REGULAR PROCESS FOR THE GLOBAL REPORTING AND ASSESSMENT OF THE STATE OF THE MARINE ENVIRONMENT, INCLUDING SOCIOECONOMIC ASPECTS

Provisional Agenda Item 4

Progress Report to the Ad Hoc Working Group of the Whole

Note by the Group of Experts of the Regular Process

1. We have been asked to provide information to the Ad Hoc Working Group of the Whole at its meeting on 9-10 September 2020 on the finalization of the Second World Ocean Assessment (World Ocean Assessment II.

Process

2. The crucial stages in the preparation so far of World Ocean Assessment II have been as follows:

(a) ***Group of Experts:*** The Group of Experts was constituted in accordance with paragraph 287 of General Assembly resolution 70/235. We have been 19 in number, rather than the planned 25, with vacancies from the Eastern European Group and the Group of Latin American and Caribbean States. These vacancies have placed added tasks on those participating.

(b) ***Pool of Experts:*** The pool of experts has been constituted with 791 members. The appointments of National Focal Points by 67 States have greatly facilitated this.

(c) ***First round of Regional Workshops:*** An initial structure for World Ocean Assessment II was developed by the Group of Experts. This proposed structure was discussed in a first round of five regional workshops, at which the outcomes of WOA I, were outlined recent regional assessments reviewed and priorities for the region identified for incorporation into this assessment. With the assistance of the host governments and (in one case) the Intergovernmental Oceanographic Commission, the five workshops were held in:

(i) Lisbon (Portugal) in September 2017 for the North Atlantic Ocean and adjacent seas;

(ii) Auckland (New Zealand) in October 2017 for the South Pacific Ocean;

(iii) Comboriú (Brazil) in November 2017 for the South Atlantic Ocean;

(iv) Bangkok (Thailand) in November 2017 for the North Pacific Ocean; and

(v) Zanzibar (United Republic of Tanzania) in December 2017 for the Indian Ocean and adjacent seas.

(d) ***Approval of Outline:*** In the light of the output of the first round of regional workshops, the draft outline was substantially revised. The Ad Hoc Working Group of the Whole approved the Outline at its tenth meeting in February/March 2018.

(e) ***Creation of writing teams:*** Writing teams were constituted for each chapter and sub-chapter, including members of the Group of Experts as Lead or Co-Lead Members. A range of methods was adopted for forming the writing teams: some members were drawn from the workshops where the chapters were discussed; others were added as a request for nominations in specific fields to the Pool of Experts; others responded to general requests to all experts in a particular field who were members of the Pool of Experts. The composition of these writing teams was approved by the Bureau of the Ad Hoc Working Group. Not all of those invited to become a member of a writing team agreed to do so, or indeed responded at all. Two of the writing teams had face-to-face meetings. Others worked through teleconferences or correspondence.

(f) ***Second round of regional workshops:*** A second round of regional workshops focused on developing chapters, as well as considering the overall approach to the Assessment.

These were held in:

(i) Koror, Palau, in August 20a18, for the North Pacific Ocean where the following chapters were considered: Chapter 6 (species biodiversity), Chapter 7 (habitat biodiversity), Chapter 10 (nutrient inputs), Chapter 13 (erosion and sedimentation), Chapter 14 (coastal and marine infrastructure), Chapter 15 (capture fisheries), Chapter 25 (invasive species), and Chapter 29 (marine spatial planning);

(ii) Valetta, Malta, in August 2018, for the North Atlantic Ocean and adjacent seas where the following chapters were considered: Chapter 6 (species biodiversity), Chapter 8 (human society and the ocean), Chapter 11 (liquid and atmospheric inputs), Chapter 15 (capture fisheries) and Chapter 26 (marine genetic resources);

(iii) Odessa, the Ukraine, in October 2018, for the North Atlantic Ocean and adjacent seas where the following chapters were considered: parts of Chapter 6 (species biodiversity: marine plants and macroalgae), parts of Chapter 7 (habitat diversity: kelp forests and algal beds, seagrass meadows and the Sargasso Sea), Chapter 17 (seaweed harvesting and use), Chapter 11 (liquid and atmospheric inputs), Chapter 15 (capture fisheries), Chapter 22 (renewable energy sources) and Chapter 23 (marine transportation).

(iv) Bali, Indonesia, in November 2018, for the Indian Ocean where the following chapters were considered: Chapter 4 (drivers), parts of Chapter 7 (habitat biodiversity: tropical and subtropical coral reefs, cold water corals, Chapter 8 (human society and the ocean), Chapter 14 (coastal and marine infrastructure), Chapter 15 (capture fisheries), Chapter 21(anthropogenic noise), and Chapter 24 (tourism and recreation);

(v) Doha, Qatar, in November 2018, for the Indian Ocean where the following chapters were considered: several parts of Chapter 7 (habitat diversity), Chapter 19 (seabed mining), Chapter 20 (hydrocarbon exploration and extraction) and Chapter 31 (overall benefits);

(vi) Accra, Ghana, in December 2018, for the South Atlantic Ocean where the following chapters were considered: Chapter 3 (scientific understanding), Chapter 10 (nutrient inputs), Chapter 13 (erosion and sedimentation) Chapter 24 (tourism and recreation) and Chapter 31 (overall benefits);

(vii) Guayaquil, Ecuador, in December 2018, for the South Pacific Ocean where the following chapters were considered: Chapter 5 (chemical and physical state), Chapter 9 (climatic pressures), Chapter 12 (solid waste), Chapter 16 (aquaculture), Chapter 17 (seaweed harvesting and use), Chapter 28 (cumulative impacts) and Chapter 30 (management approaches).

(g) ***Peer review:*** After the writing teams had produced draft chapters, these were reviewed by at least two peer reviewers for each chapter approved by the Bureau of the Ad Hoc Working Group and amended by the writing teams in the light of the comments of the peer reviewers. Chapter 1 (Summary) and Chapter 2 (Approach to the Assessment) were, exceptionally, prepared by the Group of Experts collectively.

(h) ***First draft of World Ocean Assessment II:*** The whole of the draft chapters were then reviewed by the Group of Experts at its meeting in March 2020. The full draft of World Ocean Assessment II was then circulated on 20 April 2020 to Member States for review.

(i) ***Revision of first draft:*** The Member States made 2,747 comments on the first draft. These were considered by the writing team for each chapter, who prepared draft responses and amendments. These draft responses and amendments were then reviewed by the Group of Experts. This should have been done at a face-to-face meeting. Because of the COVID-19 situation, the review had to be done at a virtual meeting over six days (3 – 10 August 2020). Since the members of the Group of Experts were spread over 14 time zones, four hours a day could be used for these virtual sessions, with some members staying up until midnight or later and another getting up for a 6:00 am start.

(j) ***Subsequent steps:*** The finalized text and responses were submitted b y the secretariat to the Bureau of the Ad Hoc Working Group and circulated to Member States on 17 August 2020.

3. There is now a period for Member States to raise outstanding issues on the revised draft. According to the Revised Timetable and Implementation Plan, this should end by 14 September 2020, when World Ocean Assessment II is due to be sent for translation into the official languages of the United Nations other than English (in which, of course, the drafts have been prepared). At the same time, the numbering of the chapters of the Assessment will be rationalized to take account of the mergers of several chapters (the initial numbering has been maintained up to this stage, in order to simplify reference to comments and responses).

4. Thereafter, the Ad Hoc Working Group of the Whole is due to consider World Ocean Assessment II on 6 November 2020 for submission to the General Assembly.

5. The preface to World Ocean Assessment II by the Joint Coordinators notes that most of the work of preparing the Assessment had been completed before the outbreak of the COVID-19 pandemic, but that this pandemic will have significant implications for human uses of the ocean. Some material has therefore been added on initial information on these implications, especially to Chapter 8C (Maritime industries).

