Ocean Food Production: LIMITS & STRATEGIES

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PHOTO: Fish landing boats, Ebodje, Cameroon by Edward Manning, Ph.D.

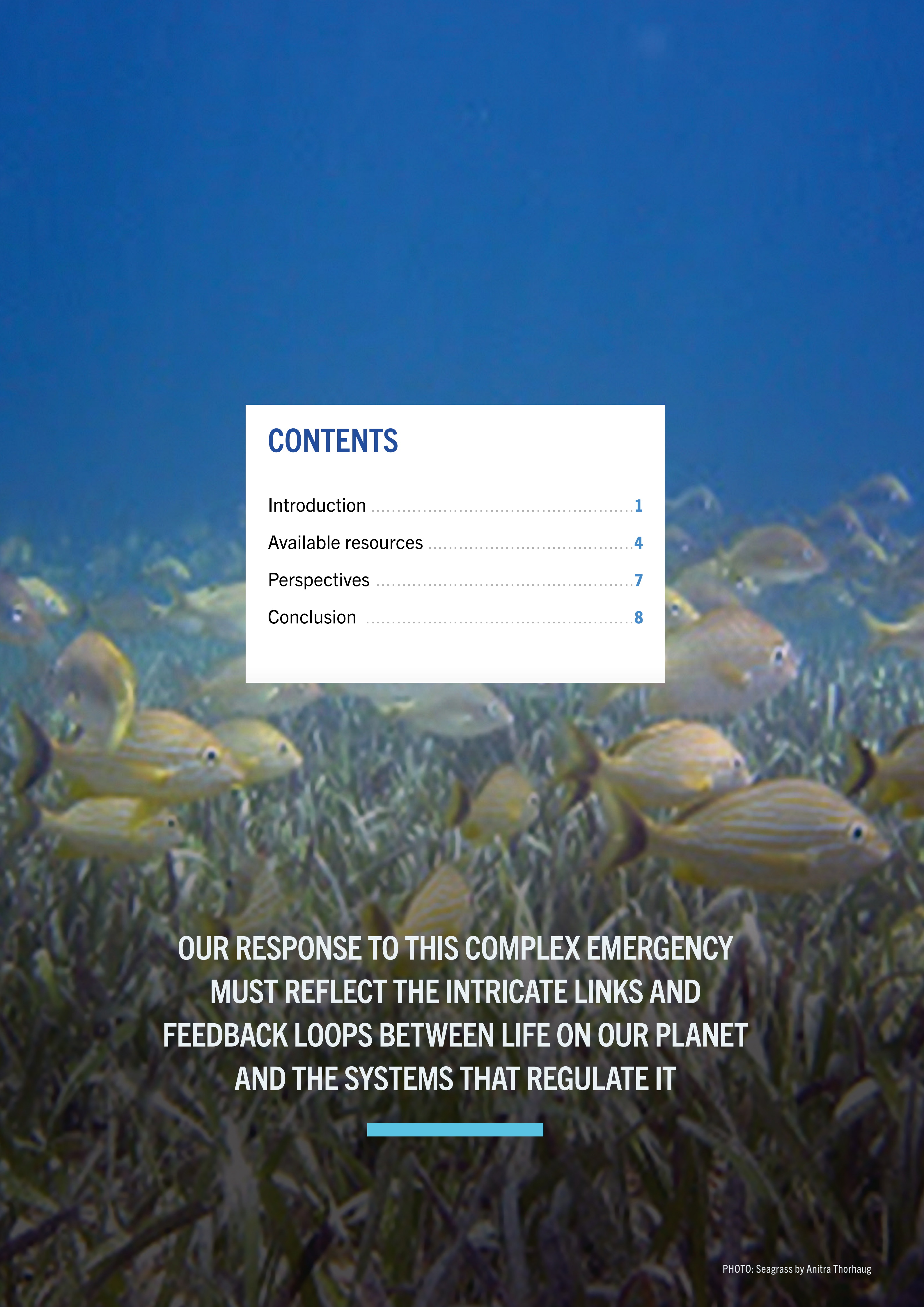

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PHOTO: Seagrass by Anitra Thorhaug

