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Coral Triangle: Marine Biodiversity and Fisheries Sustainability

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Definitions

Marine biodiversity. It refers to variability of life in the sea in terms of diversity within species (gene level), between the species, and in ecosystems. Of these three levels, the species level diversity (i.e., species richness or the number in a given area) is the common metric. However, it must be integrated with other metrics to capture the full essence of biodiversity. These dimensions of diversity vary over space and time. Only a multidimensional assessment of biodiversity can provide insights into the relationship between changes in biodiversity and changes in ecosystem functioning and services (MEA 2015).

Ecosystem Approach to Fisheries Management (EAFM). This is an integrated approach to managing fisheries within ecologically meaningful boundaries (FAO 2003). The ultimate objective of EAFM is to ensure that ecosystems are healthy, that fish stocks are sustainable, and that the well-being of the communities and stakeholders depending on them is safeguarded (WWF 2011).

Marine Protected Areas and No-Take Zones. A marine protected area (MPA) is any area of sea especially dedicated to the protection and maintenance of biological diversity, and managed through legal and other effectives means (IUCN 1994). It provides a regulatory framework for conserving the natural or cultural resources of the ocean and for managing human uses through zoning. MPAs may also be referred to as marine parks, sanctuaries, reserves, or closures; the latter two terms are used most commonly in the context of fisheries management (Hoagland et al. 2001). A No-Take Zone is an area set aside by a government where extractive activities such as fishing, mining, drilling, or others involving removal of marine resources are not allowed. No-Take Zones offer more protection to the ecosystems, habitats, and species within the boundaries of those larger, and less restrictive, protected areas (National Geographic 2011).

Significance of Sustainable Fisheries in the Context of Food Security

Sustainable fisheries play a very important role in providing food, jobs, and income. The world is facing a mounting challenge to food security because of the growth of the human population which is expected to exceed 9 billion by 2050. The food demand will be 60% more than what it is

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today (WEF 2019). It could be even higher, about 70% (FAO 2019a). Currently, when human population is about 7.7 billion, as many as 815 million (i.e., one in every nine) are hungry or malnourished (WEF 2019). The United Nations has set "Ending Hunger, Achieving Food Security and Improved Nutrition" by 2030 as one of the Sustainable Development Goals (Goal 2: Zero Hunger). Meeting these objectives requires addressing several interrelated and complex issues, because everyone needs food, the supply of which concerns all the aspects of economy and society (WEF 2019).

Land-based food systems are seriously challenged due to scarcity of natural resources, land degradation, shortage of farming areas, decline in irrigation water, crop failures, and effects of climate change. Oceans remain the last frontier on Earth to meet the demand. Seafood should, therefore, be considered within the context of global food security which implies a condition "when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (WFS 1996).

Currently, the annual aquatic food production is 210.9 million tons, with capture fisheries landings amounting to 96.4 million tons of fish while aquaculture contributing 114.5 million tons, including the harvest of seaweed (SOFIA 2020).

Seafood provides 3.0 billion people with 20% of the animal protein and another 1.3 billion people with 15% of the per capita intake of protein (HLPE 2014; Mustafa and Estim 2019). Seafood has a direct as well as indirect contribution to food security. The primary seafood-producing sectors offer employment to 59.6 million people while directly and indirectly the seafood industry engages 200 million people along its supply chain.

Another role of seafood is in sparing the highly stressed terrestrial ecosystems and the health of the planet. Prevailing agricultural practices share a significant part of the total greenhouse gas emissions and utilize scarcity-weighted water, loss of terrestrial biodiversity, and pollution of land and aquatic ecosystems through eutrophication and pesticide residues. If the current agriculture practices continue, a further 400 million hectares of natural ecosystems will be lost to pave the way for food crops and animal husbandry (FOLU 2019). This report presents facts and figures to show that 1.2 billion hectares of land which is currently utilized for agriculture will be freed up to support restoration of natural ecosystems by 2050 and help the world achieve the biodiversity goals. A sustainable seafood production can, therefore, not only enhance food supplies but also lessen the pressure on the planetary ecosystems. Transforming the food systems, with a greater investment toward aquatic food, will speed up the world's progress toward the Sustainable Development Goals (SDGs).

Concerns about seafood supplies arise from the capture fisheries in terms of the sustainability of the catch and the constraints facing aquaculture. Fisheries have a bigger direct contribution to seafood security, but they also have more challenges due to the fact that the harvest of fisheries depends on the natural ecosystem, unlike aquaculture where most of the operations are carried out under controlled conditions. The natural aquatic ecosystems are under serious stress, causing concerns about sustainable food supplies. No doubt, oceans have resilience to absorb impacts and regenerate but up to certain limits. Decline in marine populations supporting fisheries is thus a matter of grave concern (Selig et al. 2014).