6. In the past, delegations to the Ad Hoc Working Group of the Whole have asked about the distribution of members of the Pool of Experts and the writing teams among the various global regions. The present situation is as follows:

REGION	MEMBERS OF THE POOL OF EXPERTS	NUMBER OF CONTRIBUTORS TO CHAPTERS*	NUMBER OF CONTRIBUTIONS TO THE WORK OF WRITING TEAMS†
Africa	87	21	25
Asia/Pacific	128	34	44
Eastern Europe	19	5	6
Latin America and the Caribbean	134	33	51
Western Europe and Other	423	197	250
TOTAL	791	290	376

* The number of contributors is given rather than the number of members of writing teams because some experts, although designated as members of writing teams, did not actually make any contribution.

† Some members of the Pool of Experts were members of more than one writing team.

Substance

7. World Ocean Assessment II will, of course, speak for itself on the state of the marine environment, including socioeconomic aspects. It may be helpful, however, to draw attention to the keynote points that have been identified.

8. Chapter 1 (Summary) highlights the following keynote points for the Assessment as a whole:

(a) Understanding of the ocean continues to improve. Innovations in sensors and autonomous observation platforms have substantially increased observations of the ocean. Regional observation programmes have expanded with better coordination and integration.

(b) Some responses to mitigating or reducing pressures and their associated impacts on the ocean have improved since the First World Ocean Assessment (WOA I).1 These include expansion and implementation of management frameworks for conserving the marine environment, including the establishment of marine protected areas and, in some regions, improved management of pollution and fisheries. However, many pressures from human activities continue to degrade the ocean, including important habitats including for example, mangroves and coral reefs. Pressures include those associated with climate change; unsustainable fisheries, including illegal, unreported and unregulated (IUU) fishing; introduction of invasive species; excessive inputs of nutrients and hazardous substances, including plastics, microplastics and nanoplastics; increasing amounts of anthropogenic noise; and ill-managed coastal development and extraction of natural resources.

(c) Quantification of the impacts of pressures and their cumulative effects continues to be lacking. A general failure to achieve integrated management of human uses of coasts and the ocean is increasing risks to the benefits humans receive from the ocean, including food safety and security, material provision, human health and wellbeing, coastal safety and maintenance of key ecosystem services.

(d) Improving management of human use of the ocean to ensure sustainability will require improved coordination and cooperation to ensure capability development in regions where it is lacking, innovations in marine technology, integration of multidisciplinary observation systems, implementation of integrated management and planning and improved access to, and exchange of, ocean knowledge and technologies.

9. We attach at the annex to this note a compilation of all the keynote points from the various chapters.

ANNEX

World Ocean Assessment II

Compilation of Keynote Points

Part 1: Summary

Chapter 1: Overall Summary

- Our understanding of the ocean continues to improve. Innovations in sensors and autonomous observation platforms have substantially increased observations of the ocean. Regional observation programmes have been promoted and have enabled better coordination and integration of efforts.

- Some aspects of addressing pressures on the ocean have improved since WOA I. These include the implementation of management frameworks for the conservation of the marine environment, including the establishment of marine protected areas and improved management of stressors such as pollution from sewage and fisheries in some regions. These efforts have seen improvements in the status of populations of some species, for example, a number of species and populations of marine mammals and marine reptiles.

- However, many pressures from human activities continue to degrade the ocean, including important habitats such as mangroves and coral reefs. Pressures include those associated with climate change; unsustainable fisheries, including illegal, unreported and unregulated (IUU) fishing; introduction of invasive species; excessive inputs of nutrients and hazardous substances, including plastics, microplastics and nanoplastics; increasing amounts of anthropogenic noise; and ill-managed coastal development and extraction of natural resources.

- A general failure to achieve integrated management of human uses of coasts and the ocean and their associated impacts makes the cumulative effects of these pressures worse. This is increasing risks to the benefits humans receive from the ocean, including food safety and security, human health, coastal safety and maintenance of key ecosystems.

- There remain many gaps in our understanding of the ocean. Filling these gaps will require improved coordination and cooperation to ensure capability development in regions where it is lacking, innovations in marine technology, integration of multidisciplinary observation systems, and improved access to and exchange of ocean knowledge and technologies.

Part 2: Introduction

Chapter 2: Approach to the Assessment

- The Second World Ocean Assessment (WOA II) sets out to update WOA I by providing an understanding of changes that have occurred in the global ocean since 2010 and associated trends.

- The present Assessment also provides an overview of understanding of some aspects not fully covered in WOA I, such as inputs of anthropogenic noise, marine hydrates, cumulative effects, marine spatial planning and management approaches.

- The Assessment follows a modified approach to the drivers-pressures-state-impact-response (DPSIR) framework, supported through a series of workshops aimed at identifying region-specific information and input to the Assessment, a peer-review process and a process of review by States.

Chapter 3: Scientific Understanding of the Ocean

- Innovations in technology and engineering in sensors and autonomous observation platforms have substantially increased observations of the ocean and allowed for those observations to be collected at finer temporal and spatial resolutions.

- The networking and coordination of regional observation programmes has been promoted and has enabled better coordination and integration of efforts and standardization and/or harmonization of observation methods.

- Global disparities in understanding and knowledge gaps at continental regional levels remain, particularly across Oceania, Africa and South America.

- Most observation networks do not incorporate the economic, social and cultural aspects of the ocean and, as a consequence, there is a lack of focused, sustained and publicly accessible observations of these aspects of marine systems in standardized formats at regional and global scales.

PART 3: DRIVERS OF CHANGE IN THE MARINE ENVIRONMENT

Chapter 4: Drivers

- Drivers that have the greatest influence on the marine environment and its sustainability are: (i) population growth and demographic changes; (ii) economic activity; (iii) technological advances; (iv) changing governance structures and geopolitical instability; and (v) climate change.

- The relationships between drivers and pressures (and their impacts) are complex and dynamic, with interlinkages between drivers leading to cumulative interactions and effects of pressures.

- Drivers vary regionally as a result of global variability in population distribution and demographics, the degree of economic development, technological capacity and the uneven effects of climate change and, as a result, human activities and pressures vary globally; most notable differences are between temperate and tropical regions and developed and least developed regions.

- Integrated frameworks, within which scenarios can be explored that include changes to populations and economies, governance structures and the effects of climate change on maritime industries and the environment that are multisectoral and therefore provide “whole of system” approaches, are needed for identifying sustainable ocean use.

PART 4: CURRENT STATE OF THE MARINE ENVIRONMENT AND ITS TRENDS

Chapter 5: Trends in the Physical and Chemical State of the Ocean

- Ocean warming, together with land ice melt, are the main causes of the accelerating global rise in the mean sea level.

- Global warming is also affecting many circulation systems. The Atlantic Meridional Overturning Circulation (AMOC) has already weakened and will most likely continue to do so in the future. The impacts of ocean circulation changes include a regional rise in sea levels, changes in the nutrient distribution and carbon uptake of the ocean, and feedbacks with the atmosphere.

- More than 90 per cent of the heat from global warming is stored in the world’s oceans. The oceans exhibit robust warming since the 1950s from the surface down to 2000m. The rate of ocean heat content has more than doubled since the 1990s as compared with long-term trends. Ocean warming can be seen in most of the global ocean, with a few regions exhibiting long-term cooling.

- The ocean shows a marked pattern of salinity changes during the multi-decadal observations, with surface and subsurface patterns providing clear evidence of a water cycle amplification over the ocean. This manifests in enhanced salinities in the near-surface, high-salinity subtropical regions, and freshening in the low-salinity regions such as the West Pacific Warm Pool and the poles.