INTRODUCTION

The seas contain solutions to the global food crisis

The oceans' and seas' food security predicament is as catastrophic as is terrestrial food security. The oceans carry a significant hope for the future. Blue food (food drawn from the oceans, seas and estuaries) is the primary source of protein for billions of people yet it is not developed or managed to maximize its contribution or sustianablity. Clearly, both natural populations of marine and freshwater fish are in serious decline worldwide (FAO 2018) despite being historical essential pillars of human food security. Over-fishing, waste dumping into rivers and bays, chemical inputs from terrestrial agriculture and industry, infrastructure built on prime ecosystem habitats, land-reclamation have damaged estuaries (Kennish, 2002). However, a dawning of new mariculture techniques for fish, shellfish, and macro-algae has substantially bolstered nutrition from the sea at least in Asia, where the densest populations occur. However, at present mariculture and aquaculture are not sufficient to feed the growing coastal Asian populations. Both fisheries and other marine sources (e.g restored fisheries habitats of seagrass, mangroves, or mariculture of marine macro-algae etc) can significantly support greater productivity in large parts of the worlds oceans.

"Food from the sea is produced from wild fisheries and species farmed in the ocean (mariculture), and currently accounts for 17% of the global production of edible meat (Costello et al 2002). In addition to protein, food from the sea contains bioavailable micronutrients and essential fatty acids that are not easily found in land-based foods, and is thus uniquely poised to contribute to global food and nutrition security."
(Costello et al, 2021)

Acting on both terrestrial agriculture and marine food-related ecosystems, the impacts of climate change and ecological destruction are more severe and are manifesting themselves earlier than foreseen by multiple scientific predictions in previous decades. The International Panel Climate Change report (United Nations COP2021—a consensus global scientific assessment) concludes that without major interventions, the risks will reach a critical stage. However, stabilization of the climate at 1.5°C maximum above pre-industrial temperatures will slow the polar ice sheet melt and glacier retreat (causing sea level rise), help in halting the loss of biodiversity, and help protect critical biomass.

One way this passive climate change intervention can occur is to store more carbon in soils, forests and nearshore tropical and temperate estuarine and coastal habitats. This is a pathway to guaranteeing the long-term health and well-being of both the peoples and the planetary ecosystems. Our response to this complex emergency must reflect the intricate links and feedback loops between humanity's needs dependent on our planet and its ecosystems and physico-chemical systems that regulate it allowing the natural forces to activate their living habitat resilience lens. We must address the convergence of crises and tipping points which have created this Planetary Emergency including the most recent health pandemic. We must be mindful of building more resilience into both our human and planetary systems. We estimate that future crises will create increasing and dangerous feedback loops and intensify the age-old conflict of food insecurity throughout the world. We have no more time for incremental policy or "business-as usual" actions.

The resilience of food systems needs to be strengthened in such a way that the foundations (social, economic, and environmental) needed to produce sufficient, healthy food and maintain healthy ecosystems underpinning the food production are not compromised for current and future generations. These new solutions demand a comprehensive approach integrating and optimizing collective, game-changing answers to problems of climate change, biodiversity loss, conflict, epidemics, economic crises, food insecurity, malnutrition with its concomitant diseases, and equity for those in poverty, including the inequalities of food due to poorly distributed land and water management. These are structural root causes of increasing hunger. It means we crucially must also take into consideration not only the terrestrial but the oceans' habitats as major sources of food and employment for peoples throughout the earth. It should be noted that not all systems have equal resistance to climate warming effects. Some are very fragile in the face of higher temperatures while others are more tolerant and may absorb more heat before showing harmful symptoms.