Sustainable fishing does not threaten the biodiversity since the harvest is within the regenerative capacity of the ocean ecosystem. Fishing beyond this limit produces significant impacts. Obviously, the effect of fishing on the ocean ecosystem can only be judged holistically from the ecological dimensions (Cataudella and Spagnolo 2011).

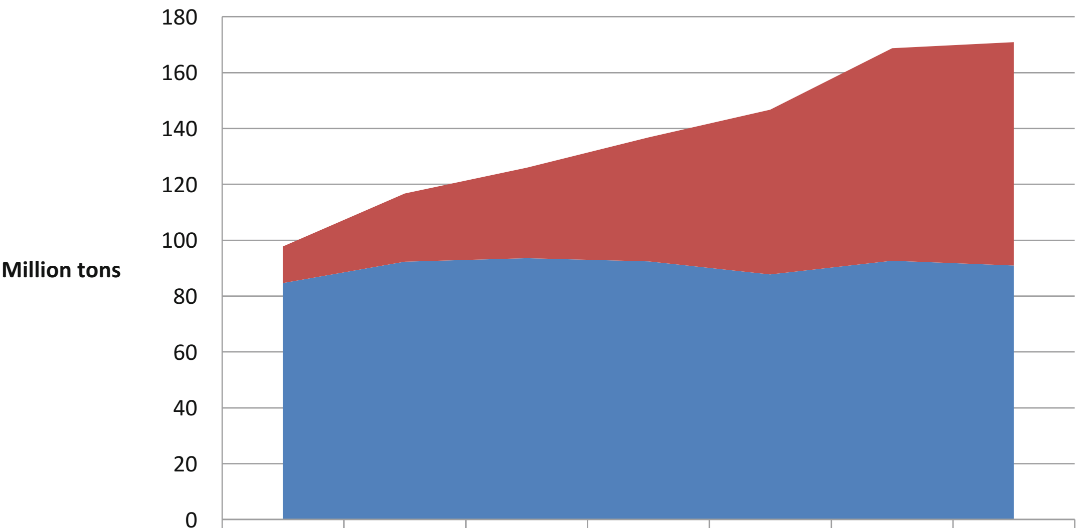
A significant threat to seafood supply comes from the collapse of some major commercial fisheries. As of now, 33% of fish stocks are overfished (at biologically unsustainable levels), 60% are harvested as maximally sustainable level, and only 7% remain underfished (FAO 2019a). This is a significant increase in the level of exploitation compared to 40 years ago when 90% of the stocks were fished at biologically sustainable scale while the unsustainable level was only 10%. This is the reason why the annual harvest amounting to 79.3 million tons of fish (FAO 2018) has not improved since around 1995 (Fig. 1). Illegal fishing that accounts for up to 31% of catches worldwide is harming the fisheries management efforts. A rapid growth in aquaculture is contributing in a big way to meeting the fish demand.

For many major fish stocks, the scale of fishing operations has breached the safe operating space, leading to a situation where there is a risk of crossing the thresholds (or Tipping Points). This can cause abrupt and irreversible consequences for the ecological systems. Tipping point reflects a condition reached due to reckless exploitation of resources where small shifts in human pressures or environmental conditions bring about large, sometimes abrupt changes in a system (OTP 2019). Such a change is caused by cumulative effect of many small-scale pressures acting over time and pushing the ecosystem to a stage that it can no longer absorb further stress. Predicting the tipping point is difficult, but its causes can be investigated after the ecosystem crash. Many factors can push the ecosystem to the limit of its tolerance, after which it becomes vulnerable to collapse. It could be the impact of one factor building over time and becoming massive, or else there may be multiple factors, which is generally the case. Sediment runoff from land into a marine critical habitat can lead the ecosystem to a tipping point by decimating biodiversity. Currently, the state of a marine ecosystem in a localized area can be monitored by pollutant discharge, scale of fishing, and other parameters. Many marine critical habitats exposed to anthropogenic pressures have undergone degradation (Waycott et al. 2009) and some sudden, drastic shifts driven by overfishing of large predatory species, change in nutrient profile, and modifications caused by climate change. These have resulted in altered ocean food webs, change in habitat attributes, and disruption in ecosystem functions. Ocean tipping points are a cause for concern because they can be very difficult to reverse. There are many tipping point symptoms in different parts of the world, but these have not been characterized as such. Among the well- known cases of tipping points is the transformation of a lush brown seaweed (kelp) forest associated with high biodiversity into a "sea urchin barren" (CCBER 2011) in North America. It has happened due to reckless hunting of sea utters to near extinction for their fur. Otters (a keystone species) are major predators of sea urchins, and depletion of their population allowed the urchins to overgrow and graze their favorite food of the seaweed that earlier supported many fish populations in addition to controlling nutrient enrichment of the coastal areas. There are many other cases where transformation of marine critical habitats has occurred, for example, excessive discharge of nutrients or sediment, resulting in dead zones in the sea, seagrass die-offs, and collapse of coral reefs due to destructive fishing methods. If investigations are able to establish links between stressors and ecosystem responses, the data will be useful in determining the environmental thresholds of all the stressors and understanding the potential indicators of the ecosystem condition as well as the tipping points. This will help in shaping the managerial interventions.

