and technical information on classes of special habitats, such as Ecologically or Biologically Significant Areas [EBSAs] (CBD) and Vulnerable Marine Ecosystems [VMEs] (FAO), and similar classes of special habitats. These are available to policy-makers and managers in shipping, seabed mining and other sectors. The tendency for biodiversity hotspots to attract human uses and become socio-economic hotspots, with a disproportionate representation of ports and coastal infrastructure (Chapter 18), other coastal land used (Chapter 20), fishing (Chapter 11) and aquaculture (Chapter 12) is one of the major challenges to conservation and sustainable use of marine biodiversity.

3. Trends in biodiversity for species and groups of species

Superimposed on these patterns at all scales are temporal trends. Biodiversity is not static, hence both random variation and multi-year trends would occur without anthropogenic pressures (for example, Chapter 36C, Figures 8,9,10, which show substantial variation in chlorophyll and zooplankton well offshore of the main influences of land-based inputs, and Chapter 36F, Table 1A; Chapter 36D.2.1, 36G.2, 36H.2.1, 36H2.2, showing substantial variation in bottom-up productivity in the open ocean and high-latitude seas where anthropogenic nutrient inputs are not large enough to be major drivers of basin-scale trends).

Human uses of the ocean have imposed much greater temporal trends on all biodiversity components. This Assessment found evidence of these temporal trends due to human drivers in every regional assessment and for all components of biodiversity, with some emergent patterns. They are summarized below.

3.1 Phytoplankton and zooplankton

Natural regime shifts have changed baseline bottom-up productivity to some extent, and the species composition of the phytoplankton and zooplankton to a greater extent (e.g., Chapter 36C, Figures 1, 3, 4) on the change in plankton community composition. Changes in species composition of lower trophic levels have broader ecological consequences, because such changes have been found to affect pathways of energy flow to higher levels, affecting species of fish, reptiles, birds, and mammals (e.g., Chapter 36A.7 [Gulf of St. Lawrence], Chapter 36G, Figure 1, both showing changes in food-web structure; Chapter 36A.3, 36D.2.1, 36D.2.2, and 36H.2.2, all showing changes in animal community composition in response to productivity drivers).

In coastal areas, human pressures on bottom-up processes were documented in all the divisions of the ocean described in chapter 36. Scales can be local to, occasionally, that of full semi-enclosed seas; the largest effects are documented where human populations are most dense (Chapter 36A.7 [Mediterranean, Baltic and North Seas], Chapter 36C, Figure 36C-6), but local effects are even seen in high-latitude seas (Chapter 36G [Trends]; 36H.1).

Many documented cases were found where high levels of contaminants or land-based nutrient runoff dramatically reduced diversity of species (Chapter 36C, Figure 36C-1; Chapter 36E.2; see also Chapter 20) or diminished or sometimes eliminated diversity due to hypoxia (see Chapter 36C.2(c) on hypoxia; Chapters 20, 44).

Many documented cases were also found where adoption of appropriate policies to address sources, along with funding for monitoring, correcting problems at source, and when necessary clean-up of affected areas, has reversed these trends and achieved good environmental quality (examples in Chapter 36A.7 [North Sea, Baltic Sea, Chesapeake Bay]).

Further out on shelves and in the open ocean, anthropogenically driven trends in lower trophic levels were less conclusively documented *except for climate change* (examples in Chapter 36C, Figures 36C-8, 9; 36D.2.1, 36G). Documentation of effects seems to emerge more strongly as monitoring continues. When direct impacts of pressures were found, causes generally were due to changes in temperature, water masses (currents, upwelling) and seasonality (examples in Chapters 36A.2, 36B.2, Table 36B1; 36C.1, 36D.2.1, 36E.2) and acidification (Chapter 6.5.3).

A second pervasive pressure on phytoplankton and zooplankton in all parts of the ocean, from coastal embayments to open-ocean areas, are alien invasive species. Ocean physical transport processes and incidental transfer by highly migratory species have always resulted in the possibility that new species would be introduced into an area, become established, and alter energy flows and community structure. As climate change affects temperature and salinity conditions in the ocean, species also may respond with changes in range; the relatively cold-adapted species in a community withdraws towards the poles and species relatively more adapted to warmer conditions expand their range towards the poles. Both types of range changes again can affect the patterns of productivity and community relationships in the areas experiencing changes in species composition of lower trophic levels (e.g., Chapter 36D.2.2). Active, albeit unintentional, transport of species with shipping (Chapter 17) and occasionally tourism can lead to invasions of species across basins and sometimes even greater distances. It is a largely academic argument whether changes associated with natural transport processes and climate-related changes in physical ocean conditions are "invasions", but the impacts on system structure and dynamics can range from negligible to dramatic.

