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Issues regarding oceans and opportunities: an introduction to the book

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1.1 Recognizing change in the oceans and its implications

Global change manifests itself in relation to multiple systems and sectors, including in the oceans. It is critical to understand the main features of these changes – which are in a large part human induced – as well as their effects on ocean life and processes, human well-being, and sustainable development in general, in order to frame possible responses to issues concerning the oceans today.

Providing an overview of change in the oceans is a challenging task. Perspectives on current and future ocean conditions ought to be based on documented change and variations in the physical, chemical, and biological nature of the marine environment over basin-wide zones and decadal or longer time-scales.

The active scientific community has been pursuing research on and observations of the marine environment since the genesis of modern oceanography, at the end of the 19th century. The second half of the 20th century has seen the development of international scientific research cooperative programmes such as the International Indian Ocean Expedition (IIOE) (1957–onward).[1] We now rely on an increasingly operational Global Ocean Observing System (GOOS), which encompasses ocean observing systems at multiple scales (national, subregional, and regional). Systems to detect ocean hazards, such as tsunami events, are being made operational on an ocean basin basis (cf. Chapter 8); daily ocean forecast services such as weather forecasting systems and services are becoming a reality.

Oceans are changing before our eyes; the magnitude and pace of those changes deserve special attention, further study, reflection and – it appears – urgent action.

One such change is ocean warming. Storage and transport of heat in the ocean are central drivers of the Earth's energy budget, which affects climate variability, the storm regime, moisture flux, and which can trigger expansion of the oceans, which is a major contributor to rising sea levels. Increasing temperatures also have an impact on nutrient supply to primary producers and influence species invasion.

The increase in ocean heat content accounts for most of the increase in the Earth's heat levels, which is corroborated by model simulations on the evolution of sea surface temperatures. The observed warming has penetrated at least 2000 metres into the deep sea. Monitoring variability in ocean heat content is crucial in an era of global climate change.

Changes in ocean salinity at the global scale have also been observed. These changes are coupled with surface forcing of the hydrological cycle, and can lead to increased stratification, with related reduced nutrient supply to the euphotic zone. Of particular concern is the documented reduction of the Arctic ice cover since the late 1970s.

Ocean circulation is critical to correction of the global heat imbalance and in regulating the global hydrological cycle, and also in contributing towards ensuring the abiotic and biotic conditions necessary to the proper functioning of marine ecosystems. It is important to develop an overview of the complex dynamics of ocean circulation, as well as identifying examples of change in various parts of the world's ocean. These result in changes in the present climate of, for example, north-western Europe; these changes are further exacerbated by positive feedback mechanisms.

The biogeochemistry of the ocean is also changing as a consequence of atmospheric greenhouse gas levels. Prior to 1750, atmospheric CO_2 concentrations had been at 260–280 ppm for about 10,000 years; in 2011 they passed 390 ppm. Consequently, different ocean basins behave in different ways: those which can out-gas (emit CO_2) behave as net sinks but, in some other cases, large ocean basins may approach saturation. Changes in ocean biochemistry also need to be seen in relation to a less dynamic ocean circulation and increased density stratification due to surface warming; both of which are expected in a warmer climate, as these will slow down the vertical transport of carbon into the deep ocean.

The increase in CO_2 in the atmosphere and the passing of roughly a third of this increase into the world's ocean have resulted in ocean acidification, which carries potentially understated consequences for life in the oceans. The projected level of ocean acidity would be higher than anything experienced during the past 120 million years, and the ongoing acidification of the ocean is occurring faster than has ever been documented previously. Current changes in pH are likely to affect the structure and functioning of marine ecosystems through interference in shell formation due to the numerous taxa of benthic calcifiers (molluscs, echinoderms, crustaceans, bryozoans, serpulid polychaetes, foraminifera, sponges, and corals).