Marine Biodiversity-Sustainable Fisheries Linkage

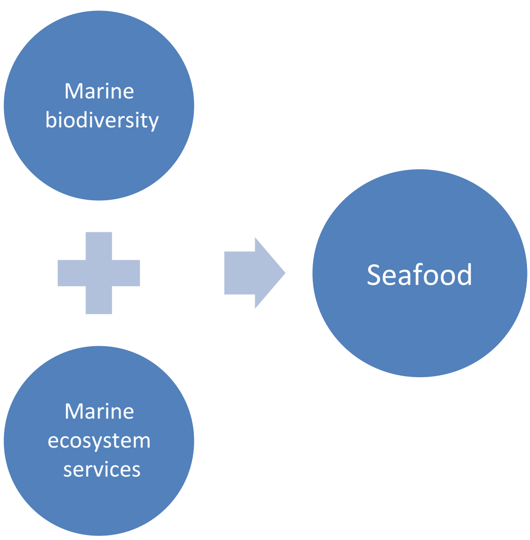
Despite their potential to meet the food supply demand, the capacity of oceans is constrained by several factors. Loss of marine biodiversity is among those major factors (FAO 2019b; Mustafa et al. 2019). Major threats to marine biodiversity include the loss of habitat, overexploitation of fisheries resources, pollution, eutrophication, and invasion by nonnative species (Venter et al. 2006). There is no dearth of scientific evidences demonstrating the impact of anthropogenic activities on the oceans that have caused declines in species diversity and abundance (Butchart et al. 2010). This has threatened the fisheries and reduced the stability and resilience of the marine ecosystem (Worm et al. 2006; Danovaro et al. 2008). A detailed analysis reveals how these impacts have played out in bringing about major shifts in food web dynamics (Duffy 2003; Springer et al. 2003).

Fish production in the ocean relies on marine biodiversity and a range of marine ecosystem



	1990	1995	2000	2005	2010	2015	2016
Aquaculture	13.09	24.38	32.42	44.3	58.96	76.1	80
Capture fisheries	84.68	92.36	93.55	92.47	87.81	92.7	90.9

Coral Triangle: Marine Biodiversity and Fisheries Sustainability, Fig. 1 Trends in capture fisheries and aquaculture production, million tons. (Source: FAO 2018)

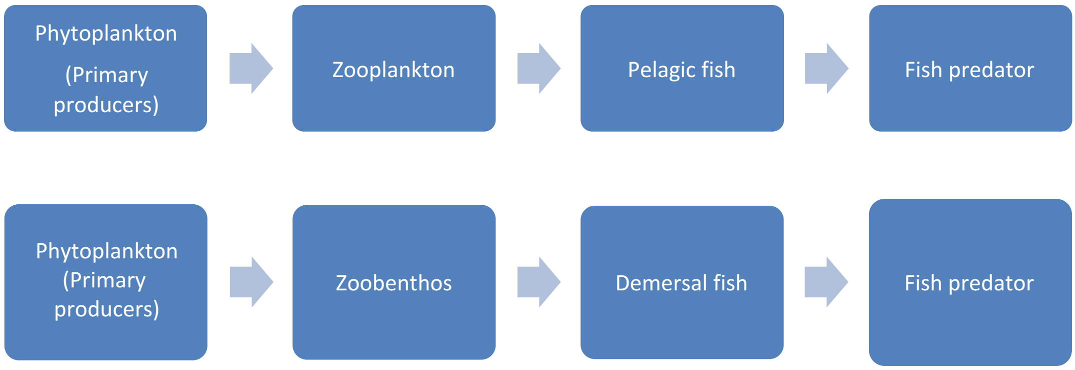


Coral Triangle: Marine Biodiversity and Fisheries Sustainability, Fig. 2 Key role of marine biodiversity in seafood production

services (Figs. 2 and 3). This aspect has not been thoroughly highlighted. Effort has been made in this article to explain the link between the two.

