Biologists and Economists perspectives on the Blue Economy

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Biologists and Economists Perspectives on the Blue Economy

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Abstract

One-third of Earth is covered by ocean, and it is strengthened by massive diversity. Throughout history, humans have resided along coastal areas, investigating the growth and behaviour of marine life to enhance resource utilization and ensure their protection. The Blue Economy focuses on economic activities concentrated around the ocean, including tourism, transportation, energy, and fishing. Blue biotechnology supports sustainable growth in maritime and marine industries for economic opportunities and innovation. The blue bioeconomy and biotechnology industries are exploring untapped marine resources like microalgae, bacteria, fungi, and invertebrates for various commercial applications. These marine organisms are being used to develop a diverse range of products like food, pharmaceuticals, cosmetics, and more. However, environmental changes are impacting marine life, affecting its distribution, abundance, and composition. This is straining the blue economy and the essential services it provides to society. Hence, this review encloses the significance of researchers in various fields like food,

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aquaculture, bioenergy, pharmaceuticals, and biochemicals. In the future, biologists must need effective policies from the government, collaboration, and support of industries for the sustainable blue economy.

Key words: Blue Economy, Marine Ecosystem, Biotechnology, Food Production, Marine Drugs

INTRODUCTION

Life evolved in oceans, which account for more than 95% of the biosphere. 70% of the earth is covered by marine environments. Most of us don't consider the connection between marine life and humans on a daily basis. The sustainable use of ocean resources for increased economic growth, better livelihoods, and ocean health is known as the "blue economy," also known as the "ocean" or "maritime" economy. The term was coined only in 1994 by Gunter Pauli, a Belgian economist, in his book 'The Blue Economy: 10 years, 100 innovations, 100 million jobs.'. The term was subsequently endorsed at the United Nations Conference on Sustainable Development, which is also known as “Rio+20”, held in Rio de Janeiro in 2012 (Khan, 2021). As an integral component of the blue economy, the evolving field of blue biotechnology leverages algae, bacteria, and seafood to ascertain sustainable utilization of marine resources for economic advancement, healthcare, personal care, animal care, and other related sectors. The blue economy concerns marine living resources, associated industrial sectors, and growth catalysts. Green processing of seafood waste for large-scale product development aimed at zero waste employing algal and biorefinery technologies has particular potential to improve blue economy.

The Indian Ocean provides a broad range of support: conservation of biodiversity and ecosystem services provided by mangroves and coral reefs and underwater grasslands to the depths of the ocean and offers economic benefits, quality goods, and services like nutritious food and livelihood. (Ninawe, 2017). A novel business concept that generates value from waste and byproducts by mimicking how natural systems operate. He emphasized how the biotechnology, aquaculture, and renewable energy industries can spur economic expansion while advancing social inclusion and environmental sustainability. (Pauli, 2011). Marine resource utilization is essential for achieving economic growth by responsibly preventing biodiversity depletion and pollution. The oceans play a crucial role in maintaining a healthy environment by acting as the largest carbon sinks, absorbing approximately 30% of the world's CO_2 emissions. (Martínez-Vázquez et al., 2021; Bennett et al., 2019). In the blue economy, biology plays a dominant role due to the uses of marine resources for economic growth and to improve livelihoods. Moreover, algae, sponges, and microorganisms are reliable to make products through various processes by the implementation of science and technology. The major advantage of these organisms is that they are very useful renewable marine resources. Hence this review is focused on the significance of biology and its output on the blue economy.

Biotechnology in the Blue Economy

A variety of industries are included in the blue economy, including marine biotechnology, energy, shipping, aquaculture, fisheries, and tourism. Its potential to support poverty alleviation and sustainable development has drawn interest from stakeholders, academics, and policymakers (Smith-Godfrey, 2016).