It is clear that the much of the oceans spaces for growing human food will respond differently to the future warming trends predicted by IPCC than the terrestrial spaces in terms of the driving forces allowing human food to be harvested:

1. **The physical properties of water will create more moderate temperature rise in the oceans than will occur on land**. This lesser marine temperature increase in the marine environment may well not be beyond the upper thermal limit of most edible plants and animals harvested from the sea (with the coral reef exception), whereas terrestrial temperature increases are already manifesting beyond a series of agricultural plants and animals in livestock upper thermal limits especially in desert areas as well as in other specific land agricultural areas;
2. **Forest fires will not impede food from the sea** as they have been demonstrated on land;
3. **Lack of required water to the point of no harvest and making lands barren** is far less likely to cause decrease in marine food productivity harvest than in terrestrial settings. But all can be damaged by pollution and combinations of pollutants and climate change.

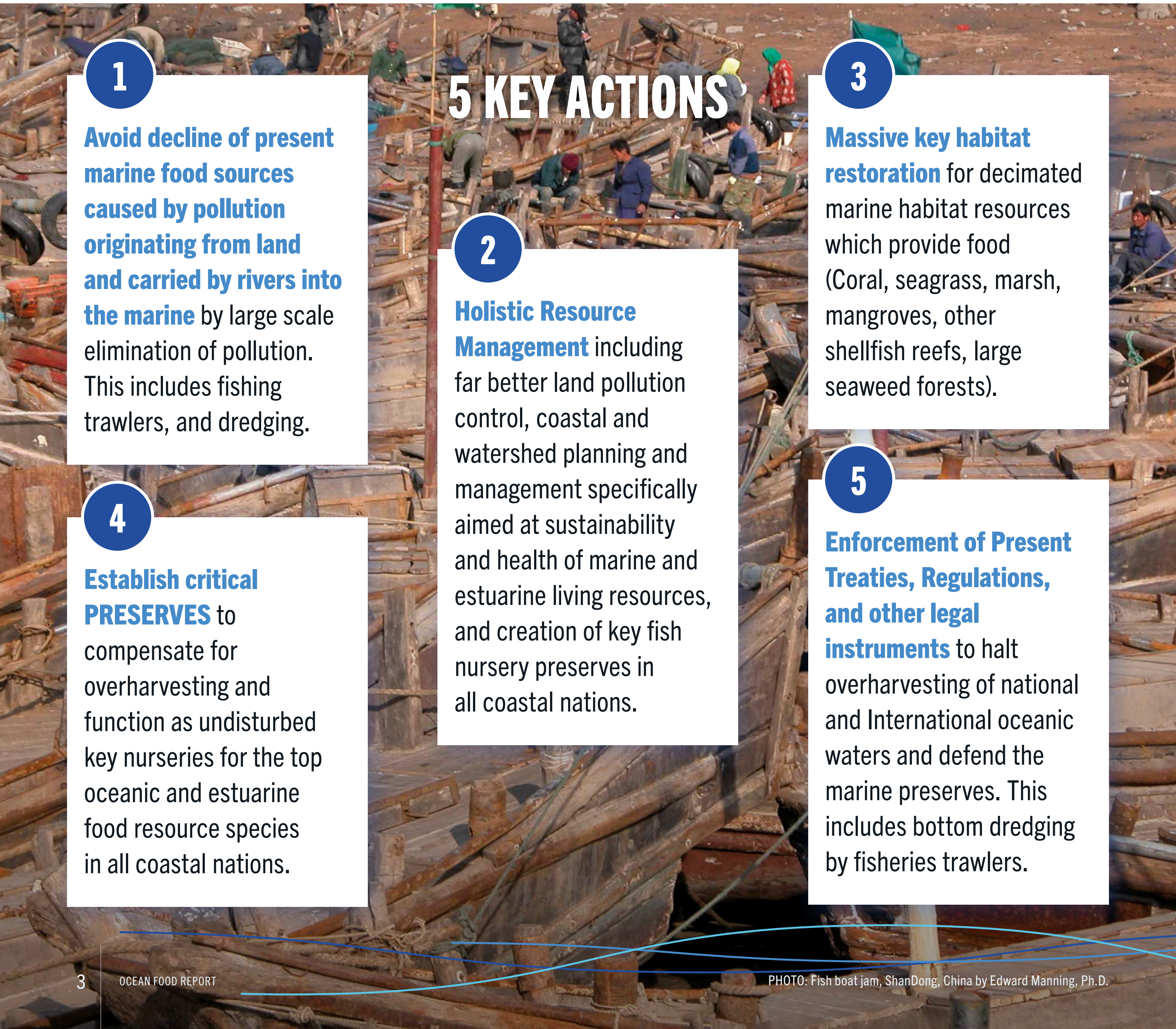
Additional to these climate change issues, the terrestrial space has few unexploited areas for additional food production, whereas the marine space has enormous potential for spaces for food production (if carefully managed for waste streams and for actions non-detriment to fundamental habitats).

