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Future-Proofing Oceans for Food Security and Poverty Alleviation

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Definitions

Ecological restoration, rehabilitation, and remediation	These are related terms which in this entry are explained as clearly as possible by adapting the definitions provided by Edwards and Gomez (2007). Restoration refers to actions or processes of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed to bring it back into, as nearly as possible, its pristine condition. Rehabilitation is about partially or, more rarely, fully replacing structural or functional characteristics of ecosystems that have been diminished or lost or the substitution of alternative qualities or characteristics than those originally present with the proviso that they have more social, economic, or ecological value that existed in the disturbed or degraded state. Remediation is the act or process of remedying or repairing damage to an ecosystem.
Blue economy and blue growth	Blue economy implies the use of coasts and seas for economic activities with due consideration of their environmental condition. Blue growth refers to expansion of such activities planned in a way as to optimize the benefits from sustainable development of marine resources. Sustainability is, therefore, a key factor in blue growth. The use of these terms and their concepts was motivated by the need to bring green perspectives to the use of oceans. In other words, it was an effort toward transferring the concept of green economy into the blue world (IOC-UNESCO-IMO-FAO-UNDP 2017).
Sustainable marine startup ecosystems	These comprise people, young business ventures, and organizations interacting in a system to create new startup companies based on marine

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ecosystem services. The organizations can be universities, research institutions, and supporting agencies such as incubators, service providers (e.g., financial, legal services), and corporations. They should all be committed to the triple bottom line of sustainable development. Examples of startups are modules of integrated multi-trophic aquaculture systems, sustainable feeds for aquaculture, biodegradable fishing nets that could prevent death of endangered marine mammals (Kim et al. 2016), and ecological restoration sites integrated with ecotourism.

Introduction

Oceans help us in multiple ways and should be of everyone's concern, not just that of researchers. They form the largest ecosystem and life support system of the Earth. Covering about 71% of the surface of this planet, oceans generate more than half of the oxygen we breathe, hold 97% of the world's water, regulate climate, supply food and pharmaceuticals, provide millions of jobs, offer unlimited recreation, and allow trade and transport (Bokova 2013). No matter how far we live from the coast, the influence of the sea is omnipresent. Our dependence on the sea is increasing with the growth of human population. It is a source of protein for more than 1.0 billion people. The ocean-based economy has been estimated to be US$ 125–145 trillion per year (Constanza et al. 2014). The value of goods and services originating from coastal and marine environments is about $2.5 trillion each year, making oceans the seventh largest economy in the world which helps in the livelihoods of 10–12% of the world's population (Northrop 2018). The total asset value is estimated to be $24 trillion (WWF 2015). Obviously, marine conservation is not a luxury; it is a necessity and should be considered for developing business models for sustainable income, food security, poverty alleviation, and social welfare.

The term "blue growth" has become a new buzz word, to highlight the significance of oceans in the global economy. It refers to enhancing the use of coasts and oceans in a way as to optimize the benefits from sustainable development of marine resources. It is a long-term strategy based on the realization that the sea is a driver of global economy and has the potential for endless innovations to spur economic growth, significantly increase its contribution to food security and to curb poverty (ECORYS-EU 2012). Food security is a major global challenge. How much it matters is not difficult to understand from some basic facts and figures. Out of 7.6 billion people in the world, nearly 821 million are suffering from undernourishment or chronic food deprivation (FAO 2018). This figure amounts to one out of every ten persons. Almost all the hungry people live in developing countries. By 2050, there will be more than 9 billion people, and the demand for food will be at least 60% more than what it is today (Breene 2016). Land-based agriculture cannot meet the demand. Land available for agriculture has declined, and humans have outstripped its carrying capacity in many ways. Oceans can be a large part of the solution to this massive problem (Mustafa 2015; Mustafa and Shapawi 2015; Mustafa and Estim 2018) provided they are in a healthy condition. Seafood is a major factor in food security. This can be imagined from the fact that capture fisheries in 2016 supplied 80 million tons of fish, while aquaculture yielded about 90.9 million tons (SOFIA 2018). Including seaweed in this global production raises the total production to 190.2 million tons (SOFIA 2018). The value of global fish exports in 2017 rose to US$ 152 billion (FAO 2018).