Biological production is also being affected by changes in the nutrient balance. This is mainly due to increased discharge of nitrate from the land due to fertilizer use and to nitrogen deposition from air. We need to be wary of the risks of eutrophication and the spreading of dead zones, where reduced levels of dissolved oxygen determine a condition known as 'hypoxia' (below 2 ml/l) or even 'anoxia'. The most affected areas are estuarine and coastal areas. Dead zones are characterized by a diversion of the energy flow towards microbial pathways, which has negative consequences for higher trophic levels in the ecosystem and for the proper functioning of the ecosystem as a whole. The observed extension of the oxygen minimum zones has consequences for the biogeochemical cycling of carbon, nitrogen, and many other important elements. Hypoxia and anoxia determine alterations in the composition of communities and have implications for ecosystem functioning. Marine organisms respond differently to hypoxia, and fish and crustaceans tend to be the most sensitive to reduced dissolved oxygen. The spreading of dead zones has to be seen in relation to coupled physical conditions in the water column (stratification, mixing, temperature, water exchange, circulation, and the air–sea interaction).

More generally, large-scale changes in ocean conditions combined with pollution, over-harvesting of fish stocks, and unsustainable fishing practices are determining the disruption of several ocean resources, which in turn has an impact on human well-being.

Rising sea level has also been observed and projected, which will affect the 600 million people who live near the ocean within 10 m of sea level. Global mean sea level has risen by 1.7 ± 0.2 mm/yr over the period 1900–2009 and by 1.9 ± 0.2 mm/yr since 1961. Several factors contribute to this phenomenon, including thermal expansion between sea level and 3000 m depth and the melting of glaciers and ice caps. We now have a comprehensive picture of the sea-level rise budget, and the related predictions confirm the gravity of the situation, in spite of the uncertainty of some of the projections. There is also a need to look at the projected rise in sea level, extreme storm surges, and waves from the standpoint of protecting life, property, and infrastructure in coastal regions.

High-latitude regions are particularly vulnerable to change. The Arctic is undergoing change which has the potential for significant consequences in relation to the global climate system, marine ecosystems, and human activities such as oil and gas exploration/exploitation and shipping. The salinity-driven stratification in the upper layers of high-latitude oceans is being altered as a consequence of an accelerated hydrological cycle and increased ice melting during the summer season. This has consequences for the food web and also in relation to invasion by species new to these areas. In the Arctic, documented change (decreases in the extent, thickness, and duration of the ice cover and the measured increase in ocean temperature in some parts of the Arctic Basin) is occurring relatively fast in comparison with other regions. Because of the interdependence between ocean basins, these changes have possible consequences at the global scale. A growing concern is that related to the Antarctic and Southern Ocean system, which is adapted to very stable conditions. In this area, however, observed and projected sea surface temperatures are too low to indicate whether significant ice melting is occurring, which calls for continued scientific observations of the Antarctic and Southern Ocean domain.

Future changes in ocean circulation and stratification are highly uncertain. The overall reaction of marine biological carbon cycling to a warm and high CO_2 world is not well understood, which is a cause for concern in the light of the ongoing debate about geo-engineering the planet.

Global change also has various consequences on ocean life, marine biodiversity, ecosystem functioning, and the services which ecosystems provide. These changes also concern deep-sea ecosystems which, contrary to the notion that they are extremely stable in terms of physico-chemical conditions, are also experiencing changes such as climate-driven temperature shifts, as a direct consequence of the prevailing surface climate conditions.

Climate-induced changes may differ strongly throughout the globe, especially along a latitudinal gradient (in general, warming appears more pronounced at the poles than at the equator). Changes in the global mean surface air temperature, not only over the past century, but also the unprecedented change in sea water temperatures recorded over the past 10–15 years, can affect the metabolic rates of marine organisms, population and community dynamics, and community structure and function. It is expected that change in the temperature of the global ocean will have consequences for the distribution of marine biodiversity throughout the globe.

The production of organic carbon in the surface ocean is also being affected, which has a consequence for food supply to deep-sea ecosystems. Change in the upper ocean temperature can affect the availability of nutrients for phytoplankton production and the subsequent flux of exported carbon to the deep-sea sediments. It appears that ocean warming has already caused a 6% decline in global ocean primary production. This tendency will continue through this century and will affect, in particular, the tropical ocean.

Long-term changes in plankton communities are likely to have an impact on commercial fish stocks, which in turn will have social and economic consequences. Changes in faunal abundance and composition, correlated to change in the productivity of the surface ocean, have been observed in the Pacific and the North Atlantic at greater than 4000 m depth. These changes, also expected in the equatorial abyss, result in dramatic effects on the functioning of deep-sea ecosystems due to the observed exponential relationship between biodiversity and ecosystem functioning in these ecosystems.