In terms of equity, most productive terrestrial farmland is in the private sectors' ownership. Most of the marine space for food production is government owned or seen as internationally available which may allow more equity in the food production process if governments and international orgnisations manage the ocean space correctly and equitably.

Many global regions have not undertaken the initiative of mariculture of both plants and animals to same level as has Asia to augment their terrestrial food production. Declining wild fish biodiversity is present in major ocean basins and is presently correlated with lower catches and higher incidence of stock collapse (FAO, 2020; WEF, 2020; WWF, 2020). Decades of overexploitation of wild fish stocks, accompanied by pollution and climate change has led to crash of stocks with observed examples of the North Atlantic cod stocks, as well as depletion of near shore and reef fisheries for artisanal fisherfolk. Alarm signals of irreversible damage to the marine ecosystems are beginning to appear (Dixon-Declève et al., in prep).

This includes several factors in the oceans' chemistry's baseline for its biota's growth changing with measurable increases in temperature, de-oxygenation and acidification (IUCN, 2019). Climate Change events are also being played out surrounding the oceanic dissolved carbon dioxide cycle demonstrating global fishing activity by industrial fishing trawlers plus dredgers, which investigators estimate to disturb 1.3% of the Earth's seafloor each year. The re-mineralization of sedimentary carbon by fishing disturbance of the seafloor is thought to be equivalent to 15–20% of the atmospheric CO_2 absorbed by the ocean each year (Sala et al., 2021). Halting bottom dredging has been carried out successfully in multiple nations, so this CO_2 input is highly probably to be regulated and managed, although many nations demonstrate poor marine environmental enforcement. This disturbance is comparable to estimates of carbon loss in terrestrial soils caused by farming.

We recommend 5 key actions for reversing the decline of fisheries and enhancing oceanic food resources and nutrition derived from the oceans and its coastal and estuarine spaces.



5 KEY ACTIONS

1

Avoid decline of present marine food sources caused by pollution originating from land and carried by rivers into the marine by large scale elimination of pollution. This includes fishing trawlers, and dredging.

2

Holistic Resource Management including far better land pollution control, coastal and watershed planning and management specifically aimed at sustainability and health of marine and estuarine living resources, and creation of key fish nursery preserves in all coastal nations.

3

Massive key habitat restoration for decimated marine habitat resources which provide food (Coral, seagrass, marsh, mangroves, other shellfish reefs, large seaweed forests).

4

Establish critical PRESERVES to compensate for overharvesting and function as undisturbed key nurseries for the top oceanic and estuarine food resource species in all coastal nations.

5

Enforcement of Present Treaties, Regulations, and other legal instruments to halt overharvesting of national and International oceanic waters and defend the marine preserves. This includes bottom dredging by fisheries trawlers.

PHOTO: Fish boat jam, ShanDong, China by Edward Manning, Ph.D.