Ocean economic opportunities are linked to ocean sustainability without which the blue economy benefits cannot be reaped for the present and future generations. All the key dimensions of human-ocean interaction need to be understood and appreciated for their significance in poverty alleviation, societal welfare, and human survival.

This entry discusses the significance of future-proofing the oceans, i.e., anticipating the future scenarios by best available evidence and scientific analysis and taking measures for minimizing the adverse effects that future events might produce on the ecosystem services. This is essential for future-proofing the supply of seafood and integrity of our economic systems due to the worsening condition of the oceans resulting from pollution, acidification, warming, oxygen deficit, biodiversity loss, and many related problems.

Key Challenges Constraining Ocean Services

Oceans are facing tremendous disruptions from human actions, directly and indirectly. The main impacts are overfishing, pollution, habitat degradation, introduction of alien species, and those linked to climate change (acidification, warming of seawater). These changes are impairing the capacity of oceans to continue to provide the ecosystem services which have a bearing on food security and human well-being. The effects on marine food web and biodiversity are receiving considerable attention. Some of their consequences are well-understood, while others are largely unknown (Jackson 2010; NRC 2010).

Future-proofing of oceans requires reducing impacts and strengthening their resilience to withstand shocks and further impairments. Marine critical habitats deserve priority because of the roles they play in biodiversity and creating living conditions for the species that support the seafood supplies (Roberts et al. 2005). There is no dearth of information showing that the decline of harvests from the sea is linked to degradation of habitats such as mangroves, seagrasses, and coral reefs. Besides, they help in sequestration of carbon and contribute to reducing the effects of ocean acidification (Roberts et al. 2017). Of all the pollutants that have been taking a heavy toll of marine environment, the plastic waste has come to the forefront of widespread attention (Estim and Sudirman 2017). About 8 million tons of plastic could be entering the oceans if the measurements presented by Jambeck et al. (2015) are given credence. Out of this, 236,000 tons are microplastic (van Sebille et al. 2015) which is hazardous for marine life.

Eutrophication (a process in which a body of water becomes overly enriched with nutrients and minerals that induce excessive growth of plants and algae and cause oxygen depletion) of the sea frequently triggers the formation of harmful algal blooms, often referred to as “red tide” (blooms of toxin-producing unicellular plantlike organisms, referred to as “dinoflagellates,” that impart a red tint to the sea water (Pinet 2009)). Certain species of the algae produce toxins that become concentrated in tissues of filter-feeding fish and shellfish. A large number of seafood species die or are rendered unfit for human consumption. People who consume contaminated shellfish may suffer poisoning, some of which are potentially fatal (Mustafa et al. 2018). Emissions from burning of fossil fuels (coal, oil, and gas) increase the concentration of carbon dioxide in the atmosphere. As oceans continue to absorb this gas, the sea water becomes acidic, and this disturbs the metabolic functions of marine organisms which become vulnerable (Pinet 2009). This has potential effects on fisheries as well as fish farming systems that depend on water supply from the sea. Simultaneously with acidification, the warming of sea linked to changing climate could have devastating effects on seafood production (Mustafa et al. 2013, 2015; Cho 2018).

Food Security and Poverty Alleviation

Food security is commonly understood as a situation when all people, at all times, have physical and economic access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for an active and healthy life (FAO 1996). The role of food harvested from the oceans for household food security depends on many factors, including availability in the market, accessibility, affordability, and stability of supply in all seasons and cultural practices in harvesting and consumption (FAO 2016). Fish landed by small-scale fisheries are a source of protein, omega-3 fatty acids, and micronutrients (vitamins and minerals), especially for the world's impoverished people. Without capture fisheries, they could not afford these nutrients from other foodstuffs that are expensive. Many small pelagic fish, especially sardines, anchovies, some species of mackerel, and others that are marketed at low price, are not nutritionally inferior and are regular food for low-income coastal communities. They have a direct significant contribution to food security and in lifting many people out of poverty and malnutrition. Being planktivorous (species that consume tiny organisms in the sea called as plankton which drift in the sea and are unable to swim against water currents), these fish are key to developing more sustainable and climate-friendly seafood systems. Anchovies and certain smaller marine crustaceans are eaten whole, and this amounts to more efficient utilization of sea harvest. For a better assessment of the role of fish, it is necessary to understand that poverty has many dimensions related to lack of means to meet the basic personal needs such as food, clothing, and shelter. Thus, it is not merely lack or shortage of money but many aspects of life experiences in matters of health, education, and quality of life marked by deprivations as explained by the United Nations Development Programme in 2006.