The combined effects of multiple stressors (environmental change – in particular, habitat destruction – associated with climatic change) on large ecological processes determine changes in larval dispersal and recruitment success, shifts in community structure and range extensions, and the establishment and spread of invasive species. The disruption of the connectedness among species may lead to a reformulation of species communities and to numerous extirpations and possibly the extinction of some species, and the loss of some species may have negative effects on ecosystem function. The role of alien species therefore should be assessed in a more integrated and dynamic context of shifting species' ranges and changing compositions and structures of communities.

Global change has an effect on multiple marine habitats. The response of marine systems to climate change will also depend on interactions with other human-induced changes in the marine environment, which will lead to different responses in different types of marine habitats and systems, from coastal water ecosystems (where current losses of seagrass ecosystems, mangrove forests, and coral reefs are expected to accelerate, with consequent reduction in services such as nutrient cycling, sediment stabilization, enhanced biodiversity and trophic transfers to adjacent habitats); to submarine canyon ecosystems and deep-sea basins (the former are being affected through the alteration of the seasonal transport of particulate organic matter associated with dense shelf water cascading; the latter by changes in water temperature due to climate change, with likely implications at the global scale).

For the first time in recent history, a new ocean is opening. The Arctic Ocean is highly variable and undergoing rapid change: there is evidence that within a few decades the Arctic will likely be an ice-free ocean during the summer season. Currently observed changes may reflect reorganization of the Arctic system. This may include new characteristics of production, diversity, function, distribution, and abundance of organisms. These changes are believed to be the beginning of a much more complex process than simply a northward shift in current species distributions.

Global change at the level of ocean regions and basins may entail non-uniform and non-linear responses in biological patterns. In the Arctic, such responses may affect the microbial and micro-phytoplankton levels, the size and/or concentration of primary producers, bloom regimes, the efficiency of the pelagic food web, migratory patterns and abundance of species aggregations and consequent impacts on commercial fisheries, and also cause the impoverishment of benthic communities due to reduced primary production as a result of early spring ice retreat. Moreover, the effects of these changes can also be cumulative in nature.

Exploring, understanding, adapting, and coping with an ocean which is changing before our eyes constitutes a unique opportunity for humanity, and our ability to understand and predict change will allow us to adapt and minimize the risks inherent in surprise.

The above-summarized changes in the oceans are documented, described, and analysed in detail in Chapters 3, 4, and 5 of the book.

1.2 Realizing that global change is largely determined by humans

We live in a planet the biophysical processes of which are increasingly impacted upon by human activity. Human uses of ocean areas have impacts at multiple scales.

Fisheries and aquaculture, shipping, recreation, energy, water extraction, military activities, underwater cables, scientific research, and mining represent the main uses. These all have potential and actual impacts on the marine environment, in the form of physical and chemical alteration of habitat features, biodiversity erosion and loss, climate change, ocean acidification, unsustainable depletion of species stocks, alteration of dispersal patterns, as well as social impacts such as disruption of local livelihoods due to the collapse of local natural resources, competition between industrial versus locally based fishing and aquaculture activities, and unsustainable tourism plans and initiatives.

Therefore there appears to be a clear need to reconcile human uses of ocean areas and resources therein with the imperative of preserving the functional integrity of the world ocean so as to ensure healthy and productive oceans for current and future generations. The first step in this direction is to fully realize the value of the oceans.

Marine ecosystems provide around two-thirds of the global aggregate of ecosystem services through the provision of seafood and other natural resources, worth trillions of dollars per annum, regulation of the Earth's climate, and the modulation of global biogeochemical cycles, water quality maintenance, opportunities for renewable energy production from the sea, trade-related services, and cultural and aesthetic benefits. There is a need to capture the broader change in social welfare which has derived from management intervention related to the marine environment.

Change in ecosystems can lead to welfare benefits even in the absence of a market price, hence the need for valuation methodologies in economics to value non-marketed benefits deriving from nature. The presumption that a cost or benefit arising in the near future affects our welfare more than that same cost or benefit arising in the distant future, also known as 'discounting', tends to privilege decision-making towards immediate benefits and delayed costs, which in turn impacts on sustainability and on inter-generational equity.