Cases are documented in all regions of alien species becoming established in new areas, and a portion of such invasions have caused almost complete restructuring of the plankton communities at scales from bays to semi-enclosed seas, with consequences for the biodiversity of all higher trophic levels (Chapter 36A.7 [Black Sea]; 36C, Figure 7).

3.2 Benthos

Temporal trends have been less widely documented because of the more local scale of patterns in seafloor biota. Quantifying trends requires expensive and local sampling, which has been undertaken for the most part only in rich countries, in restricted sites close to coasts, and often where problems are already thought to exist, usually due to human pressures.

In cases where appropriate monitoring has occurred, trends in benthos are commonly associated with human pressures. Causes include direct removals for harvesting

(Chapter 11), indirect impacts due to fishing gear and aggregate extraction (Chapter 36A.7 [North Sea]; 36D.2.3; Chapters 11, 42, 43 [corals], 44 [estuaries], 51 [seamounts]), and indirect effects due to pollution, sedimentation, etc. For example, loss of coral cover has been linked to catchment disturbance (Chapter 36D.3; Chapter 43), and species loss due to pollution is widespread in many estuaries (Chapter 44). Salt marshes have been drained, diked, ditched, grazed, sprayed for mosquito control, and invaded by a range of non-native species that have altered their ecology (Chapter 50). Many examples were found of high pollution, etc., altering benthic communities extensively and changing both species composition and biomass/productivity (Chapter 36A.7, 36B.4 [hydrocarbons]; 36C.2b; Chapters 20, 44). Trends in benthic populations or communities are often used as indicators for effects monitoring, because some benthos are sensitive to specific pressures and have high local patchiness of occurrence in specific response to those particular pressures.

This Assessment also contains many documented cases where adoption of appropriate policies to address sources, along with funding for monitoring, reducing the threat at source, and when necessary taking actions to remediate or restore damaged populations, communities or habitats, have reversed these trends and achieved good environmental quality (Chapter 36A.4.b, 36B.4.3, 36D). For example, coral-reef fish populations have been shown to recover within MPAs after they have been declared (Chapter 43) and management of shrimp aquaculture that prohibits clearing of mangroves and replanting of new forest has resulted in an improved condition of that habitat (Chapters 12, 48). Climate change also affects benthic biodiversity, but documentation and understanding of pathways and consequences are at an early stage (Chapter 36A.3, 36G.3).

For offshore benthos, the overwhelming pressure is the impacts of fishing gears. Trends were documented in all regions, and the commonality of these trends has led to the occasional characterization of all mobile bottom gear as a destructive fishing practice. Many types of seafloor habitats and benthic communities, particularly those comprised of soft bodied and leathery species, do show recovery from bottom trawling when the pressure is released, although just as with the fishery communities that are being exploited, full recovery may requires years to decades. During periods of disturbance and recovery the *relative* species composition is changed, as long-lived species are reduced in abundance and dominance. However, as long as recovery can commence rapidly and is secure, such perturbations are sustainable and the habitats are considered to have resilience (Chapter 36A.3, 36B.4, 36C.3.b; Chapter 11). However, some special types of habitats and benthic communities are not resilient. Pressures, causing changes to seabed structure or increased mortality of species that are more hard-bodied and that create habitat diversity through burrowing or creating three-dimensional structures, may cause large and lasting trends in the benthic community. Productivity can be reduced and recovery, if feasible at all, could take many decades to centuries (e.g., cold-water coral communities, especially on seamounts; Chapters 42, 43, 51). In such cases, spatial management to prevent impacts is the only effective option to mitigate these trends and allow recovery to commence. Some policies that protect these highly vulnerable to sensitive benthic habitats are in place for the high seas and many national jurisdictions. For example, some States and intergovernmental entities have adopted measures for the protection of seamounts and other deep water habitats within EBSAs, VMEs and MPAs, as discussed in Chapters 42 and 51. But this has not been done in most parts of the ocean, since the task of identifying such areas of particular importance to biodiversity is incomplete in some parts of the ocean. In addition, the necessary scientific and technical information is sometimes not available to the relevant States and intergovernmental organizations.