All the populations of marine species, including those that are harvested as seafood, have complex biotic and abiotic links in the environment (Tursi et al. 2015). They use ecosystem resources to survive through numerous selective factors in the natural environment governed by laws of biological evolution, predator-prey relationships, various levels of organic productivity, and hydrodynamic conditions. Some of their interactions with the ecosystem such as the trophic ones are obvious while others are not so explicit. Even a species of fish or shellfish harvested from the deep sea that does not appear to be associated with certain specific marine ecosystem components has used the services provided by those components in one way or the other. For example, mangroves and seagrasses filter the water and clarify it to enhance the quality of living medium for a fish caught from the open sea that apparently has not maintained any organic links with this coastal vegetation.

The actual mechanisms of organic production in the ocean are complex but can be understood by examining the extent of interrelationships of each of the marine species in the web of life with the



Coral Triangle: Marine Biodiversity and Fisheries Sustainability, Fig. 3 Simplified pathways of fish production-marine biodiversity links. (Adapted from van-Denderen et al. 2018)

living (biodiversity) and nonliving factors of the marine environment. Significance of these links in ocean productivity has been established by scientific studies in the past (Cushing 1975; Frank et al. 2005; Daskalov et al. 2007; Casini et al. 2008; Chassot et al. 2010; Hessen and Kaartvedt 2014; Kavanagh and Galbraith 2018). These investigations have demonstrated the reliance of marine fish on photosynthetically captured energy and dissolved oxygen, and the role of phytoplankton in transforming the dissolved inorganic carbon into organic matter at a rate that depends on nutrient availability, temperature, light, and other factors. In a straightforward form, the process involving the three trophic levels has two levels of energy transfer in the flow of carbon from one to the next level in the production of a planktivorous fish such as anchovy. Based on the widely accepted calculations suggested by Ryther (1969), the primary production in coastal waters amounting to 100 g C/m^2/year can be used for productivity determination. When there are two energy transfer levels, the total yearly phytoplankton production multiplied by two transfer efficiencies ($0.1 \times 0.1 = 0.01$) can be used for measuring anchovy production (Fig. 4).

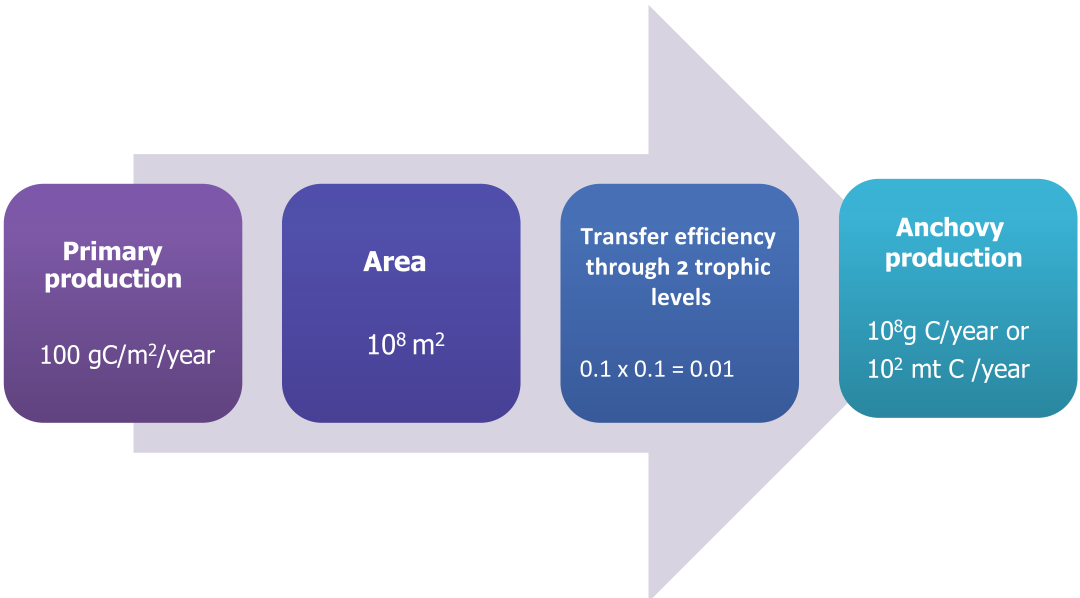
The processes involved in the transfer of organic matter to fish through heterotrophic pathways link the abundance and production of all trophic levels to the photosynthetic organisms and critical environmental factors. These are reflective of the complex nature of trophic cascades in the ocean. There are, of course, species of the marine biodiversity complex that are associated with each of these trophic levels in unique ways, with some visible while others such as invertebrates and microorganisms that are not human food or part of the fish catch that is not apparently so conspicuous in its roles. This "associated biodiversity" comprises a vast range of organisms, many of them yet to be identified and described. Included in this group are the microorganisms which can be identified by molecular and sequencing techniques.