- An increase in atmospheric carbon dioxide levels, and a subsequent increase in carbon in the oceans, has changed the chemistry of the oceans to include changes to pH and aragonite saturation. A more carbon-enriched marine environment, especially when coupled with other environmental stressors, has been demonstrated through field studies and experiments to have negative impacts on a wide range of organisms, particularly those that form calcium carbonate shells, and alter biodiversity and ecosystem structure.

- Decades of oxygen observations allow for robust trend analyses. Long-term measurements have shown decreases in dissolved oxygen concentrations for most ocean regions and the expansion of oxygen-depleted zones. A temperature-driven solubility decrease is responsible for most near-surface oxygen loss, though oxygen decrease is not limited to the upper ocean and is present throughout the water column in many areas.

- Total sea ice extent has been declining rapidly in the Arctic, but trends are insignificant in the Antarctic. In the Arctic, the summer trends are most striking in the Pacific Sector of the Arctic Ocean, while, in the Antarctic, the summer trends show increases in the Weddell Sea and decreases in the West Antarctic sector of the Southern Ocean. The spatial distribution of the changes in sea ice are attributed to changes in wind and ocean currents.

Chapter 6: Trends in the biodiversity of main taxa of marine biota

Chapter 6A: Plankton (Phytoplankton, Zooplankton, Bacteria and Viruses)

- Unicellular microbes dominate marine life in terms of their abundance and diversity and plankton food webs sustain most of the ocean's biodiversity. Nutrient cycling is driven by microbial food webs fuelled by photosynthetic picoplankton, while fisheries and the biological pump are supported primarily by metazoan food webs fuelled for the most part by diatoms and microbial food webs.

- Marine phytoplankton account for ~ 50 per cent of the Earth's primary production, oxygen supply and N2-fixation and for > 90 per cent of dimethyl sulphide (DMS) emissions to the atmosphere. Diatoms and photosynthetic picoplankton account for most primary production.

- Climate-driven upper ocean warming and associated increases in vertical stratification and decreases in inorganic nutrient supplies to the euphotic zone are likely to result in decreases in phytoplankton productivity and cell size, increases in the flow of energy through microbial food webs relative to metazoan food webs, decreases in export productions to the deep ocean and decreases in fish landings. A decrease in export production would reduce the capacity of the oceans to absorb CO2 which would accelerate warming of the global atmosphere.

- Climate-driven ocean acidification may impact the abundance and distribution of calcareous plankton (coccolithophores, foraminifera and pteropods) but, to date, only the pteropod Limacina helicina has been shown to be impacted under natural conditions in the ocean.

- Current global ocean observations do not explicitly monitor marine plankton biodiversity and its environmental parameters (e.g., upper ocean warming and acidification, dissolved oxygen concentration, turbulence, nutrient supplies, abundance of higher order predators, fishing pressure) on global or regional scales with sufficient resolution in space and time to provide accurate estimates of plankton diversity. Measures to address this deficiency through the development of an integrated observing system of ocean life as a component of the Global Earth Observing System of Systems should be an immediate and high priority of the community of nations.

Chapter 6B: Marine Invertebrates

- As of 2019, 153,434 marine benthic invertebrate species have been described globally.

- 10,777 new marine benthic invertebrate species have been described since 2012; at the same time biodiversity is declining globally at rates unprecedented in human history, creating the potential for species extinction before they have been described.

- 43 per cent of the Earth's surface is deep sea, where around 95 per cent of species remain undescribed.

- Temperature increase, physical impact to the seabed, coastal use, threat from invasive alien species and pollution are the main pressures to benthic invertebrates.

- Large areas of the globe, including areas beyond national jurisdiction, still lack effective, adequate long-term monitoring and/or protection.

- Despite new research contributions regarding many important ecosystem processes, functions, goods and services, huge knowledge gaps exist in understanding how reductions in benthic biodiversity impact on human well-being and ecosystem dynamics.

Chapter 6C: Fish

- Mobilization of existing data and development of tools and open, global repositories provide a global picture of the diversity of 17,762 species of marine fishes, including 238 species described since the WOA I.

- Knowledge of the biodiversity of marine fishes exceeds that of many other marine taxa but further improvements in taxonomic and biosystematic infrastructure will be required to obtain a complete inventory.

- Over half of known marine fish species have had their conservation status assessed, with approximately a third of these assessments occurring since WOA I.

- Of those fish species with conservation assessments, around 6 per cent of bony fishes are threatened or near threatened with extinction, rising to almost 50 per cent of elasmobranchs, both species of Coelacanth and 10 per cent of chimeras.
- Capacity for documenting and understanding marine fish diversity continues to grow, but significant gaps remain for some important components (e.g. mesopelagic fishes) and in predicting responses to multiple simultaneous stressors.

Chapter 6D : Marine Mammals

- Marine mammals continue to provide significant economic and cultural contributions to coastal communities. Globally, they play ecosystem engineering roles that benefit all marine ecosystems.
- The number of species for which a conservation status is available has increased, with 36 per cent of baleen whale species increasing in abundance. Overall, the status of coastal dolphins is deteriorating, with one species close to extinction.
- Fisheries bycatch continues to be a dominant conservation threat. Indirect threats such as habitat alteration, including overfishing of prey, noise pollution, ship strike and disturbances are becoming more prevalent, particularly in coastal zones.
- There is apparent increasing consumption of illegally hunted and bycaught small marine mammals in some coastal developing nations.

Chapter 6E: Marine Reptiles

- Changes in conservation status of marine turtles since WOA I is highly variable, with some populations experiencing positive growth rates, while others have experienced catastrophic declines.
- Most sea snake and marine iguana populations remain at similar conservation status to WOA I, though huge data gaps remain.
- The main threats to marine reptiles remain similar to WOA I. Bycatch is the most significant threat, although targeted harvesting, marine pollution, habitat loss, coastal development, disease and climate change are also key threatening processes.

Chapter 6F: Seabirds

- Since WOA I, the global conservation status of seabirds has worsened, continuing a long-term trend.
- Thirty-one per cent of species are now threatened with extinction, up from 28 per cent in 2010.
- Pressures related to fishing (by-catch and prey depletion) are now affecting more species, while pollution is affecting fewer species (although marine debris, especially plastics, is an emerging threat with poorly understood consequences).
- Invasive alien species and climate change also remain major causes of seabird decline and affect similar numbers of species as in 2010.
- Current capacity and resources limit the ability to assess population-level consequences and implications for ecosystem services of existing and emerging threats.

Chapter 6G/H: Marine Plants and Macroalgae

- An extinction risk of about 90 per cent of mangrove, seagrass and marsh plant species has been determined; 19 per cent of mangroves, 21 per cent of seagrass species and one marsh plant species are on the International Union for Conservation of Nature (IUCN) Red List of Threatened Species.
- Among macroalgae, 1 species of red seaweed from Australia, *Vanvoorstia bennettiana*, is listed as extinct and 21 are listed as threatened, 9 of which are red and 12 of which are brown. The number of macroalgal species assessed and reported on the IUCN Red List is less than 1 per cent of the total number of species listed in the Ocean Biogeographic Information System (OBIS). All the threatened species are endemic to the Galapagos Islands. This highlights the knowledge gap with regard to macroalgae.

• In terms of macroalgal endemism, Antarctica ranks highest, with 33 per cent endemics, followed by South America (22 per cent) and the Red Sea Large Marine Ecosystem (LME) (9 per cent).

• New techniques such as genomics have been developed for species identification and for elucidating phylogenetic relationships and, as a result, the number of species is expected to rise, especially for macroalgae but, due to uneven human and infrastructure capacities among regions, some regions will be less studied than others.

Chapter 7: Trends in the state of biodiversity in marine habitats

Chapter 7A/B: Biogenic Reefs, Sandy, Muddy and Rocky Shore Substrates

• Reefs and sandy, muddy and rocky shores support high biodiversity and a wide range of ecosystem services that benefit human populations.