As with the plankton in the water column, invasions of alien species pose a risk of altering benthic biodiversity on scales from local and coastal to seas or large stretches of coastlines. The same processes of natural transport of reproductive propagules, range changes in response to climate-related changes in ocean conditions, and accidental transport with shipping or tourism have all been documented, with resultant major changes in benthic and occasionally pelagic community structure at scales at least of bays of hundreds of kilometres of coastline documented in all regions where sampling is adequate to detect such effects (Chapter 36A.3, 36B.4, 36C.3.b). In addition, a few cases are recorded of intentional introduction of larger invertebrates to develop new harvesting opportunities, with subsequent expansion of the species well beyond the area of introduction (such as Kamchatka crab in the Barents Sea Chapter 36A).

The shipping industry is actively seeking to improve practices and reduce risk of transferring species to new areas, and cost-effective risk-management practices are available (Chapters 17, 27). Detection of new benthic species requires intensive and often costly monitoring, for which capacity is limited in many areas. Once alien species are established, their elimination and remediation of the impacts have proven to be very difficult, costly, and rarely feasible.

3.3 Fish and pelagic macro-invertebrates

As with the other species groups, fish communities have always varied in abundance over time, sometimes by orders of magnitude, especially for small pelagic species in areas with variable oceanographic conditions (examples in Chapter 11, Chapter 36A.4, 36B, 36C, Figure 36C-4; 36D [salmon]; 36D.2.4). In several ocean basins changes in major portions of fish and invertebrate communities are well documented, and these are often related to corresponding changes in the physical ocean (Chapter 36A.4, 36C.3.a.iv, 36G.4).

Range changes of fish and macro-invertebrates in response to naturally changing ocean conditions are also documented in all regions (examples in Chapter 36A.4.4, 36C.3, 36G.4, 36H.2.3). The responses of fish populations and communities to climate change have been a particular priority for mid- and high-latitude parts of the ocean, with documented effects on productivity, timing of life history processes (e.g., Chapter 36H.5), and community structure in essentially all regions, with magnitudes of effects varying both with the life history of the species and the magnitudes and patterns of change in the oceanographic conditions (examples in Chapter 36.A.4, 36C, Figure 36C-4; 36D.2.4).

Another type of documented trends in ranges of fish and invertebrate species are invasions of non-native species (example in Chapter 36C, Figure 36C-7) almost certainly associated with shipping. Some of the invasions by large pelagic invertebrates, such as comb-jellies, have completely changed the fish community on the scale of bays, and of the entire Black Sea (Chapter 36A.7, 36C.2). Although the magnitude of the disruptions from such invasions may diminish over time due to both natural ecosystem processes and management interventions, it has not been possible to eliminate or reverse such changes quickly, if at all, and costs have been high both in terms of costs to try to control the invading species, and in foregone benefits from the disrupted fish community (e.g., Black Sea). Prevention of introductions is by far the most logical and cost-effective option, and is receiving attention from the shipping industry. Again, however, resources are needed to implement and ensure adherence to best practices.

Trends in fish populations are linked to contaminants, pollution, and particularly habitat degradation due to land-based sources. However, population-scale effects have been restricted to nearshore areas or semi-enclosed seas where contaminant, pollution and/or sediment levels are high and water quality is degraded, with many fish populations and communities particularly susceptible to reduced oxygen levels in the water due to both climate change and increased nutrient enrichment (Chapter 36A.7 [Gulf of St. Lawrence, Chesapeake Bay, Gulf of Mexico]; 36B.2, 36C and F). However, the concern exists that long before population-scale impacts of contaminants may be apparent, fish may accumulate levels of contaminants in their flesh that pose health risks for consumers (Chapters 10, 15). In addition, it was noted earlier that some specialized habitats that are hotspots for fish and invertebrate biodiversity are also particularly attractive for other human uses. Downward trends in fish populations associated with such habitat losses are documented in many coastal areas (Chapter 36A.7 [all cases]; 36F).