Heiskanen et al. (2016) have emphasized the importance of giving due consideration to food web structure and functioning in studies on diversity of life in the ocean in view of its role in the dynamic functioning of the marine ecosystem. The fisheries production system is more resilient to shocks and stresses, including those caused by climate change, when all the ecosystem links are functionally intact. Undoubtedly, biodiversity is a key resource in efforts to increase food production while limiting negative impacts on the environment (FAO 2019b).

Critical Issues in Marine Biodiversity

Marine Biodiversity Inventory

Developing the marine biodiversity inventory is among the key steps in giving this topic due significance in sustainable development of marine biological resources, including those that serve as seafood. Inventory requires efforts to identify and



Coral Triangle: Marine Biodiversity and Fisheries Sustainability, Fig. 4 Steps in the movement of carbon (C) in a marine food web. (Adapted from Pinet 2009)

document all the marine species living in a defined area in the sea. For an inventory, we need to know: what, where, when, and how many? This information helps in gaining insights into the distribution and habitat associations of the species, their relative abundance, and population trends. Currently, there is a glaring vacuum in knowledge of the full life history of most of the marine species, their ecological niches, population structure, and interactions with the various components of the ecosystem.

Biodiversity inventory provides baseline data on the occurrence, distribution, abundance, and existing state of the complexity of species links for a management area so that any change could be examined. We need to know how many species are there to begin with and to be able to understand exactly how many species the oceans are losing. According to the World Register of Marine Species, there were 243,000 species described in 2017. The total number of species living in the oceans is unknown but could exceed 10 million. Ideally, changes in marine biodiversity can be accurately studied if baselines are used as a reference, but it is not easy to establish baselines for most coastal regions, open ocean, deep sea, and abyssal areas (Canonico et al. 2019). It remains a work in progress. However, where it is being monitored, most of indicators show that the biodiversity is declining (EASAC 2005). The unfolding trend of marine diversity compels us to believe in the assessment of UNESCO (2017) that without action, more than half of the world's marine species could be on the brink of extinction by the year 2100. Even accepting a modest extinction rate of merely 0.01%/year, then out of 100,000,000, as many as 10,000 can go extinct every year. There is a possibility that many potentially useful species could be lost before being discovered and documented. It deserves mention that while the number of described marine species increases by, on average, 1500 each year, the vast majority of species are yet to be discovered or described (Heip and McDonough 2012).

Biodiversity inventory requires a long-term structured monitoring program to examine the spatial and temporal dynamics of species. Such information is important from a marine conservation point of view so that relative frequency of organisms in their habitat, interspecies relationships, and interactions with the physical environment could be understood. In a wider context, knowledge that the biodiversity inventory generates will enhance our understanding of the ecological niches, differences in community profiles of different marine areas, corridors used by species for normal movements and migrations, and linking biological data with general attributes of the marine environment. Because biodiversity is central to healthy functioning of the marine ecosystem, managing key drivers of adverse impacts is necessary for sustainable management of marine resources.

Biodiversity Indicators

Biodiversity can and should be measured even though it is multidimensional (species, gene, and ecosystem levels) and too complex to be fully quantified to address the widespread concern about its loss and implications thereof. It is more appropriate to consider this process as biodiversity assessment, rather than biodiversity measurement, because the measurements are carried out to assess the state of biodiversity in relation to a baseline, target, pressure, or remedial action taken (EASAC 2005). Indicators or indexes are used to provide a basis for assessment of the state of marine environment or its biodiversity and any possible changes taking place (Fig. 5).

Indicators generate information that is not only helpful in understanding the status and trends in biodiversity but also in examining the impact of the main drivers and pressures that cause the biodiversity loss, and the success, or lack of success, of steps taken to conserve and/or restore biodiversity (EASAC 2005).

The indicators are not perfect, but they are useful to show in which direction the key components of biodiversity are heading. Their development or selection should be based on the question to be answered. EASAC (2005) has discussed the use of the following biodiversity "state" indicators in the form of proxy or surrogate measures to characterize the biodiversity:

1) Population trends (to provide comparisons between habitats, areas, and management practices).
2) Extent of different habitats (to explain the way habitats and ecosystems are changing over time).
3) Trends in the status of threatened species (to indicate the trends toward extinction of species and provide a basis for Red List).
4) Trends in the impacts of a specific pressure (for example, impact of fishing on fish stocks; in this context, the Marine Trophic Index can be used to measure changes in the status of fisheries catches as an indicator of fishing pressure).