Farming of species such as groupers and lobsters which sell at a high price may be beyond the purchase capacity of poor communities, but monetarily it helps people through employment opportunities that the farming creates. However, in the context of food security, it should be of concern that landings of low-price species are not diverted to feed expensive farmed fish. The integrated multi-trophic aquaculture that combines farming of high-value fish, shrimp, or lobster with seaweeds and benthic invertebrates (animals that do not have vertebral column and live on, in, or near the seabed) is the low-carbon aquatic food farming that maximizes the yield for growers and minimizes the impact on the environment (Estim 2015) in addition to making fresh food available to the indigenous communities.

Seafood production and processing provide jobs and income to millions of people (fish workers and their families). This helps in their capacity to buy food to stay nourished. There is a long value chain comprising harvesting associated with the capture fisheries or farming, processing, and marketing which are all labor-intensive and engage a large number of people. Women control most of these operations, and this helps in meeting the social empowerment goals of sustainable development. In most of the developing countries where malnourishment is widespread, the communities benefit directly from small-scale fisheries (Cliffe and Akinrotimi 2015).

While the Sustainable Development Goal 2 (**end hunger, achieve food security, improve nutrition, and promote sustainable agriculture)** exclusively deals with this matter, all the other Sustainable Development Goals are directly or indirectly connected to sustainable and healthy food (Fabbri 2017), and seafood is playing an increasingly important role in this matter. These are the reasons why fish ranks high in programs aimed at combating malnutrition and poverty (Belton and Thilsted 2014).

An economic powerhouse of the scale of oceans requires generating a momentum for action across the society and a massive mobilization of informed people. It is too late to leave oceans to take care of themselves and undo the damage done by the humans. We need to assume stewardship role and demonstrate it by responsible actions and solutions to revive the ocean ecosystem. Therefore, investment in ocean management should continue through formal education for development of expert human resources and generation of knowledge. The informal education should simultaneously need to pick up to bring all the sections of the society on board for dealing with the issues of sustainability and future-proofing (Ottosson and Samuelsson 2009).

Due to the vastness of the sea and the very visible maritime contribution to socioeconomic development, it makes sense to develop a blueprint aimed at mobilizing the accredited as well as unaccredited education sectors to engage with the oceans. Attaining the desired outcomes will require smart, inclusive, sustainable, and lifelong learning. It is an enormous undertaking that would need transforming the aptitude and attitude of the society. Humans have capabilities and skills which could be innate or acquired and perfected over time (How et al. 1998), but they also have to have the thinking that motivates them to determine how much they can do and how far they can go on matters as important as the sustainable use of oceans. In the context of blue growth, it would imply making efforts toward economic and social progress within the framework of sustainable development. There are many case studies providing evidence of the role of problem-solving research in supporting seafood industry and helping the community. For example, production of hybrid seed of popular species of groupers by scientists of the institutions of higher education contributed to supporting the seafood industry (Shapawi et al. 2018). Cottier-Cook and Miller 2016 have reviewed the specific problems surrounding sea farming and solutions provided by scientific research related to production of disease-resistant shrimp and general biosecurity needs of marine farms. The authors have drawn attention to seaweed industry that accounted for more than 49 percent of total mariculture production in 2014, generated US$ 6.4 billion, provided jobs, and contributed significantly to poverty alleviation. In view of the serious disease problems facing the seaweeds, there is a strong demand for research centers to leverage their knowledge to sustain the industry and help the farming communities (Cottier-Cook and Miller (2016). Significance of linking ocean management for securing blue wealth and economic welfare with new knowledge is evident from the highly analytical work published by Visbeck (2018).