Regardless of the cause of habitat loss or degradation, fish populations and communities have been documented as recovering when effective remediation measures have been taken (Chapter 36.A.4, 36C, Figure 36C-11; Chapter 41). Again, however, costs of remediation have often been high, time lags long, and prevention of loss or degradation is usually the more cost-effective option, with less uncertain outcomes than remediation initiatives.

Exceeding all of these other causes of trends in fish populations and communities are the effects of fishing. Fishing necessarily changes the total abundance and size/age composition of the exploited populations, with effects increasing as bycatch rates increase and as fishing becomes more intense and more selective of only particular species and sizes. The search for levels and methods of fishing that have sustainable impacts has gone on for over a century (Chapters 10, 11). Nevertheless, overfishing has not been eliminated, and downward trends in exploited populations, sometimes to depleted levels, can be found in all regions (Chapter 36A.4, 36B.4, 36D.2.4). Estimates of the economic cost of such depletions are available (Chapters 11, 15), but ecosystem costs from the biodiversity impacts of overfishing exist as well. If genetic diversity of populations is depleted, resilience to naturally varying environmental conditions is reduced (Chapter 34; Chapter 36A.4). Also as the abundance of large fish in a community is reduced through fishing at levels that allow few fish to live long enough to reach their full potential size, any top-down structuring of community dynamics through predation is weakened, again weakening the resilience of the community to any other perturbation (Chapter 11 [ecosystem effects]; Chapter 36D.2.4). The properties of harvesting strategies that would keep effects of fishing sustainable for the exploited species and communities are generally known, and many examples show that when fisheries are managed with sustainable practices, populations can rebuild to and subsequently remain at healthy levels, although varying in response to natural perturbations (Chapter 11; Chapter 36.A.4, 36D.2.4, although recovery may take decades; e.g., 36H.4). However, management authorities must adopt sustainable policies and practices that take biodiversity considerations into account, implement them consistently, monitor population status and fishery performance effectively, and ensure compliance through a combination of stewardship, surveillance, and enforcement that is appropriate to the fishery and community of human users (e.g., Chapter 36A.6, 36H.4).

3.4 Marine Reptiles, Seabirds, and Marine Mammals

Many of the species with the greatest declines in abundance are in these groups of top predators (marine mammals, marine reptiles and seabirds); some species of all three higher taxa are assessed as at risk of extinction by IUCN (Chapters 37, 38, 39). In cases where overharvesting was a contributing factor, some of these declines have lasted for over a century (Chapters 37, 39; Chapter 36H.4). All the factors considered for the above groupings of biodiversity are also implicated in the trends in marine reptiles, seabirds and mammals.

Seabirds and marine reptiles have been particularly affected by habitat degradation, e.g., where terrestrial breeding sites were converted to intensive use by coastal industries or tourism (Chapter 39), or, particularly for seabirds, where new predators were introduced on previously isolated breeding sites (Chapter 38). Body burdens of contaminants have been implicated in reduced breeding success of several populations of pinnipeds and smaller cetaceans (Chapter 37; Chapter 20), and in a few cases this pressure alone may be sufficient to pose a risk of extinction to small populations (Chapter 36A.5; Chapter 37).

Bycatches in fishing gear are well-documented threats to populations and species in all three groups of top predators. Most types of fishing gear have been documented to pose potential threats to specific populations or species, including: mobile trawl gear for turtles and sea snakes; longlines for seabirds and turtles; suspended nets for seabirds, small cetaceans, and pinnipeds; and entanglements of whales with lines connected to traps and pots used in fishing (Chapters 37, 38, 39). Practices which mitigate these risks have been proven to be effective for many types of gear, through changes in gear design (e.g., excluder devices), fishing practices (e.g., surface deployment of longlines), and other methods. However, implementation of mitigation techniques often requires training in their use and is specific to the species, fisheries, and areas where the fishing occurs. Hence additional measures, such as periodic and area closures in areas of high bycatches, or closures of fisheries when allowable bycatch numbers are exceeded, are often applied, with or without gear-based measures (Chapters 38, 39). Downward trends in marine reptile, seabird, or marine mammal populations due to bycatch impacts can be stopped and population increases facilitated by the appropriate combination of these mitigation measures, but require expert study of the nature of the bycatch problem and evaluation of the potential effectiveness of alternative mixes of measures, monitoring of the fishery and the populations suffering the bycatch mortality, often requiring expenditures of capital, time and training in acquiring, adapting, and learning to use the tools, and appropriate surveillance and enforcement.