• There is a gap in interdisciplinary research and participative governance to promote resilience and provide for the sustainable development of these habitats.

• Due to their cultural significance and importance for tourism worldwide, they are in a unique position to serve as flagship habitats to promote the role of the ocean in the implementation of the 2030 Agenda for Sustainable Development, including Sustainable Development Goal (SDG) 14.

Chapter 7C: Intertidal Zone

• The intertidal zone encompasses many different habitats on the coasts around the world.

• A large proportion of humans live in proximity to the intertidal zone.

• Human activities impact the intertidal zone directly, through coastal modification, and indirectly, through climate change.

•Despite our close relationship with intertidal habitats, key knowledge gaps remain and taxonomic infrastructure is needed in developing countries to resolve baseline data.

Chapter 7D: Atoll and Island Lagoons

• The health of atolls and island lagoons and sustainability of communities that depend on them for their livelihoods are challenged by many environmental limitations and stressors, often exacerbated by human actions.

• Islands on atolls and other coral reefs are low-lying and very vulnerable to impacts of climate change, particularly sea level rise; individual islands are likely to respond in different ways.

• Climate change threatens coral reef ecosystems with implications for habitability of islands. Of particular significance are: coral bleaching; erosion and inundation of islands; carbonate dissolution; and the effects of extreme events, such as tropical storms.

• Developed urban atoll islands are increasingly dependent on engineering solutions, which need to integrate “hard” and “green/blue” options to avoid unintended impacts, whereas less populated rural island communities rely on the health, productivity and function of surrounding marine and coastal ecosystems.

Chapter 7E: Tropical and Sub-Tropical Coral Reefs

• Global declines in coral cover continue, primarily due to increasing ocean temperatures associated with climate change, extractive activities, pollution and sedimentation and physical destruction of coral reefs.

• The frequency of disturbances caused by heatwaves, storms, flooding and crown-of-thorns starfish outbreaks has increased as recovery time between disturbances has decreased.

• Understanding of the value of ecosystem services provided by coral reefs is improving, not only in terms of direct economic benefits (market use value) but also through less tangible use, such as aesthetic value.

• Substantial knowledge gaps remain, particularly on responses of coral reef communities to climate change and how these responses might influence human use of coral reefs.

•Projections of future states suggest continued decreases in coral abundance, reef-associated fishes and the architectural complexity of reef frameworks.

Chapter 7F: Cold Water Corals

• Cold water corals are common features along continental margins and mid-ocean ridges, and on seamounts worldwide, providing habitats for numerous species and mitigating climate change through carbon sequestration.

• Threats from fishing, offshore oil drilling, deep-sea mining, waste deposition and climate change continue. Some efforts to curb deep-water bottom trawling and establish marine protected areas have been effective. However, because of the slow-growing and long-lived nature of cold water corals, recovery from anthropogenic impacts can take decades to centuries.

• Cold water corals are highly sensitive to elevated temperatures and deoxygenation, but recent work suggests they are relatively resilient to ocean acidification, particularly when nutritional resources are plentiful.

• Future projected declines in cold water coral abundance will result in reductions in habitat availability for commercially significant species, reduce carbon sequestration in deep waters, eliminate potential genetic resources and have an effect on numerous Sustainable Development Goals (SDGs), particularly SDG 14, but also SDGs 2, 10, and 12.

Chapter 7G: Estuaries and Deltas

• Human populations, fisheries, shipping and recreation/tourism exert pressures on the resources and health of estuaries and deltas.

• Interactions between multiple stressors on estuary and delta habitats are inadequately understood.

• A key gap remains in identifying measurable indices of ecosystem health and human well-being across diverse estuarine and deltaic systems.

Chapter 7H: Kelp forests (merged with Chapter 6G/H)

Chapter 7I: Seagrass Meadows

• Seagrass meadows are continuing to decline at alarming rates, particularly where they are in conflict with human activities.

• Marine ecosystems are being reconfigured as a result of climate-driven changes in species distributions, with some species projected to be functionally extinct by 2100.

• Blue carbon sequestration will play a role in mitigating climate change impacts.

• Successful long-term solutions around conservation and restoration will require a balance between social, economic and environmental drivers.

Chapter 7J: Mangroves

• Despite their ecological and socioeconomic importance, mangrove forest areas have been decreasing annually.

•Although deforestation continues in most areas, afforestation and the replanting of mangroves on all continents have partially decreased the speed of mangrove area loss from ~2 per cent per year to <0.4 per cent per year.

• Increasing human population density and unplanned development in the coastal zone are the main threats to mangrove forests.

• Global climatic change, such as rising sea levels and temperature, is causing expansion of mangroves towards the poles and landward into salt marsh in some areas.

• Local actions and international agreements have helped mangrove conservation, but bureaucracy and the lack of commitment on the part of local, state and national government and local communities have limited their success.

Chapter 7K: Salt Marshes

• Salt marshes, as defined in WOA I are intertidal, coastal systems that are regularly flooded with salt or brackish water and dominated by salt-tolerant plants adapted to regular or occasional immersion by tides.

• Salt marshes serve as nesting, nursery and feeding grounds for numerous species of birds, fish, molluscs and crustaceans, including some commercially important species.

• Salt marshes are very effective “blue carbon” sinks, as they sequester carbon dioxide (CO_2) due to their high levels of primary production and low rates of decomposition, but they can also produce greenhouse gas emissions.

• Salt marsh area is declining globally despite protective measures in many areas.

• Sea level rise poses the biggest threat, and marshes must either increase their elevation to keep pace with rising seas or move inland. Since WOA I, this has changed from a future issue to a present reality. If coastal development or restrictions on sediment supply and delivery make either adjustment difficult, salt marshes are converted to mudflats and open water.

• Many marshes worldwide are already showing signs of waterlogging, which indicates that they are not elevating rapidly enough.

• Some evidence suggests that marshes with certain invasive plants may be better able to keep up with sea level rise.

Chapter 7L: Continental Slopes and Submarine Canyons

• Continental slopes represent 5.2 per cent of the ocean, with over one-fifth of the slope comprised of submarine canyons; they are critical transition areas between the continental shelf and the deep sea; and are important for carbon burial, and a key habitat for species of ecological and economic importance.

• Strong vertical hydrographic gradients, complex geomorphic features and fluxes of fluids from the sea floor make communities of organisms in slope and canyon settings highly heterogeneous.

• Hundreds of newly discovered methane seep, coral and sponge habitats enhance biodiversity and host novel interactions with surrounding sediments.

• Canyons can be hotspots of biological activity but their communities do not always differ from those on adjacent slopes which are also highly productive; slope and basin sediments can be an archive of historical information about climate effects on biodiversity.

• Naturally occurring oxygen minimum zones reveal that biodiversity is highly sensitive to oxygenation and suggest climate-induced global expansion of low oxygen zones on slopes will reduce biodiversity; projected declines in pH and food supply are likely to affect cold water coral ecosystems.

• Due to their proximity to shore, slopes and canyons are subject to expansion of deep-water oil and gas activities, offshore energy installations, bottom fisheries and, potentially, minerals mining activities, as well as to increasing contamination, including litter and mine tailings from land.

• Exploration has accelerated discovery of new ecosystem functions and services, including novel productivity and carbon transfer mechanisms, nursery grounds, contaminant and waste transfer. However, most canyons and slope areas remain largely unexplored, with major questions about species ranges, ecological connectivity, bentho-pelagic linkages, sensitivity to climate and direct disturbance being still unanswered, particularly in the southern hemisphere and along African and South American margins.