Marine Strategy Framework Directive (MSFD) has proposed monitoring the marine environment using 11 descriptors of 2 categories:

1. Biodiversity-related descriptors: Biological diversity, food webs, and seafloor integrity.
2. Pressure-related descriptors: Fisheries, non-indigenous species, eutrophication, contaminants in the environment, litter, contaminants in seafood, energy, and noise.

Martin et al. (2015) have suggested use of indicators with the following attributes:

1. A single measurable parameter (for example, number or abundance of a species).
2. A parameter value integrated over time or in space (for example, total number of species in a sea area, habitat diversity measure for a certain area).
3. A calculated index (for example, Shannon-Wiener index, Benthic Quality Index).
4. A trend in population or other quantitative feature of marine biodiversity.

There are already many marine biodiversity indicators (Table 1), and the list is growing. Selection can be made according to feasibility of monitoring and practicality.

There are other biological indicators which are not true biodiversity indicators in the sense that they are not used to directly assessing the state of the marine biodiversity but in examining the biological consequences against certain pressures. These could be useful for monitoring of fish

Coral Triangle: Marine Biodiversity and Fisheries Sustainability, Fig. 5 MARMONI framework for assessment of marine biodiversity

Coral Triangle: Marine Biodiversity and Fisheries Sustainability, Table 1 Key marine biodiversity indicators (Martin et al. 2015)

Name of indicator	Indicator description
Fish indicator	Abundance and distribution of selected species of fish Abundance index of large-sized fish of a selected species in routine monitoring of catch (length-frequency distribution) Trophic diversity index of selected species-changes in average trophic level of marine predatory species
Pelagic indicators	Phytoplankton diversity index Zooplankton diversity index
Benthic indicators	Community heterogeneity Biodiversity index Benthic habitat diversity Accumulated cover of seagrasses

stocks or state of the ecosystem of which they are a part (Martin et al. 2015). Marine Trophic Index (MTI) mentioned above is an effective indicator of fishing pressure. MTI has been endorsed by the Convention on Biological Diversity as a measure of marine biodiversity inasmuch as it reflects on the overall ecosystem health and serves as a proxy measure for overfishing. MTI data can serve as a measure of the richness and abundance of fish species of the higher trophic level, and providing insights into the scale of change in fish stock composition in the marine ecosystem, depletion of larger fish higher up in the food chain, and mounting fishing pressure on smaller fish species. This characterizes a condition defined as “fishing down the food web” whereby fisheries have depleted the large predatory fish on top of the food chain, and have turned to increasingly smaller species, leading to exploitation of natural stocks of previously spurned small fish and invertebrates (Pauly and Watson 2009). This is a condition that is typical of unsustainable fisheries and is a threat to marine biodiversity. Analysis of Catch Per Unit Effort (CPUE) data can be related to marine biodiversity and in interpreting the socioeconomic impacts and management responses through Drivers, Pressures, State, Impact, Response (DPSIR) framework (Smeets and Weterings 1999). For the effective use of a DPSIR indicator in marine management, it should measure changes in the environment caused by human activity provided the impact and significance of those changes are known (Normander et al. 2009).

Borja et al. (2017) have emphasized that the development and validation of marine biodiversity indicators requires improved data with better spatial and temporal coverage based on accurate and holistic monitoring methods that are ecologically relevant and responsive to pressures. The data collected using this approach should be such that it can be incorporated into models in order to extrapolate marine assessments for larger spatial regimes and temporal scales. Accuracy of the quantitative methods is vitally important since there are sampling biases as highlighted by Costello et al. (2017). The authors have suggested the need for comprehensive observations using complementary methods over extended periods to produce an inventory of species that reflects the pattern of occurrence of the species, species richness, and the ecosystem condition.

Marine Biodiversity and Seafood Security in the Coral Triangle Region

Biodiversity-rich areas (or hotspots) or other categorizations such as ecoregions have always been selected for conservation planning in marine ecosystems (Brooks et al. 2006). Thus, Marine Protected Areas (MPAs) and No-Take Zones are considered valuable tools for protecting marine biodiversity, especially in places such as coral reefs. This supports the coastal fisheries while playing a vitally important role in conservation of marine biodiversity.