Not all harvesting-related mortality of marine mammals, seabirds, and marine reptiles is due to bycatches in fisheries. Directed take of marine mammals reduced many whale populations to one or a few per cent of historical populations, and recovery of these species has often been extremely slow, even after harvests were largely eliminated (Chapter 37). Directed harvests of seabirds were historically common in many areas, and are still a practice in some places that still depend on subsistence hunting and fishing (Chapters 36A.5, 36B.8, 36G.6; Chapter 38). Directed harvest of sea turtles was intensive until the early 20th century and depleted many populations, but is now prohibited in most jurisdictions, although again recovery has been slow, usually due to other pressures (Chapter 39).

Aside from directed take and bycatches, fisheries can also affect marine reptiles, seabirds and marine mammals through trophodynamic pathways (examples in Chapter 36B.8). Fisheries on small pelagic stocks have been implicated in depleting the food supply of seabirds, particularly when feeding chicks in breeding colonies (Chapter 38), and cases are documented where the discarding of fishing waste at sea has promoted large increases in populations of scavenging seabirds that in turn displace other seabirds from breeding colonies (Chapter 38). Spatial management measures and adjustments to overall harvesting levels have been successful in dealing with the first type of impact (Chapter 38), and the increasing policy dialogue about managing discard practices in fisheries (Chapter 11; Chapter 36A.5) is at least considering the implications for seabird communities.

Climate change has the potential to affect trends in all three of the types of top marine predators. Studies are being conducted on how changing ocean conditions may affect breeding and resting sites (e.g., sea-level rise and turtle and mammal breeding beaches), loss of ice cover affecting high-latitude seabirds, polar bears, cetaceans and pinnipeds, range changes of species from all groups as temperature and salinity patterns change, and indirect food web effects (Chapter 36.G.5.5, 36H and 38) . Given the long life expectancies of most of these types of species, population impacts of climate drivers may only show up gradually, but may be hard to reverse. Moreover the impacts may be non-linear once they start to be manifest, with possibly steep "tipping points", further increasing the policy and management challenges. Some interest exists in spatial management tools as a way to partially mitigate impacts of climate on these populations, but work to test and, as appropriate, implement such measures is in the early stages (Chapters 38, 39).

For all of these species groups, measures to mitigate any of the anthropogenic and climate drivers of decreasing trends in populations have opportunity costs from displacing or refraining from conducting an activity providing social and economic benefits and direct costs of deploying more expensive fishing gear, patrolling of breeding sites of turtles and mammals, etc. (Chapters 37, 39). However, the high regard in which many societies hold these types of species (Chapter 8) also provides opportunities for increasing public awareness of all marine biodiversity concerns, and building public and industry support for taking appropriate actions to address trends and ensure practices are sustainable.

4. Trends in biodiversity for habitats

In cases where habitat features make an area a hotspot for marine biodiversity, the potential for negative trends in biodiversity is greater for several different types of reasons:

– Special habitat types can host uncommon or rare species requiring the special features of these habitats for some aspects of their life histories. Their inherent rarity and high ecological specialization can make such species particularly vulnerable to impacts from human activities and changes in environmental conditions. This Assessment found examples of such vulnerable species in most habitat types examined: for example, the general importance of seagrasses for juvenile fish as well as dugongs and human activities that affect seagrass and/or water quality (Chapter 47), and salmon sensitivity to human impacts on coastal areas (Chapter 36C.5).
– Just by being rich in biodiversity, particularly high interdependencies can exist among the species in these specialized habitats. Perturbations of even a few key species in these ecosystems can affect many other species with which they have ecological relationships, spreading and sometimes amplifying the initial perturbations to produce much greater consequences for the biodiversity as a whole. Again, such vulnerabilities of the biotic community to perturbations of even a few components were found in many of the special habitats assessed in the WOA. For example, overfishing of herbivorous reef fish has resulted in decline of coral cover because of overgrowth of algae (Chapter 43).
– Areas that are biodiversity hotspots often are associated with specialized structural features of the seafloor and/or the water column for which many

species use those particular areas for some or all life history processes. If those specialized structural features are disturbed intentionally or collaterally by human activities, their ability to serve those functions for all the species depending or attracted to them is reduced, again with the potential for widespread detrimental effects on biodiversity. Some of the specialized habitats examined showed many examples of declines in biodiversity due to such alterations or elimination of the physical attributes of the habitats. For example, bottom trawling in many areas and cases of oil and gas development in some places have removed large areas of cold water corals and its associated biodiversity (Chapters 42, 51).