Ocean Future-Proofing Strategies

Due to too many impacts and issues facing the oceans, multipronged strategies are required for their future-proofing. These include the main ones suggested by Galland and Dorothee (2009):

- Education, research, innovation, and outreach
- Future-proofing marine ecosystem
  - Strengthening ocean resilience: reducing impacts (e.g., illegal, unreported, and unregulated fishing, acidification)
  - Rehabilitation of marine critical habitats for protection of biodiversity
  - Expanding marine protected areas
    Designation of multiple-purpose zones
    Enforcement measures: monitoring and accountability
    Data collection systems
    Expansion and ecological connectivity
- Future-proofing the seafood systems
  - Adopting ecosystem approach to fisheries management
  - Embracing ecological aquaculture practices – low-carbon systems, low food chain species, integrated multi-trophic aquaculture, and devising sustainable feeds
  - Climate change adaptations – alternative livelihoods, stock enhancement of low trophic level species, and nature-based solutions
  - Integrated governance (habitat conservation, fisheries, and other areas of blue growth)
- Informed decision-making
  - Linking science with policy
  - Linking national development plans with Sustainable Development Goals

Role of education and research. Education, research, and out-of-the-box innovations can play vital roles in shaping the above strategies for future-proofing the oceans for sustainable development. Education produces informed citizens who can think and act in a rational and responsible way. Research and innovation are critical components of worthwhile higher education (Lassnigg et al. 2017). They provide an essential knowledge base for making wise choices and decisions in matters as important as human interaction with the oceans. There is no better way to comprehensively understand the dynamics of ocean ecosystem and implications of human actions than to look into the evidences provided by scientific investigations. Synthesis of information based on scientific data is generating a great deal of insights into the state of the oceans resulting from inaction as well as from human interventions. Both these projected scenarios and the prevailing condition of the oceans should be convincing enough to decision-makers to act in the interest of sustainability. There is an increasing demand for linking actionable science with the decision-making based on socio-ecological knowledge to build environmental resilience (Grove et al. 2016). However, a significant progress toward sustainability can be made through specific approaches, frameworks, and practices for such actionable science (Childers et al. 2015; Grove et al. 2015). This will be greatly facilitated by institutionalizing the systems for co-designing and co-production of knowledge involving policymaking and funding agencies and institutions of higher education. Such an approach will envisage development of structured projects and use of the information that these projects would generate. The process of collaborative knowledge production will shape the research efforts to be demand-driven and ensure commitment of the decision-making bodies to implement the findings (Nystrom et al. 2018). In the long-term, such collaborations will foster a scientific temper across the agencies and pave the way for stronger linkage of science with policy and practice (Sepulveda-Machado and Aguilar-Gonzalez 2015). In order to implement the Sustainable Development Goals by the signatory countries, it is necessary to consider that there are multiple actors and stakeholders involved. The economic planning departments have to understand that environmental sustainability of oceans and the blue growth they support are critical to the economic integrity of maritime countries (WB 2018). Success of collaborative projects where specific conservation interventions enhance economic dividends from ecosystem services will become a convincing proof of the essential relationship between environmental sustainability and economic growth. The economic losses and disruption of food supply that will result from inaction (Watson 2016) will also be obvious from the gains that will accrue from the appropriate actions. In developing countries, the poor coastal communities which heavily depend on ecosystem services would obviously disproportionately suffer from food shortage, health, and quality of life (McGuigan et al. 2002).

If the conventional management approaches are inadequate to provide the healing touch to the oceans as rapidly as needed, then the emerging green technology solutions should be worth considering to stemming the decline of the marine ecosystem assets.

A significant turnaround in future-proofing of oceans would require strong policies and plans in favor of a systems approach that recognizes the nexus among the various components of development. Economic growth is inconceivable without environmental resources, and this has been summed up nicely by Juniper (2013) "Nature is not a drag on growth – its protection is an unavoidable prerequisite for sustaining economic development."