AVAILABLE RESOURCES

To evaluate the possibility of Earth's oceans to theoretically provide food for humankind we can start from the basic characteristics of Earth's ecosystems. The sea covers about 71% of the world's horizontal space, whereas the terrestrial realm covers 29 % and fresh water space covers 2%. Much of the productivity of the oceans occurs in the interface between land and sea, the shallow estuarine and coastal realm throughout the oceans and seas. Although occupying little space, this areas' productivity is great, particularly in the tropics. In the open oceans, a large portion of the photosynthesic productivity occurs in the thin red to green light layer at the top of the oceans from small unicellular plants (blue-green algae). On the temperate coastal shelves, the macro-algae forests, in estuaries and open coasts the intertidal marshes, and seagrasses while in the tropics the coral reefs, mangrove forests and seagrasses form the fundamental ecosystems.

In terms of converting the suns' energy into consumable materials energizing humans as food, the oceans' productivity is great due to its massive plant ecosystems. The microscopic plankton photosynthetic rate per unit mass is much higher than that of terrestrial plants, so that the total oceanic productivity rate is high despite the difference in biomass, which biomass is greatly skewed in land plants toward the trunks and roots (which are non-photosynthetic plant portions) and are meant to support the leaves access to sunlight. Within the "net primary productivity" (NPP) measurements, there are similar amounts for terrestrial and for oceanic productivity, both in the order of 50 Gt (gigaton) of carbon per year.

In the terrestrial space, large areas of the world's forests have been altered chiefly to create space for agriculture and animal husbandry, but also for urbanization and human infrastructure (FAO, 2020) (animal husbandry consumes much of this space). In ocean space much habitat destruction also has occurred. For example, in the southeast Asian estuaries 50% of the ecosystems are considered to have been damaged or destroyed (Ooi et al., 2011; Fortes et al., 2018), in Atlantic Oceans' Gulf of Mexico about 50% near shore and estuarine destruction occurred. (Duke and Kruczynski, 1992). When we examine the human food potential from the oceans, we find two types of food: animal protein and plant-based foods. The sea is one of the few areas in which mankind continues their practice of "hunting and gathering" , which has been replaced by growing food in almost all reaches of the planet. This is changing rapidly as the last frontier of the "Hunt" since mariculture has overtaken "wild-catch" rapidly. In the light of increasing mariculture amounts from the sea there are new realities and a new vision is occurring. "Food from the sea is produced both from wild fisheries and increasingly from species farmed in the ocean (mariculture). The protein produced in these spaces currently accounts for 17% of the global production of edible meat" Costello et al. (2020) "edible food from the sea could increase by 21–44 million tonnes by 2050, a 36–74% increase compared to current yields. This represents 12–25% of the estimated increase in all meat needed to feed 9.8 billion people by 2050" Costello et al. (2020). Maricultured protein production is rapidly increasing, especially in Asia however, also in other regions in newly industrializing nations, but insufficiently to completely substitute for livestock protein. Maricultured vegetative algae in Indonesia, as an example is increasing rapidly to surpass the last decade the mariculture of protein from fish and shellfish. (Note: these marine vegetative products have all minerals needed and many organic compounds such as vitamins for human nutrition.) Additionally, fish production supplies about 12% of global employment. The questions

of food production efficiencies, genetic creation of nutritious plants, and other normal agricultural investigations have not yet been applied in wide-scale to mariculture, especially plant mariculture. However, this lack of "seed" companies, and fertilizers, etc. and the government owning most of the marine space makes the equity of food production greater in mariculture than in agriculture.

Overall, fisheries production (including invertebrates, e.g. crustaceans, mollusks, etc. an important primary protein source for 3.1 billion people) is 177.8 million metric tonnes per year (FAO, 2022). Terrestrial protein production is 202 million metric tonnes. The world production of grain has been of some 2.2 billion tonnes in 2017 of 9.4 Billion Tonnes. So, the food that forms the staple diet of humans, grain, is produced in an amount that is about 12.4 times larger than that of marine protein and 10.9 greater than terrestrial proteins. From the net oceanic productivity, the current human extracted resource portion from the sea estimate is a very small percentage.