• Better integration of climate science, connectivity research, conservation biology and resource management, combined with increased taxonomic and geographic expertise, will improve the distribution of knowledge, technology, analytical tools, and methodologies required to advance global understanding and promote sustainability of slope and canyon ecosystems.

Chapter 7M: High-Latitude Ice

• High-latitude ice habitats are characterized by high, but geographically variable, declines in sea-ice extent as a consequence of climate change.

• The loss of Arctic sea-ice habitat and Antarctic ice shelves allows expansion of both pelagic and benthic species into the newly open water environments.

- `In general, however, many ice-dependent species are decreasing in abundance and spatial distributions, particularly in the Arctic.

- Decreasing sea-ice extent in the Arctic provides increased opportunities for a range of human activities, including fishing, navigation and hydrocarbon exploration, with positive implications for several Nations Sustainable Development Goals (SDGs).[1]

- Many of these activities, however, will remain marginal for some time as a seasonally ice-free Arctic is not expected until later this century.

- Decreasing sea ice will, however, reduce local community access to subsistence hunting opportunities.

Chapter 7N: Seamounts and Pinnacles

- Seamounts and pinnacles are common topographic features of the global ocean.

- Sampling effort has increased in recent years but, overall, only a small percentage of seamounts has been sampled in detail.

- Limited sampling, combined with high environmental variability among seamounts, constrains biodiversity knowledge.

- Fishing, and bottom trawling in particular, constitutes the single greatest threat to seamount ecosystems but marine debris/litter, climate change and potential seabed mining are additional concerns. However, initiatives to protect seamounts are increasing.

- Recent time-series research on deep seamounts shows limited, if any, recovery of stony coral communities even 15–20 years post closure.

Chapter 7O: Abyssal Plains

- The abyss lies between 3 and 6 km water depth and covers more of the Earth's surface than all other habitats combined.

- This is the first World Ocean Assessment chapter dedicated to the abyss, covering biodiversity, regional differences, biogeography and changes and impacts as a result of natural stressors and anthropogenic activity.

- Abyssal biodiversity is not well understood, and many gaps exist in our understanding of abyssal evolution, biogeography and organism distributions, connectivity and responses to changing conditions.

- Abyssal taxonomic knowledge is fragmentary, mostly as a result of difficulties in sampling this vast and remote area, and hence limited research effort, thus limiting the advance of scientific knowledge.

- Most abyssal environments support the processes that drive deep-sea and global ecosystem functioning and are intensely linked to surface production and pelagic processes

- The abyss, while remote, is affected by climate change and anthropogenic impacts.

Chapter 7P: Open Ocean

- Global warming is already impacting the open ocean and marine heatwaves are likely to increase in frequency and strength in the future.

- Climate change induced changes in the open ocean biological pump will alter the ocean's ability to take up anthropogenic carbon.

- Deoxygenation of the open ocean is already leading to habitat compression for some pelagic species with subsequent impacts on fisheries.

- Increasing fluxes of plastic litter from the land are impacting open ocean ecosystems.

- A critical knowledge gap exists for deep pelagic (e.g. mesopelagic and bathypelagic) environments as they are poorly sampled and understood.

Chapter 7Q: **Ridges, Plateaus and Trenches**

- Most recent studies of ridge biology address chemosynthetic environments (see Chapter 7R of the present Assessment).

- Climate change models show that bathyal environments will suffer a reduction in pH, which will affect benthic communities.

- Ridges, rises, plateaus and banks are under human pressure arising from existing and potential exploitation of resources, while evidence of pollution in trenches is accumulating.

- The vulnerability of those ecosystems to human pressures has triggered both increased societal awareness and new regulations.

Chapter 7R: Hydrothermal Vents and Cold Seeps

- Hydrothermal vents and cold seeps have uniquely complex habitats and communities, diverse endemic species, high biomass and productivity supported by chemosynthesis.

- These ecosystems are sources of biotechnological and biomedical innovation.

- They have a significant role in global ocean processes, sequestering carbon dioxide (CO_2) and methane, and contributing to surface ocean productivity through iron export.

- In the last five years, explorations using new tools to detect water column signals located tens to hundreds of vent fields and cold seeps.

- Resource exploration (polymetallic sulphides and methane hydrates) and the need to map and protect vulnerable habitats and species support recent studies.

- The International Seabed Authority has signed three more mineral exploration contracts since 2014 encompassing vent sites in the Indian and Atlantic Oceans.

- Vulnerable marine ecosystems (VMEs) and marine protected areas (MPAs) in exclusive economic zones (EEZ) and in areas beyond national jurisdiction (ABNJ) protect some vents and seeps.

- Knowledge gaps include spatial and temporal patterns, impacts from direct disturbance, changes to deep-water circulation, deoxygenation, warming and acidification.

- Ocean warming triggering gas hydrate dissociation is a leading threat for seeps.

- Capacity-building is a priority, particularly in island States.

Chapter 7S: Sargasso Sea

- The Sargasso Sea is a high seas area, internationally recognized as a fundamentally important part of the global ocean because of its role in climate regulation and its unique ecosystems.

- The Bermuda Atlantic Time-series Study (BATS) continues to collect observations enabling inferences on the impact of climate change in the ocean and increased understanding of ocean processes. Continuation of this fundamental long-term research is essential.

- Mass blooms and strandings of *Sargassum* since 2011 are due to a previously rare form of *Sargassum natans*. These are causing major socioeconomic problems for the region and may also adversely impact unique oceanic *Sargassum* communities.

- The importance of the Sargasso Sea as a spawning area for both the European and American eels has been emphasized by satellite tracking of adults and widespread larval surveys. Increased understanding of the ecology of commercial tuna and tuna-like species and awareness of the use of the area by endangered and threatened species is increasing the need for ecosystem-based fishery management.

- Most changes and threats, including climate change, overfishing of eels, plastic pollution and mass blooms of *Sargassum* are externally driven. These increasing threats will adversely impact the contribution of the Sargasso Sea to Sustainable Development Goal (SDG) 14 to conserve and sustainably use the oceans, seas and marine resources for sustainable development and, therefore, other SDGs.[1]

- Despite its importance, the increasing threats to the Sargasso Sea demonstrate the weakness of the current system of ocean governance in addressing cumulative impacts of human activities on the high seas.

Chapter 8: Trends in the state of human society in relation to the ocean

Chapter 8A: Coastal communities (merged with Chapter 8C)

Chapter 8B: Human Health as Affected by the Ocean

- There are both health benefits and risks to living near the sea. The advantages can include good air quality, exercise opportunities and ready access to food from the sea, which itself has health benefits.

- The ocean presents health risks from tsunamis, storms and tropical cyclones. Human activities have also enhanced risks from contaminated food from the sea, sea level rise and increased risks of storms and cyclones from climate change.

- Chemical contaminants, harmful algal blooms and pathogens pose health risks, particularly in estuarine and coastal waters where there is adjacent urbanization and/or recreational usage.

- Novel pollutants, such as nanomaterials and microplastics, are a cause for concern.

Chapter 8C: Maritime Industries

- About 40 per cent of the world's population lives in the coastal zone, that is, within 100 km of the coast. This proportion is increasing.

- Coastal communities play a key role in supporting all components of the ocean economy, as well as a range of social and cultural values, and all forms of coastal and marine management and governance. While coastal communities often have to deal with physical and social vulnerabilities, they are crucial contributors to conservation, to marine hazard responses and to climate mitigation and adaptation.

- The ocean supports a wide range of economic activities, including the harvesting of food, shipping, seabed mining, offshore hydrocarbon exploration and exploitation, tourism and recreation, use of marine genetic resources, production of freshwater by desalinization and production of salt. These various economic activities are steadily growing in scale. Separate Chapters in Part 5 of the present Assessment, on trends in pressures on the marine environment, give more detail on areas not discussed in depth here.