- By having specialized physical characteristics and by supporting many different kinds of marine life, the specialized habitats can be particularly vulnerable to some kinds of human uses (e.g., Chapter 36D.2.3). Some are activities that focus on the special physical features, such as use of high local productivity for aquaculture (for example, conversion of mangrove or other estuarine habitats; Chapters 44, 48) and/or on the high concentration of biodiversity, such as fishing or tourism (for example, coral reefs; Chapter 43). Others are activities that may not intentionally focus on the hotspot, but on the physical features and processes that result in the areas supporting high levels of biodiversity; these also result in the areas being especially exposed to collateral impacts from other human activities, such as the types of biodiversity hotspots that are areas of high land-based inputs or that support higher concentrations of coastal residents than other areas. Examples include estuaries (Chapter 44), mangroves (Chapter 48) and salt marshes (Chapter 49).

This Assessment not only found widespread evidence that specialized habitats commonly show particularly strong negative trends in components of biodiversity, it also found global spatial patterns in the types of vulnerabilities of various different types of specialized habitats.

A few of the specialized habitats were either offshore and/or deep-sea habitats (seamounts, hydrothermal vents and seeps, cold-water corals, the Sargasso Sea, high-latitude ice), where human populations and industrial activities have historically not concentrated. These are highly specialized habitats requiring particularly high adaptation by the biological community to their specialized conditions. However, in providing unique features, such as the enhanced biological productivity of seamounts and the ice edge, high three-dimensional structure of the corals, etc., the areas become biodiversity hotspots relative to adjacent areas that are not as productive. In these habitats, recovery from physical damage to the specialized habitat features and/or depletion of the biological populations is often extremely slow and uncertain, just because of the harshness of the background conditions in adjacent areas, and/or the particularly high specialization of the species to these special environments, and/or the complexity of the specialized habitat itself. Climate change poses particular threats to some of these types of special habitats, because ice melting and thermal stress are altering the special habitat features themselves (e.g., reduction in the area of Arctic sea-ice habitat (Chapter 46) caused by global warming). Also coral bleaching is widespread and has affected the quality of coral reef habitat in all areas of the oceans (Chapter 36D2.3; Chapter 43).

Fishing is the primary activity likely to be attracted to the biota at these special habitats, particularly in the deep sea. Both the complex structure of the habitats and the highly specialized fish populations may be highly vulnerable to physical damage and/or exploitation, and the slow recovery potential of much of the associated biodiversity is a particular risk (for example, cold-water coral communities on, e.g., seamounts; Chapters 42, 43). Many human activities, such as shipping lanes, undersea cables, etc., can be designed to avoid these special areas. However, as the capacity to exploit the physical resources of the deep sea increases, extractive uses may be attracted to exactly these specialized habitats (for example, species found associated with deep-sea hydrothermal vents and cold seeps; Chapter 45). The potential for increased shipping and tourism in the high latitudes is also an increasing threat to biodiversity.

The other specialized habitats are generally associated with nearshore and coastal areas (kelps and seagrasses, mangroves, salt marshes, estuaries and deltas), although low-latitude/warm-water corals may extend out onto continental shelves for many kilometres. A much wider range of human activities poses potential threats to these habitats. Many have the high vulnerability to land-based run-off discussed above (e.g., estuarine habitats), high attractiveness of their biota to directed uses, such as fishing and tourism (e.g., coral reefs) and adjacent coastal development, and of their physical features to extractive uses (for example, carbonate mining of reef rock; Chapter 43) or intentional alteration (e.g., conversion of mangrove habitat for aquaculture; Chapter 48).

The productivity of these more coastal areas is often higher, such that recovery from some types of perturbations of the biodiversity may be more rapid and secure than in off-shore, deep-water habitats (Chapter 36H). On the other hand, these specialized habitats and their biodiversity are likely to be exposed to a myriad of pressures from multiple human activities. That diversity of pressures means that the cumulative impacts on these habitats and communities can be high, even when individual pressures may be managed, and the effectiveness of management measures applied to one pressure may be affected by the nature and intensity of other pressures, e.g., salt marshes (Chapter 49). As a result, protection of these specialized habitats and their biodiversity may require complex and coordinated planning and implementation, and it may be hard to motivate single industries to bear the costs of mitigation measures if the pressures from other uses are likely to continue (illustrations from all of Parts V and VI).