Ocean economy is vast and can grow many more times with conservation which would provide careers to people of all levels of skills. It is a misplaced notion that investing in conservation is a luxury of the rich and offers a choice between economic growth and sustaining nature (Hill 2011; Vivien 2018). This sort of thinking has been an impediment to environment-friendly policies. There is no economic activity in the world that does not depend on the services and benefits provided by nature. Coastal communities and researchers have been observing that the degradation of marine critical habitats curtails the fish catch. The worst sufferers are those doing fishing for a living. Catch improves when marine ecosystem is protected (Annita-Yong et al. 2012; Manjaji-Matsumoto et al. 2018). Pursuit of blue growth at the expense of marine ecosystem is the kind of delusion that constraints conservation intervention in policies, resulting in economic losses. As economic returns increase from investment in ocean conservation, ocean-based enterprises will expand, and more career paths (green jobs) will be created. This nexus will help in transitioning to a low-carbon marine economy which will significantly contribute to adaptation to climate change. This is amply clear from wherever studies have been undertaken on the economic benefits arising from marine conservation (Clevo and Tisdell 2002). Based on their observations on marine protected areas, Weigel et al. (2014) have elaborated on how biodiversity conservation matters in fisheries, food security, and sustainable livelihoods. The report generated by Organization for Economic Co-operation and Development (OECD 2017) contained a detailed account based on examination of the effectiveness of marine protected areas around the world. Benefits evident from this report include conservation of marine areas that are home to rich biodiversity, fisheries, buffering the impacts of storms and waves, removal of excess nutrients and pollutants from water, creating more suitable ecotourism and recreational avenues, and enhancing non-use values such as those associated with culture and heritage. Progress in expanding the coverage of marine protected areas has got a great push from the Sustainable Development Goals. OECD (2017) has projected the ocean-based industries to double their contribution to global value-added ecosystem service benefits by 2030. Brander et al. (2015) have estimated these benefits to be around US$ 622–923 billion over the period 2015–2050 if the world can achieve the target of increasing the coverage of these areas to 10% of the ocean surface. Marine protected areas can be more effective with rigorous management and networking for connectivity as these efforts will boost ecological connections over vast areas rather than limited locations. Ideally, networks of marine protected areas should be designed with due consideration of future challenges (Jackson et al. 2014).

The integration of science and practice to advance the goals of resilience and sustainability of oceans should be the core of collaborative knowledge production but not to the exclusion of other sources of knowledge or the experiences of the communities. Knowledge generated by academia in the areas of social science, economics, and humanities as well as the traditional knowledge, even if non-scientific, held by the communities that have a long history of interaction with the sea, deserves consideration in devising management measures that are acceptable to all sections of the society (Hasan 2011). It motivates the communities to join the efforts of scientists and decision-makers. Ignoring the traditional knowledge will not help in evolving viable solutions (Senanayake 2006). The issues involving coastal communities are not uniform across the regions and cannot be addressed by a fixed high-tech solution. Harvest and income from coastal marine environment have been at the center of the food systems and local economies of maritime countries, but there are qualitative and quantitative differences depending upon ground realities. This has to be accepted as a basis for adapting diversified approaches toward sustainable living and for unlocking the potential of the key sectors such as fisheries, aquaculture, and nature tourism targeted for socially inclusive and environmentally sustainable blue growth and green economy. The strategies suggested by Shephered (2004) comprising conservation and sustainable use of the natural resources support this view. Furthermore, the local and regional experiences pertaining to sustainable exploitation of ocean resources have been highlighted in the report published jointly by many international agencies (UN-DESA, UN-DOALOS, OLA, IAEA, IMO, IOC-UNESCO, UNDP, UNEP, UNWTO 2014).

Role of green technologies. It is pertinent to discuss the issues concerning the so-called disruptive innovations (innovative use of any enhanced or new technology that replaces and disrupts the use of an existing technology due to significant advantage(s) it offers) to address the concerns of many people and what it means for sustainable development. Oceans are a subject of global attention for examining their rapidly deteriorating condition and exploring ways and means of protecting the ecosystem services they provide. The world is realizing that transformative changes in managing the oceans are urgently needed. Marine conservation efforts are likely to gain from this attention. Already, there is an increase in the coverage of marine protected areas, and more regulatory regimes are being implemented (Halik et al. 2018). If the conventional management approaches are inadequate to provide the healing touch to the oceans as rapidly as needed, then the emerging green technology solutions as elaborated by WEF (2017) are worth considering to stemming the decline of the marine ecosystem assets. Their application should move hand in hand with rigorously monitoring the consequences of the various interventions and shaping the technologies that protect the ecosystem. Innovations such as satellite-based monitoring of fishing activities, collection of data by underwater drones, robotic fish and other gliders equipped with artificial intelligence, low-cost sensors, DNA-based tracking, processing of big data, and other such devices may greatly help in conservation efforts and creating a new future for the oceans. Marine restoration can also be boosted by 3D printed artificial reefs and other habitat components. This has been shown by new coral growth and shelter that these structures provide to many marine animals (Guest et al. 2018).