- Shipping carries about 90 per cent by volume of international trade, which makes it fundamental to the global economy. It is recovering from the economic crisis of 2008–2011.

- Globally, tourism continues to grow at about 6 per cent a year. Coastal tourism represents a substantial proportion of overall economic activity for many countries, especially small island developing States.

- Desalinization continues to grow in importance, particularly in the Middle East, North Africa and small island States. Sea salt production also continues at a generally steady level, but accounts for only about one-eighth of total salt production.

Chapter 8D: Maritime Cultural Services (merged with Chapters 30 and 31)

PART 5: TRENDS IN PRESSURES ON THE MARINE ENVIRONMENT

Chapter 9: Pressures from Changes in Climate and Atmosphere

- ***Extreme climate events***. Marine heatwaves and tropical cyclones are shown to be increasing in severity due to human activities and are having an impact on natural and human systems. Extreme El Niño events have been observed but, because they occur infrequently, a human influence has not been detected. All three phenomena are projected to increase in the future with the severity of impacts also increasing, but such increases can be reduced by climate change mitigation efforts.

- ***Sea level rise***. The alarming observed pace of sea level rise, combined with increasing storminess and coastal urbanization, has resulted in amplified susceptibility of coastal cities to erosion, flooding and increased the need for substantial hard infrastructure investments and the incidence of proposals for relocation. The result is a diminished capacity of human use and enjoyment of natural coastal areas.

- ***Ocean acidification and deoxygenation***. Under more acidic or deoxygenated conditions, both in nature and in the laboratory, marine organisms that support ecosystems and human livelihoods and nutrition typically respond poorly. Marine habitats become simplified, many long-lived organisms die, and a few resilient species proliferate. Less serious damage to life supporting ecosystems would be possible under lower emissions scenarios.

- ***Other physical and chemical properties***. Changes in ocean temperature and salinity induced by climate change and human activities are affecting marine ecosystems by changing marine primary production, decreasing the ecological value of coastal ecosystems and changing the distribution of marine species. Human well-being and economy are consequently affected.

Chapter 10: Changes in Inputs to the Marine Environment of Nutrients

- During the course of the twentieth century, inputs of N and P to coastal ecosystems via river runoff and atmospheric deposition increased due to anthropogenic inputs derived primarily from the use of synthetic fertilizer, combustion of fossil fuels, and municipal wastes.

- Ecological responses to increases in anthropogenic nutrient inputs to the coastal ocean include increases the severity and extent of coastal hypoxia, acidification and toxic algal events. The process is a serious threat to the health of coastal ecosystems and their capacity to provide services valued by society.

- It is projected that anthropogenic N production will increase by nearly a factor of two during the first half of the twenty-first century. Aggressive actions to reduce anthropogenic inputs of N and P to the coastal ocean will be needed to reduce the extent and risk of coastal eutrophication during the course of the 21st century.

Chapter 11: Changes in Liquid and Atmospheric Inputs to the Marine Environment from Land (including through Groundwater), Ships and Offshore Installations

Persistent organic pollutants

- Persistent organic pollutants (POPs) continue to be a global issue, persisting at concentrations likely to cause biological effects.

- POPs are detected in remote locations far from their source of production - this includes the deepest parts of the ocean and the polar regions.

- The number of POPs continues to increase and thus the mixtures to which biota are exposed become more complex, making determination of the likelihood of individual or population effects ever more challenging.

Metals

- There is a critical need to develop and expand coastal metal time series globally.

- Trends in metal concentrations vary regionally, though most show levelling of dissolved metals and a slight increase in metals in higher trophic organisms.

Radioactivity

- There have been no significant nuclear accidents affecting the ocean since WOA I.

- Generation of electricity from nuclear power plants continues to increase - by about 5 per cent globally between 2013 and 2018. Improved technology may be reducing discharges of many radionuclides, but those of tritium are probably increasing in line with electricity generation. Tritium is, however, only weakly radioactive.

- Published information on recent discharges of radioactive substances to the ocean from nuclear power plants and nuclear reprocessing plants is not available except for the North-East Atlantic and its adjacent seas. In that area, discharges to the ocean of radioactive substances from nuclear power plants and nuclear reprocessing plants continue to decline.

- On the basis of information available, there is no reason to think that adverse impacts of radioactivity on the ocean have become significantly worse since the situation reported in WOA I.

Pharmaceuticals and personal care products

- Hundreds of pharmaceuticals and personal care products (PPCPs) have been detected in the ocean, including in the Arctic and Antarctic.
- Novel analytical techniques have been developed for non-target analysis of PPCPs and their transformation products in the marine environment.
- A "watch list" of PPCPs should be formulated and implemented into long-term international, national and regional monitoring programmes to serve as a scientific data basis for assessing the status of PPCPs in the ocean.

Shipping

- There is a global decreasing trend regarding shipping accidents leading to oil spills (over 7 tonnes).

Hydrocarbons

- Knowledge gaps exist on the long-term impact of discharged produced water from oil and gas exploration.
- An increased rate of offshore platform decommissioning poses a challenge for the marine environment.

Chapter 12: Changes in Inputs and Distribution of Solid Waste in the Marine Environment (other than Dredged Material)

- Plastics now represent up to 80 per cent of marine litter or marine debris.
- A large part of marine litter is from land-based sources, and results from poor waste management practices, especially in some rural and developing regions.
- Marine debris is present in all marine habitats and affects the environment, and marine organisms through entanglement in, ingestion of and rafting through marine litter.
- Increasing trends, mainly in remote and unpopulated areas that are receiving marine litter.
- Time series data are needed to assess and monitor the impact of marine litter and of micro- and nanoplastics.
- Although a decreasing trend is observed, there is a need to harmonize reporting on dumping at sea.

Chapter 13: Changes in Erosion and Sedimentation

- Coastal erosion can lead to coastal retreat, habitat destruction and loss of land resulting in significant negatecological and socioeconomic impacts on the global coastal zone.
- Sediment supplies and transfers determine coastal morphology and dynamics, which influence the nature and health of coastal ecosystems. Human activities affecting sediment dynamics, both on the coast and on land, modify the naturally occurring patterns of erosion and sedimentation.
- Globally, abstraction or interruption of sediment supplies to the coast has been increasing, through upstream dams, as well as coastal and river sand mining. Reduced sediment supply enhances shoreline retreat.
- Results of recent investigations reveal that, at approximately 15 per cent of all sandy beaches worldwide, the shoreline has been retreating with an average trend of 1 m/year or more over the last 33 years, while almost half of the world's sandy beaches are stable.
- Many areas of observed historical shoreline advance are related to reclamation and impoundment by coastal structures. These human activities modify coastal dynamics, typically resulting in downdrift erosion.
- Climate change impacts, including sea level rise and potential increases in the frequency and intensity of severe tropical and extra-tropical storms, can accelerate coastal erosion. Human activities have focused impacts on deltas and adjacent coasts, with potentially severe impacts on other coastal systems such as sand spits, barrier islands and wave-dominated estuaries.

Chapter 14: Changes in Coastal and Marine Infrastructure

- Coastal and marine infrastructures realize human activities and materialize use functions of the system of coastal and marine natural resources.
- Infrastructures can influence natural systems and their use, and create pressures and conflicts or favourable conditions.
- The years 2010 to 2020 saw a continuing trend of more newly developed and a renovation or upgrade of marine and coastal infrastructure.
- The most significant changes are coastal and offshore land reclamation, especially in East Asian countries, for new coastal urban development, and roads, coastal defence structures and port and harbour and touristic facilities.
- Depending on the case, coastal and marine infrastructures may cause substantial damage or reduce damage to coastal and marine ecosystems.
- The new coastal infrastructure development approach, known as "blue infrastructure development" can harmonize coastal protection/development and habitat/ecological protection, thereby reducing ecological damage.
- Coastal and marine infrastructure development in general has created new opportunities for coastal dwellers and supported sustainable socioeconomic coastal development.