In a Nature Journal article titled, "The Future of Food from the Sea", Costello et al. (2020), attempted an answer to the question of how much sustainable oceanic food production can be extracted from the sea in the near future with a scientific and economic roadmap: The authors conclude that by 2050, the ocean could sustainably provide 80-103 billion kilograms of food, a 36-74% increase compared to the current yield of 59 billion kilograms. Crucially, the 2050 numbers were not a simple calculation of the carrying capacity of food production, but instead reflected the economic realities of growing and harvesting food in the ocean. The authors identified four key steps towards a more bountiful ocean:

1. **Improve fishery management**
2. **Implement policy reforms to address mariculture**
3. **Advance feed technologies for fed mariculture**
4. **Shift consumer demand** (Costello et al., 2020)

Note: The human appropriation of primary production from the sea may seem to be small at present, but a portion of it is the result of the extremely high photosynthetic rate of phytoplankton and the fact that humans do not gather phytoplankton. Thus humans lose much advantage of the bottom of the food-web biomass by eating from the seas at higher trophic levels unlike their pattern of eating grains from terrestrial spaces. This fact may begin to be adjusted by the Asian mariculture which has a substantial increase in macro-algal for foods. A second factor is that eating at the top of the marine food web as in Europe and the Western Hemisphere, misses much productivity since fish reproduce slowly and most of their eggs are consumed into the food web. Many shellfish reproduce less slowly. The real appropriation level of fisheries protein has been estimated at around 17%, somewhat similar to that on land.

PHOTO: Fishing port, Agadir, Morocco by Edward Manning, Ph.D.

How does this transform human food production?

We need a political will at the global level to manage the sea holistically and equitably for all citizens to benefit. We need an integrated coastal contamination management with enforcement as being set forth at the 2022 United Nations Oceans Decade Conference with Heads of International Agencies and Heads of State. This would include an improved network of monitoring contaminants.

We also recommend training in sustainable mariculture practices throughout the world as essential to accelerating the revolution in food production outlined above. A second important way of enhancing marine food while sequestering carbon for lowering global temperatures is an enhancement of global marine foundation species restoration (Mangroves, seagrasses, corals, marshes, algal forests).

PHOTO: Fishing boats, West Coast, Sri Lanka by Edward Manning, Ph.D.

PHOTO: Fishing nets, Kochi, India by Edward Manning, Ph.D.

These above efforts combined can increase estuarine and coastal food production by 25-40%. A balance between consumption, production, waste food, and preservation of habitats is also needed. Each citizen can adjust their consumption and their waste of food. Additionally humans need to explore possible food products to add marine products to their diets as Asians have added seaweeds to their various soups, and added a variety of marine invertebrates to their nutritious foods making them more delicious.

PHOTO: Fishing port, Agadir, Morocco by Edward Manning, Ph.D.

PERSPECTIVES

POLLUTION: It is essential to avoid decline of the present marine food resource of 3-5 billion people by land-based pollutions carried by rivers by large scale elimination of pollution. There are several examples of such large-scale successful efforts, for instance, with the cleanup of the North American continent's Great Lakes, the Chinese restoration of the Yangtze River and of Lake Tai (the latter two providing 20% of the freshwater fish consumed in China).

HOLISTIC RESOURCE MANAGEMENT: is required including far better land pollution control, coastal planning and management specifically aimed at health and sustainability of marine and estuarine living resources, and creation of key fish nursery preserves in all coastal nations. Better knowledge of the resources and resource potential of ocean areas is required and must be shared. Like managed aquatic areas (noted as Great, Lakes, some enclosed aquatic areas) these need to be managed sustainably and holistically based on better science. Many areas of the oceans presently have limited inventories and understanding of the aquatic ecosystems.