In summary, this Assessment finds that specialized habitats that are also biodiversity hotspots face a potential triple threat from higher vulnerability to perturbations, higher attractiveness to many human uses, and higher challenges to recovery from perturbations if they occur. Correspondingly, evidence of degradation of habitats and communities from one, two, or all three of these factors is widespread for all habitat types and in all regions where they are found. Nevertheless, many cases exist where the threats have been adequately managed, the habitats and their biodiversity protected, and at least some recovery from past perturbations has been recorded. For example, 24 estuarine case studies reported that management has resulted in improving estuarine health (Chapter 44) and declaration of MPAs has prompted the recovery of ecosystem and fish populations in coral reefs (Chapter 43). Although the benefits of coordinated planning and management of pressures cannot be overemphasized, targeted and proactive measures can have high payoffs if even one pressure is reduced effectively (e.g., seasonal closures of fisheries to protect spawning aggregations (Chapter 11); stopping mangrove habitat conversion for aquaculture (Chapter 48)). It is important, however, to match the management tool to the particular needs of the specialized habitat; for example, limits on catches or effort in a fishery may keep a fishery sustainable at the population level, but spatial tools may need to be added if the fishery can concentrate on biodiversity hotspots causing local depletions of species serving key functions in the biotic community (illustrations from Part IV, Chapters 36, 42-51]. However, progress and even success is possible with the proper suite of measures, and the capacity to implement them.

Methods used in the assessment of the status and condition of species and habitats have undergone a rapid transformation in recent years with the advent of predictive habitat modelling (PHM). This approach has revolutionized the study of many habitats and their associated biota. For example, cold-water coral communities were virtually unknown prior to the discovery of extensive bioherms off Norway in the early 1980s, but the application of PHM enabled the discovery of a completely new habitat for scleractinians on steep submarine cliffs in 2011 and was confirmed almost immediately through field observation in the Mediterranean and Bay of Biscay (Chapter 42).

In summary, the diversity of the world's oceans is rich and dynamic, but it has been incompletely quantified, and even descriptions and inventories of marine biodiversity are incomplete for the open ocean, the deep sea and many shelf and coastal areas. Despite our incomplete knowledge, however, trends in measures of biodiversity at the scales of populations, species, communities and habitats are found almost everywhere, demonstrating that our information is sufficient to look for trends, and often to inform development of policies and management measures to address drivers of the trends. Natural processes play some role in these trends, and occasionally can be a prominent driver. However, in the majority of cases, anthropogenic drivers are the major influence on changes in biodiversity.

The nature of the human activity generating the pressure will strongly influence the scale of impacts in space and time. Some pressures, such as climate change, inherently operate at large (global) scales, others, such as fisheries, may operate at the scale of individual fisheries, but fisheries are widespread and have adversely affected biodiversity in most parts of the ocean. Other pressures are inherently more local in both operation and occurrence, such as hydrocarbon extraction and seabed mining, but they can be intensive pressures where they do occur. Moreover, it is common for biodiversity on local to basin-wide scales to be exposed to cumulative effects of multiple pressures interacting in ways that are usually poorly understood.

Certain types of species, such as marine mammals, seabirds, marine turtles, large sharks and fragile benthic taxa, such as corals and sponges, and certain types of habitats, including coral reefs, hydrothermal vents, estuaries, mangroves, and others, are both particularly sensitive to pressures from many types of human activities and attract human uses in large part because of their biodiversity characteristics. These are often the components of biodiversity showing the strongest declines over time, and thus pose particularly great conservation concern.

Notwithstanding the widespread negative trends in biodiversity and the number and ubiquity of anthropogenic pressures associated with those trends for all components of biodiversity and all types of pressures, positive examples of eliminating or mitigating pressures and reversing the unsustainable trends exist. The likelihood of success in managing threats and protecting and recovering biodiversity that has been affected increases with better knowledge of biodiversity and the pressures in the area, adoption of policies appropriate to the context, and the improvement of capacity to implement the policies effectively.