Accounting for marine ecosystem services such as those provided by marine protected areas can contribute to enhancing the socio-political enabling framework for such protection measures of the marine environment and provide a level playing field for the capacity of various stakeholders to affect decisions.

Valuation of various marine ecosystem services, including from the standpoint of monetized versus qualitative benefits, is therefore necessary. This is, however, rendered challenging, not only by considerations related to the need to develop tailored and sometimes novel methodologies specific to the marine environment, but also by bias in preference methods and limitations inherent in the application of stated preference techniques in the terrestrial domain to the marine domain. In fact, values derived in primary studies are context-specific in ecological and socio-cultural terms, and there is a clear paucity of data for open ocean environments.

Main human uses and impacts of ocean areas are described in Chapter 2, while the contribution of economic assessments to informing societal choices in relation to the marine environment is treated in Chapter 7 of the book.

While economic valuation does not provide all of the answers to informing decision- and policy-making, it can support the conservation outcome of the particular set of management actions envisaged. And, because the risks involved in commoditization of nature are real and there is a requirement to take into account not only ‘credence attributes’ of marine habitats (related to perceptions) but ‘sensory’ or ‘experience’ attributes as well (this is particularly true for the open and deep ocean environments), there is a need for economic valuation in the future to focus on both valuable as well as under-researched ecosystem services from the oceans (cf. Chapter 7).

1.3 A holistic and responsible approach to ocean management

The progressive realization of human impact on the oceans, coupled with the recognition that we should maintain healthy and resilient oceans rather than merely continuing to consume our natural capital, calls for the application of an ecosystem approach to the management of oceans and their resources.

The ecosystem approach has arisen largely due to the current crisis faced by biodiversity and natural resources, to which single species and single sector management approaches cannot respond adequately. In general terms, an ecosystem approach can assist in dealing with multiple impacts of human activities while at the same time maximizing long-term economic, social, and cultural benefits, and in mobilizing a wide range of stakeholders by defining use and conservation priorities.

Many different ecosystem approaches are available to us, including traditional and indigenous approaches to the use of the oceans and the resources therein. Analysing and comparing these approaches allow us to derive certain common principles which apply, as reflected in the United Nations Convention on the Law of the Sea (UNCLOS, or LOS Convention) and its 1995 Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982, relating to the conservation and management of straddling fish stocks and highly migratory fish stocks (the UN Fish Stocks Agreement).

Case studies and lessons learned on the application of the ecosystem approach to the marine environment show that the CBD (Convention on Biological Diversity) Principles on the Ecosystem Approach are currently implemented through a variety of tools and approaches, including national and regional bioregional planning processes, marine protected areas, rehabilitation of ecosystems, fostering sustainable use of biodiversity, and participatory and bottom-up activities promoted by local stakeholders.

Currently, integrated marine and coastal area management is expanding to encompass the bioregional or large marine ecosystem scales, in an effort to also promote the application of the ecosystem approach to the management of marine areas beyond national jurisdiction. It is in this context that current efforts by the CBD related to the identification of 'ecologically and biologically significant areas' and the efforts under the Food and Agriculture Organization of the United Nations (FAO) to identify 'vulnerable marine ecosystems' should be considered.

The FAO ecosystem approach to fisheries is also to be recognized; this approach entails significant implications for the operation of Regional Fisheries Management Organizations (RFMOs – cf. Chapter 2), and the principles guiding its application appear to be largely consistent with those for the ecosystem approach developed in the context of the CBD. The FAO approach is also being increasingly tested and pursued in large marine ecosystems in various regions of the world, although current efforts have been focusing on the planning process related to an ecosystem approach to fisheries rather than on its actual implementation.

Indigenous holistic approaches to marine management can also be consistent and greatly contribute to the implementation of the ecosystem approach. Relevant case studies from different regions of the world demonstrate that, for example, in the Pacific region, communities that depend on resources from the sea for their subsistence tend to have an integrated view of peoples and nature, reflecting the perceived connection between all living things and their environments. In this regard, governments can learn significantly from these communities in their efforts towards fully embracing and applying an ecosystem approach while pursuing an integrated approach to ocean management.

Experiences and lessons learned in implementing the ecosystem approach are described in detail in Chapter 6.