RESTORATION: Twenty-five to fifty percent of critical and fundamental marine and estuarine habitats have been destroyed over the past century. It is essential to enhance oceanic food sources to restore these fundamental habitats including elimination of the contaminants presently degrading their health. **It is proved that the fisheries rapidly reassemble once the habitat is restored (McLaughlin et al., 1983)**. There are multiple examples of this success, including many vigorous actions to restore whole estuaries in the USA as well as a series of various coral reefs being actively restored at present. The restoration of fundamental habitat species brings more services than fisheries production alone, but also creates shoreline resilience and massive blue carbon accumulation to assist in lessening temperature increases to fight climate change.

PRESERVATION: Quotas have been shown to be insufficient to manage the marine resources. A superior solution is allow the marine ecosystems to rebuild themselves. A rapid path is establishing marine preserves where human activity except viewing is banned. An interesting example is the Pelagos Sanctuary for Mediterranean Marine Mammals, a protected area extending about 90.000 km^2 in the north-western Mediterranean Sea between Italy, France, and the Island of Sardinia.

MARICULTURE: Finally, mariculture has proved to provide additional high-quality food resources when correctly managed, avoiding the excesses of the current high-intensity and high-capital industrial approach with waste streams. In Asia, major efforts to teach sustainable mariculture techniques to fisherfolk by FAO have created multiple success stories of large nutritional benefits within specific nations. Asians consume a great deal more marine plants than other regions. The Chinese (Temperate species) and USA (tropical and subtropical) technologies of mariculture of seaweed are presently expanding rapidly on all continents, providing highly nutritious food sources and interesting new foods. Improved rules and management systems for mariculture are needed to ensure that no negative impacts of adjacent and used ecosystems and damage to naturally occurring species are permitted

ENFORCEMENT: Present Treaties, Regulations, and other legal instruments to halt overharvesting of national and International oceanic waters can add substantially to greater fisheries resilience and food sources if properly enforced globally.This includes the global commons beyond national boundaries. Most especially in key areas of fish biodiversity and abundance.


PHOTO: Best wicker fish traps, Diani Beach, Kenya by Edward Manning, Ph.D.

CONCLUSION

Humans have been exploiting the Earths' oceans and the rivers for tens of thousands of years. During the past two centuries fishing has become an industrial activity of asset exploitation, although it continues to be a "hunting and gathering activity". In more ancient times, fishing was carried out chiefly for the sustenance of coastal populations, but today it is dominated extensively by pursuit of economic profits for large companies who deplete global and national resources at extremely low costs to themselves (Pauly and Zeller, 2016). This present concept of fisheries leads to a short-term view of fishing as an economic activity using a common asset to exploit with the process of "hunting and gathering" enhanced by 21st century technologies. The result is often twofold: 1.) The exploitation of the fisheries workers; and 2.) A series of nations in specific oceans and seas have participated in the destruction of the ecosystems' food-webs creating short-term maximized profits for certain fisheries industrial sectors. We cannot expect miracles from the "Blue Economy," but a wise and sustainable and regenerative management of the existing resource ecosystems can provide a supply of high-quality food, much needed by the world's human population, especially the poorest who often live near coastal locations. This points to mariculture of key species of plants and animals for human food as well as regeneration of food-webs for natural species. Especially regeneration of food webs such as seagrass and mangrove forests in the tropics and temperate kelp forests (all 50% decimated) can generate renewable ecosytems for the future, while employing millions of low skill workers to carry this out. Mariculture of specific marine plants and animals shows great promise for greatly increasing food from the sea when carefully carried out to avoid wastes damaging ongoing ecosystems within a well regulated and managed global and local system seeking long term sustainability and shared benefits.

PHOTO: Fishing boats, Scott's Head, Dominica by Edward Manning, Ph.D.

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