By 2017, about 3.5% of the sea was designated as MPA, out of which only 1.6% was No-Take Zone (Lubchenco and Grorud-Colvert 2015). This coverage is far short of the United Nations target of 10% of the ocean protected by 2020. Sala and Giakoumi (2017) have reviewed the importance of MPAs in a global context and pointed out their value in restricting certain activities, for example, trawling, sand mining, and habitat destruction. The ecological benefits of these measures should be visible within and beyond their boundaries. However, the authors have strongly advocated the expansion of no-take marine reserves since they are by far the most effective in restoring the biomass and structure of fish assemblages, and healing the ecosystems to a more complex and resilient state. In view of the outstanding ecological and economic benefits of such conservation measures within and beyond the protected zones in the sea, the Coral Triangle Initiative was launched. Coral Triangle (CT) is a vast marine environment of roughly triangular shape covering 5.7 million square kilometers or 1.5% of the world's oceans along the equator at the confluence of Western Pacific Ocean and Indian Ocean (Green et al. 2011). It comprises marine areas of six countries: Indonesia, Malaysia, the Philippines, Timor-Leste, Papua New Guinea, and the Solomon Islands. Due to its rich marine biodiversity, the CT region is considered a global priority for marine conservation (Roberts et al. 2002; Allen and Adrim 2003; Bellwood et al. 2004; Allen 2008) and is often called as the "Amazon of the seas". the main features of marine biodiversity heritage of CT are presented in Table 2.

This region has a population of 126 million people and supports livelihood of 126 million people (Green et al. 2011). The Coral Triangle Initiative on Coral Reefs, Fisheries and Food Security launched in 2007 (CTI-CFF 2019) has five goals of regional plan of action: Priority seascapes designated and effectively managed; Ecosystem Approach to Management of Fisheries (EAFM) and other marine resources fully applied; MPAs established and effectively managed; climate change adaptation measures achieved; and threatened species status improving.

Benefits of Conservation Intervention

Marine biodiversity crisis is a serious matter but not given the importance it deserves in decision-making. It needs urgent attention as the stakes are too high. Oceans are in peril, and so is the life on Earth. There are reasons to believe that ocean acidification and other effects of climate change, overfishing, destructive fishing, and habitat degradation, especially the loss of marine critical habitats, are changing the oceans as never before. Loss of marine life is a matter of concern to all of mankind. Calls from the scientific community for real action for conserving and managing the marine environment in order to maintain healthy ecosystems and human well-being are getting louder (Bennet et al. 2017). In response, an international consensus was evolved through Convention on Biological Diversity (Aichi Target 11) and United Nations Sustainable Development Goal 14 for at least declaring 10% of the vast environment as the MPA by 2020. This is just one of the tools for governance of sustainable fisheries, blue carbon stocks, spatial planning, and adaptation measures. The scale of impacts is much higher than conserving just 10% of its area, but for any further expansion to be effective we need to consider if the society is onboard as the livelihood of millions of people is closely tied to marine resources.

Coral Triangle: Marine Biodiversity and Fisheries Sustainability, Table 2 Marine biodiversity features of Coral Triangle

S.no.	Marine biodiversity features	References
1.	76% of the known coral species	Veron (2000)
2.	>30% of the world's coral reefs	Green et al. (2011)
3.	>3000 species of fish	Green et al. (2011)
4.	37% of the 6000 coral reef fishes in the world	Allen (2008)
5.	52% of the reef fishes of the indo-Pacific	Allen (2008)
6.	73,000 Km^2 (or 29%) of the global coral reef area	Burke et al. (2012)
7.	50% of razor clams	Saeedi et al. (2016)
8.	Six out of the seven sea turtle species	Asaad et al. (2018)

Bennet et al. (2017) have highlighted the societal issues needing attention in planning and implementation through a code of conduct that is socially acceptable and ecologically effective. If humans are to play the ocean stewardship role, it is essential that our actions should be based on current knowledge and experience for effective future-proofing of oceans and sustainable benefits to the future generations.

Protecting biodiversity and the essential ecosystem services that it supports has become a priority for generating knowledge and capacity development for achieving the multiple SDGs. There is no dearth of topics that can be pursued, but it makes sense to identify thrust areas to be given special attention to combining knowledge that exists or likely to be gained through problem-solving innovations. The species of animals serving as seafood can no longer be regarded in isolation from other species and habitats. A sustainable seafood supply system requires ecosystem-based management of oceans. This has been amply emphasized by Mustafa and Estim (2019). Priority areas emerging from their key points pertaining to conservation and sustainable development are presented below:

1. Baseline knowledge of all the three levels of marine biodiversity (genes, species, and ecosystems) at temporal and spatial scales, and the factors that control generation of diversity
2. Digital documentation of data pertaining to marine biodiversity that can be easily updated and shared
3. Further insights into the role of marine biodiversity in marine ecosystem health and stability of planetary life support systems
4. Understanding of the factors that promote, preserve, and threaten marine biodiversity
5. Adaptation of marine species to modifications caused by changing climate, and implications of such changes for oceans and human well-being
6. Links between marine biodiversity and ecosystem functioning in the context of sustainable development goals
7. Quantifying the specific marine biodiversity indicators and their use in management systems
8. Nationwide efforts toward accurate understanding of marine biodiversity tipping points and their consequences for economic sectors such as seafood security
9. Delivering economic benefits through projects designed to capitalize on sustainable use of marine biodiversity in fisheries, aquaculture, marine biotechnology, and nature tourism
10. Applying the state-of-the-art technologies including those of the Industrial Revolution 4.0 for new knowledge, real-time monitoring, and governance, especially in marine biodiversity hotspots
11. Facilitating disruptive innovations in marine biodiversity knowledge, seafood production systems, and climate change adaptations in fisheries and aquaculture

Linking marine biodiversity with food security through credible research aimed at seeking synergies between the two will generate benefits for ecological, social, and economic development (Cramer et al. 2017). Countries do develop policies and action plans to implement SDGs nationwide, but a fast-track progress can be achieved by localizing the efforts at institutional levels. While analyzing the positive outcomes of biodiversity-focused practices, FAO (2019b) reported that researchers in many countries continue to emphasize the need for more investigations which delays action. Many biodiversity-focused practices are relatively complex, with many interlinked issues and variables, but implementable in a knowledge-based and context-specific ecosystem. However, to be successful, the plans and actions should be based on a good understanding of the local environment (FAO 2019b). Universities that have transformed into EcoCampus and are racing for green metrics scores are in a better position for adapting the SDGs to local situations, and incorporating them in institutional programs of education, public outreach, and ways of working (Mustafa et al. 2019; Shaleh et al. 2019). By localizing the efforts for conservation of marine natural resources and related issues, the institutions can leverage their expertise toward investment in partnerships to achieve more impact on the society, far beyond what can be accomplished by working alone. The challenges facing marine biodiversity and fisheries are interconnected and qualitatively similar in many countries, so the partnerships can lead to exchange of knowledge and sharing of experiences that will help in overcoming the challenges and collective actions in various ways:

1. Disseminating the evidences arising from scientific trials to inform the key features of successful methods for possible adoption or adaptation.
2. Governance mechanisms that have proved effective.
3. Data for informed decision-making.
4. Benefits of inclusive approaches.
5. Showcasing feasible solutions.

Local efforts can benefit from knowledge of the marine biodiversity generated internationally since some countries have already made a significant headway in this area. In fact, as a result of sustained investment in research, several marine biodiversity databases that provide a rich source of information have already been developed and can be consulted. These include: World Register of Marine Species, Marine Regions Ocean Biogeographic Information System, Global Marine Environment Datasets, FishBase, and AlgaeBase.

Conclusions and the Way Forward

Marine biodiversity which underpins our seafood systems is declining. This is putting at risk the food security, livelihoods, health, and other aspects of human welfare. Realizing that seafood seeks to bridge the gap between food supply and demand, health of the oceans has taken the center stage as the last frontier on Earth for food production. This scenario is likely to prevail due to population growth and changing food consumption habits of people.

Maintaining all of the biological components of the marine ecosystem at functional levels is necessary for its ability to meet additional food demand. There are many effects of biodiversity loss that are not so much tangible as seafood, and these include chemicals used in biopharmaceuticals and raw materials used in industries. Now that the blue growth is emerging as a significant sector of the global economy, sustainable ocean management should be a major factor in national policies and practices. It is necessary to undertake structured initiatives for marine ecosystem for species survival and diversity, and seafood security. There are many marine biodiversity indicators, but more research is needed on this topic for their responsiveness to pressures in a dynamic ocean ecosystem and their accuracy to reflect changes. This will enhance the confidence in the information that the indicators would generate and its use in biodiversity management policy framework. It will augur well for marine biodiversity conservation if further studies link it with the societal benefits. Focused studies on marine biodiversity-sustainable development of fisheries linkage will contribute significantly to highlighting the conservation benefits for long-term seafood security.

Cross-References

- ▶ Estuaries: Dynamics, Biodiversity and Impacts
- ▶ Fisheries Management and Ecosystem Sustainability
- ▶ Higher Education and Sustainable Development of Marine Resources
- ▶ Marine Animals and Human Care Towards Effective Conservation of Marine Environment
- ▶ Sustainable Coastal and Marine Ecotourism: Opportunities and Benefits

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