Digital disrupting technologies are also making way into sea farming (aquaculture) to increase seafood production. This is the fastest-growing animal food production industry in the world. The consumption of farmed aquatic food has exceeded that harvested from the wild (FAO 2018). This proportion is likely to increase as supplies from land-based food systems decline and oceans compensate for shortfall in agriculture. The emerging technologies are showing a new dimension for spectacular increase in aquatic food production to meet the seafood security targets. Examples include farming of fish in the deep sea and using technology for programmed automatic feeders to keep the fish nourished, deploying drones and robotic devices with artificial intelligence to monitor and repair the cages and to flush out fouling organisms. Some of these applications have been outlined by Mustafa et al. (2016) and WEF (2017).

Disruptive technologies will certainly have a bearing on the employment market. Some job duties could be automated as employers see a better and more efficient control on their operations and reduced expenditure (WEF 2017). Any major shift from established to disruptive technologies is unlikely in small-scale fisheries and fish farming sectors in the near future. These enterprises involve labor-intensive operations and are managed as a family business (Iruo et al. 2018). Bringing high-end technologies will not happen so soon in this sector. Moreover, the scale of operations is small, and gadgets equipped with artificial intelligence are costly and their functionality beyond the skills of fisher folk (WEF 2017). It is when the industry grows and increases the product turnover that jobs will be created for graduates who would be more knowledgeable of emerging technologies (Girard and Payrat 2017). Many universities around the world have started future-proof education by exposing the students to disruptive technologies as a part of their efforts to move with the Industrial Revolution 4.0. Universities in Malaysia are being urged to embrace this technological revolution in teaching and research (Shapawi 2018). The topics of priority in marine biological resources management and aquaculture include artificial intelligence, robotics, augmented reality, biosensors, and, of course, the technology that interconnects various technologies for computing and communications (Internet of Things). For example, in open ocean fish farming systems, the robotic devices capable of collecting data obtained through sensors will transfer the information to computers or smartphones or even take measures as programmed without further human intervention. All the sub-sectors of blue growth will continue to need hard as well as soft skills no matter what the level of automation is used to commercially develop them. Creative entrepreneurs will always find ways of income generation in the innovation-driven blue growth.

Conclusions and the Way Forward

The ocean economy is essential to the global food security, health, prosperity, and general well-being of humankind. As the world's population continues to grow, we will have to increasingly rely on oceans to provide goods and services. However, unleashing the full potential of oceans would require knowledge-based approaches to turn development challenges into inclusive and sustainable blue growth opportunities. Blue economy rejects the notion that economic growth and environmental protection are mutually exclusive. In fact, compatibility with the environment is a prerequisite for the ocean-based businesses to be sustainable and profitable.

As explained above, many of our food systems are currently unsustainable. They have adverse consequences for marine biodiversity and ecosystem and cause nutrient losses, depletion of fish stocks, and carbon footprint. There are complex interlinkages between the ways natural resources are used in producing seafood and environmental impacts of all the food-related activities. An understanding of these processes calls for decoupling of fisheries and fish farming from environmental degradation. This is entirely possible. The ecosystem approach to fisheries management and ecological aquaculture that uses knowledge to integrate natural processes that forms links in seafood production provides a strong basis to make a rapid transition to sustainable development of these sectors. Understanding and unlocking the potential of oceans are keys to achieving all the Sustainable Development Goals. While the Sustainable Development Goal 14 focuses on oceans, the intricate interconnections of this goal with all others in providing diverse benefits to human beings are too obvious to be ignored. Viewed from this perspective and translated into action on that basis will promote coherent ocean policies for a thriving blue economy as well as fast-tracking progress across the global goals of development. The bottom line is that our decisions should be informed by science and the best evidence available from diverse sources of knowledge. Integration of this broad knowledge base with policy and practice will advance the oceans' resilience and sustainability, will promote blue economy, and will augur well for future-proofing the oceans.

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