Chapter 15: Changes in Capture Fisheries and Harvesting of Wild Marine Invertebrates

- Worldwide, from 2012–2017, estimated landings in marine capture fisheries increased by 3 per cent to 80.6 million metric tons (MT) and estimated gross landed value increased by 1 per cent to 127 billion United States dollars (in 2017).
- Many of the world's capture fisheries have continued to be plagued by overexploitation, vessel subsidization, ineffective management, discards, habitat degradation, abandoned, lost, or otherwise discarded fishing gear (ALDFG), and illegal, unreported or unregulated (IUU) fishing.
- In 2017, the World Bank estimated annual net losses to global capture fisheries of 88.6 billion dollars for the year 2012 (expressed in 2017 dollars) due to overfishing. If allowed to persist indefinitely, such annual losses would constitute a lost natural capital asset worth trillions of dollars.
- The great majority of small-scale, artisanal or subsistence fishery (SSF) landings were destined for local human consumption, thus contributing importantly to food security and nutrition in developing States, but IUU fishing posed a threat to many people who depended upon fisheries for protein, exacerbating poverty, augmenting food insecurity and thwarting efforts to achieve SDG targets.
- Promisingly, scientific stock assessments and management have been shown to lead to more sustainable outcomes, and management reforms have been predicted to lead to rapid (decadal-scale) rebuilding of stocks. These are important lessons as the world looks to unexploited and as-yet unregulated fisheries in the Polar regions and the deep ocean (the mesopelagic zone).
- The adverse effects of climate change on the oceans were expected to hinder sustainable outcomes, and fishery-dependent developing States, particularly their SSFs, were highly vulnerable to climate-related changes.

Chapter 16: Changes in Aquaculture

- Global aquaculture production in 2017 (animals and plants) was recorded as 111.9 million tonnes, with an estimated first sale value of 249.6 billion United States dollars. Since 2000, world aquaculture no longer enjoys the high annual growth rates of the 1980s and 1990s (10.8 and 9.5 per cent, respectively). Nevertheless, aquaculture continues to grow faster than other major food production sectors. Annual growth declined to a moderate 5.8 per cent during the period 2001–2016, although double-digit growth still occurred in a small number of countries, particularly in Africa, from 2006 to 2010. Fish produced by this rapidly growing sector are high protein, and contain essential micronutrients, sometimes essential fatty acids, which cannot easily be substituted by other food commodities.

• The United Nations predicts that the global population will reach 8.5 billion in 2030. This will inevitably increase the pressure on food sectors to increase production and reduce losses and waste. Production increases must be able to ensure sustainability, given the context in which key resources, such as land and water, are likely to be scarcer and in which the impact of climatic change will intensify. Aquaculture is no exception. Success in achieving the long-term goal of economic, social and environmental sustainability of the aquaculture sector, to ensure its continued contribution of nutritious food to keep the world healthy, will depend primarily on continued commitments by governments to provide and support a good governance framework for the sector. As the sector further expands, intensifies and diversifies, it should recognize relevant environmental and social concerns and make conscious efforts to address them in a transparent manner, backed by scientific advice

Chapter 17: Changes in Seaweed Harvesting and Use

• About 80 per cent of world seaweed production is for direct human consumption.

• World production of seaweeds has steadily risen over the five-year period (2012–2017) at a rate of about 2.6 per cent annually or about 1.8 million tonnes (wet weight) per year due to demands mostly from farming or aquaculture with an estimated value of about 12 billion United States dollars.

• China remains the top supplier, followed by Indonesia. The Republic of Korea replaced the Philippines as the third largest producer, due mostly to the series of typhoons that have hit the latter's farming areas.

• Major species farmed are still the carrageenan-producing reds, *Kappaphycus alvarezii* and *Eucheuma* spp., while the alginate-producing brown kelps are the major species harvested.

• Production has been affected negatively in typhoon-vulnerable areas.

Chapter 18: Changes in desalinization and in the production of sea salt (merged with Chapter 8C)

Chapter 19: Changes in Seabed Mining

• New technologies to reduce the impacts on the marine environment are now envisaged for exploitation of placer deposits, traditionally mined by dredging. Prospects for mining phosphorite deposits have faced opposition from stakeholders and are waiting to become a reality.

• Deep-sea mineral deposits considered--polymetallic sulfides, polymetallic nodules, and cobalt-rich crusts--are being considered for mining, with 30 contracts for exploration given by the International Seabed Authority (ISA).

• One driver for these activities is that deep-ocean mineral resources contain diverse rare and critical metals needed to support the implementation of Sustainable Development Goals adopted by the United Nations in 2015.

• Environmental impacts from exploitation of deep-water mineral resources is a scientific community focus and transparent and inclusive regulations are being developed to avoid, reduce, and mitigate impacts to ecosystems.

• A lack of information on biodiversity, connectivity, and services exists and a robust collection of baseline ecological data is necessary for predictions related to the future deep-sea mining activities.

• The ISA has considered different financial models for commercial mining of polymetallic nodules. Incomes must first compensate the Common Heritage of (Hu)Mankind and provide funding for environmental and regulatory monitoring and remediation. Metal prices are difficult to predict, which can create significant risk that may delay commercial mining.

• Deep-sea mineral resources are typically located far from human communities and social impacts may be less than for terrestrial mining. However, significant concerns exist about loss of biodiversity and ecosystem services, including the role of the deep sea in climate regulation. These legitimate concerns constitute the basis for a "social license to operate".

Chapter 20: Changes in Hydrocarbon Exploration and Extraction

• Since WOA I, the offshore oil and gas sector has continued to expand globally, particularly in deep and ultra-deep waters. The use of tension leg platforms, spars and Floating Production, Storage and Offloading systems (FPSOs) are key to such expansion.

- In the next decade, frontier regions such as the eastern Mediterranean, east coast of South America (Brazil and Guyana), and west coast of Africa could be the major growth drivers for offshore oil and gas exploration and production.
- There is an upward trend in decommissioning activity, particularly in mature regions such as the North Sea and Gulf of Mexico.
- Exploration and production practices continue to evolve to minimize potential impacts on the surrounding environment.
- Creation of regulatory capacity to effectively manage offshore resources, especially in frontier regions, requires significant commitment and long-term institutional investment.
- Technological innovation and sophisticated industrial capability built over a century by the offshore oil and gas sector are benefiting the emergence of the marine renewable energy (MRE) industry.
- A major thrust of the offshore hydrocarbon sector since WOA I is technological advancement in analysing offshore exploration and production data to enhance operational and financial efficiencies.

Chapter 21: Trends in Inputs of Anthropogenic Noise to the Marine Environment

- The main anthropogenic noise sources in the ocean include vessels, industrial activity, including seismic exploration and renewable energy development, and sonar.
- Anthropogenic noise levels vary across space and time, primarily driven by levels of human activity and propagation characteristics in the region. However, it is worth noting that noise does not persist once the sound source has been removed from the environment.
- Areas with the highest level of anthropogenic noise are those with heavy industrial use, such as the Gulf of Mexico, the North Sea and the North Atlantic Ocean.
- Areas where anthropogenic noise is expected to increase include the Arctic, as the area opens to shipping, and Africa, as investment in the region increases.
- Understanding of the impacts of anthropogenic noise on marine biodiversity is increasing with associated increased recognition of the need to monitor and possibly reduce noise entering the marine environment.