While the policy relevance of applying the ecosystem approach is widely recognized, the application suffers from the frequent lack of availability of adequate analytical and scientific tools necessary for its implementation. Lack of an understanding of what the ecosystem approach entails may play a critical role in hampering its application. Hence it is important to present lessons derived from the successful implementation of the ecosystem approach, rather than its theoretical aspects. Relevant case studies must illustrate not only environmental and economic considerations, but also social and cultural factors affecting the management of ocean areas and resources, including from the perspective of how contemporary sector-based management approaches may have undermined the important contribution of indigenous and local knowledge systems to ocean management.

1.4 Towards an effective international governance of the oceans

An important step towards an effective governance of the oceans is the design and implementation of collaborative programmes involving multiple nations, especially in relation to transboundary ocean areas, shared resources, as well as areas beyond national jurisdiction. In this regard, a significant contribution can be provided by successful international scientific cooperation programmes.

Marine science and technology have an important role as regards contributing to good ocean governance through the provision to decision makers of information on marine science and technology. Transfer of technology and appropriate policies to ensure the production and dissemination of scientific information are also essential conditions to maximize the contribution of marine science and technology to a better governance of the oceans.

UNCLOS contains extensive provisions related to marine scientific research (MSR) and to development and transfer of marine technology. The Convention calls on competent international organizations to establish general criteria and guidelines to assist states in ascertaining the nature and implications of MSR. Since the adoption of UNCLOS, major technological developments have taken place in relation to the study and monitoring of the oceans, such as the use of satellites, aircraft, ships of opportunity, autonomous vessels, buoys, and floats. Hence additional guidance on how to deal with such developments can be provided under the above-mentioned criteria and guidelines.

The provisions of UNCLOS related to MSR do not apply to the collection of meteorological information in the marine environment under the World Meteorological Organization (WMO). These activities are routine observations for the collection of data which were recognized by WMO member states to be of common interest to all countries and to have universal significance, and collection of meteorological data for weather forecasts and warnings is recognized under the International Convention for the Safety of Life at Sea (SOLAS). The United Nations Framework Convention on Climate Change (UNFCCC) also calls on the parties to support and further develop international and intergovernmental programmes and networks or organizations involved in research, data collection, and systematic observation, including promoting access to, and the exchange of, data and analyses obtained from areas beyond national jurisdiction.

The development of tsunami early warning and mitigation systems can be seen from the perspective of the emergence of new regional regimes dealing with marine scientific research, especially with regard to the institutional arrangements put in place for such systems, which include governance mechanisms, operational standards and requirements, and separate agreements for the provision of tsunami watch services. These arrangements are based on commitment to principles in the policies of competent international organizations to establish general criteria and guidelines to assist states in ascertaining the nature and implications of marine scientific research (the Intergovernmental Oceanographic Commission (IOC), in the case of tsunami warning systems), rather than on compliance with binding agreements for their development and implementation, nor on modalities for their enforcement. An analysis of the evolution in the dynamics of the intergovernmental regional coordination groups established for tsunami early warning shows the adaptive nature of these governance mechanisms which reflects change in key concepts and principles, change in the group of leading actors, and expansion in the functional scope of the early warning systems.

The international Argo Project (the set-up and systematic running of networks of facilities for the continuous monitoring of ocean parameters such as temperature, salinity, and velocity of the upper 2000 m of the ocean) stresses the need for participating countries to agree on some form of international legal regulation related to the employment of thousands of voluntary observing ships and ships of opportunity, tide gauges, surface drifters, subsurface drifters, moored buoys, and profiling floats that may drift into national exclusive economic zones (EEZs). The Argo Project provides a clear example of a very successful programme aimed at collecting, organizing, and making available data on a free, unrestricted, and real-time basis which – as in the case of the data generated through the tsunami early warning system – are critical to the protection of life and property (information and data collected through the International Argo Project contribute to the development of, for example, sea-level rise projections). The project is intended to operate in a way which is consistent with UNCLOS. Yet, different interpretations exist with regard to whether it should be seen as an activity characterized as operational oceanography, not governed by the UNCLOS provisions related to MSR, or as part of the latter. A central feature of the Argo Project is that participating states are divided into implementers (i.e. deployers) and coastal states, whereby the floats belonging to the implementer may operate on the high seas or the territorial sea or the EEZ of the implementer or any other coastal state, while coastal states play a passive role by letting the implementer collect data from waters under their jurisdiction.