Chapter 22: Developments in Marine Renewable Energy Sources

- The offshore wind sector is expanding globally to regions with no utility-scale installations at present. The use of floating platforms is a step change for the industry to open up large areas with deeper waters.
- In the next decade, Asia and the United States of America could be major growth drivers for offshore wind power development and installation.
- Current wave, tidal and ocean projects have not yet achieved full commercialization at utility scale. However, at the global scale there is high wave energy potential.
- Progress in energy storage could make a significant contribution in the development of offshore wind power and other marine renewable energy (MRE).
- Proper siting of MRE projects could minimize conflicts with other ocean uses and have positive impacts on the marine environment.

Chapter 23: Developments in marine transportation (merged with Chapter 8C)

Chapter 24: Developments in tourism and recreation activities (merged with Chapter 8C)

Chapter 25: Invasive Species

- Globally, about 2,000 marine non-indigenous species (NIS) have been introduced to new locations via human-mediated movements. A few of these have economic value, but most have had negative ecological, socioeconomic or human health impacts, with increased trade and climate change, biological invasions will likely increase.

• NIS can pose significant biosecurity and biodiversity hazards. Large-scale NIS surveys with broad taxonomic coverage are lacking, as are studies documenting the range of potential impacts in recipient environments.

• Major invasion vectors (i.e. ballast water, biofouling, aquaculture, trade in live organisms, canals) lack characterization and understanding at global and many regional levels and, with the exception of ballast water/sediment management, regulation is lacking. The multi-vector nature of both NIS introduction and spread requires comprehensive and integrated legal instruments with robust enforcement to mitigate the movement of species.

• Better tools are urgently needed to assess the potential risks of NIS under changing environmental conditions and to identify the native species and ecosystems most at risk. This is especially true for species with no previously documented invasion history.

Chapter 26: Developments in Exploration and Use of Marine Genetic Resources

• Marine genetic resources (MGRs) continue to be the focus of an expanding range of commercial and non-commercial applications.

• Rapidly sinking sequencing and gene synthesis costs and swift advances in the metabolic engineering and synthetic biology fields within the biotechnology sector have rendered scientists less reliant on physical samples, and increasingly dependent on the exponentially expanding public databases of genetic sequence data.

• Sponges and algae continue to attract substantial interest for the bioactive properties associated with their natural compounds.

• Within the context of the Sustainable Development Goals,[1] capacity-building issues persist, with entities in a handful of countries conducting the majority of research and development associated with MGRs.

• Multiple international processes with relevance to MGRs are in progress, most notably on biodiversity in areas beyond national jurisdiction (BBNJ), with an Intergovernmental Conference working towards concluding a potential BBNJ treaty covering access and benefit sharing for these resources.

Chapter 27: Marine Hydrates – a Potentially Emerging Issue

• Marine hydrates (mainly methane hydrates) exist in large quantities in the ocean where gas is available, pressure is high enough and temperature is low enough, mainly on the continental slopes.

• Concern has been expressed about the climatic risks from the sudden release of large amounts of methane from marine hydrates. However, this hypothesis is not widely supported at present and is not mentioned in the recent special report of the Intergovernmental Panel on Climate Change on the ocean and cryosphere in a changing climate.

• Areas of gas seepage in the deep sea associated with gas hydrates host a very rich biodiversity supported by chemosynthesis.

• Initial successes have recently been noted by China and Japan in producing methane from marine methane hydrates.

Chapter 28: Cumulative Effects

• Increasing pressures on marine environments from multiple sources are resulting in biodiversity loss, habitat damage and fragmentation and disease.

• Effective implementation of ecosystem-based management requires an appreciation of how and to what extent human activities and natural events interact and affect different ecosystem components and their functions, and identification of solutions to prevent and/or mitigate the pressures being caused by these interactions.

• Over the past two decades, many frameworks for assessing these interactions, known as cumulative effects, have been developed using different approaches and terminologies and applied at differing scales.

• Although approaches vary, cumulative effect assessments (CEAs), aimed at advising management and planning conducted to date, have mostly involved three main steps: (i) collation of information on the intensity and footprint of activities that may be affecting marine ecosystems; (ii) identification of the responses of ecosystem components; and (iii) identification of management measures that could be applied in response.

• Despite their increase in use, assessments focused on particular regions, areas or values that follow the same general steps outlined above are largely lacking from areas outside Europe and North America.

• This geographical bias in implementation of CEAs highlights clear knowledge and capacity gaps, and the need for the development of approaches that: (i) can be implemented in regions where data is lacking; (ii) are easily implementable; and (iii) produce outputs that can be readily understood and translatable to decision-making processes, particularly in developing countries.

PART 6: TRENDS IN MANAGEMENT APPROACHES TO THE MARINE ENVIRONMENT

Chapter 29: Developments in Marine Spatial Planning

• The growing scale of human activities and the associated impacts on the marine environment mean that conflicts are increasingly occurring between different uses of the ocean. Marine spatial planning is an effective way of resolving such conflicts.

• Over the past two decades, marine spatial planning has been instituted to a growing extent in many jurisdictions, in a variety of forms: some are simply zoning plans; others include more complex management systems.

• The legal status of marine spatial planning varies between jurisdictions: in some it is guidance to be taken into account; in others it has legal force constraining specific management decisions.

• In general, marine spatial planning has been most effective where it has been developed with the involvement of all relevant authorities and stakeholders.

Chapter 30: Developments in Management Approaches

• The ecosystem approach is one of the most significant approaches to ocean management, consisting of the environmental, social and economic management of human interactions with oceans and coasts at multiple scales (i.e. transboundary, regional, national and local).

• While there is general agreement that the ecosystem approach provides an effective framing of ocean management, further research and capacity-building is needed to realize its full potential benefits across the oceans.

• Management has two different levels of governance, namely, decision-making processes that provide a framework to make decisions and implement policy focused on the conservation and sustainable use of marine resources; and management tools (area-based and non-area based) that can be used to regulate and modify human activity in a particular system.

• The implementation of the 2030 Agenda for Sustainable Development[1] requires management grounded in the ecosystem approach in order to achieve the integrated set of global priorities and objectives set out in its Sustainable Development Goals (SDGs). This will allow for the integration of the interactions, benefits and trade-offs between the SDGs and support achievement of each of the ocean-related targets.

• There is a growing trend towards incorporating the cultural values of the ocean into management.

Chapter 31: Developments in the Understanding of Overall benefits from the Ocean to Humans

• Ocean resources provide main sources of livelihoods to millions of people across the globe. They also provide a wide range of ecosystem services or benefits including oxygen production, carbon storage, genetic resources and general life support services. However, these ecosystem services from marine and coastal ecosystems are deteriorating at an alarming rate.

• Human activities are directly or indirectly affecting ecosystem services and thus can reduce or erase benefits that otherwise would be provided. As human activities in the marine environment are expected to increase in the future, in particular in areas beyond national jurisdiction, they will not only exert growing pressure on natural resources, but may also threaten marine biodiversity and thus the benefits people obtain from ecosystem services.

- International law as reflected in the United Nations Convention on the Law of the Sea[1] plays a crucial role in the conservation and the sustainable use of the ocean and its resources and in safeguarding the many ecosystem services that the ocean provides both for current and future generations. Actions and efforts should primarily focus on implementation and regulatory gaps, especially in areas beyond national jurisdiction.
- This gives added significance to the current negotiations at the United Nations on the elaboration of an international legally binding instrument under the United Nations Convention on the Law of the Sea on the conservation and sustainable use of marine biological biodiversity of areas beyond national jurisdiction.
- The distribution around the world of the benefits drawn from the ocean is still very uneven. Gaps in capacity-building and resource and financial constraints hamper less developed countries in taking advantage of what the ocean can offer them.
- Capacity-building and shared scientific knowledge and the transfer of marine technology will empower States to fully participate in and benefit from the conservation and sustainable use of the ocean and its resources and assist them in meeting their obligations.