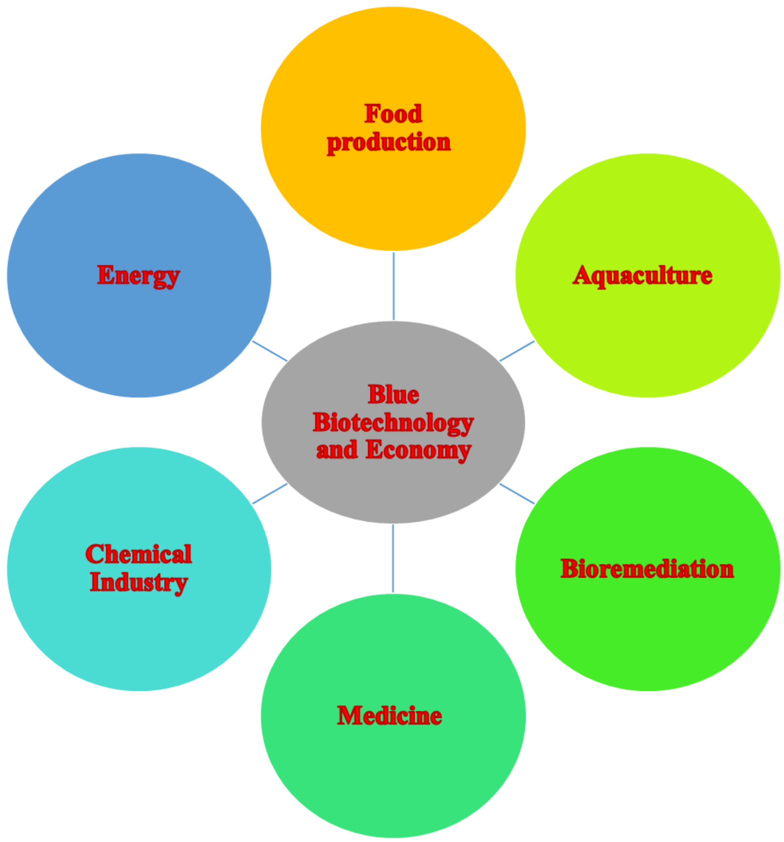

Figure 1. Applications of Biotechnology in Blue Bioeconomy

The green processing of seafood waste biomass for large-scale product development, with a focus on zero waste through the utilization of algal and bio-refinery technologies, holds specific potential for enhancing the blue economy. The isolated products can be applied in health, therapeutic, and industrial sectors, promoting zero-waste seafood processing and supporting environmental conservation and the blue economy while contributing to the United Nations' Sustainable Development Goals (Venugopal, 2022). Utilizing biorefinery methodologies can help process seafood waste biomass in an environmentally friendly way. Future advancements in food waste management aim to create a circular system that balances resources. Technological advancements and a circular bioeconomy policy, including the blue economy, can help achieve sustainable development goals (Mark et al., 2020).

In another direction, developments in eDNA and associated genomic tools have the power to transform the field of biology, covering a wide range of life forms from microbes to mammals, across various environments like the ocean floor and the sky. Progress in tagging and tracking technology is enhancing research in marine life, with advancements expected in acoustics in the coming years. This information will offer valuable insights into ecosystems and could potentially uncover new possibilities in regenerative medicine and beyond. Cutting-edge technologies will play a crucial role in defining the future of the blue economy (Curry and Ausubel, 2021).

Marine Food Products in the Blue Economy

Biotechnology offers great potential for creating natural products that could be used in the food and pharmaceutical industries (Rotter et al., 2020; Martínez-Vázquez et al., 2021). The term "blue foods" refers to animals and plants harvested from oceans and coastal waters, as well as from inland waters, known as aquatic foods. The blue economy and blue food sector aim to increase profits and seafood production, working together to improve nutrition and food security from the oceans (Simpson, 2011; Troell, 2019; WorldFish, 2020). Generally, the rise of the blue economy can lead to increased production and consumption of blue food. The industrialization of the ocean economy may impact the food supply, and increasing food production can reduce hunger by ensuring easy access to existing food. Mariculture is expected to surpass capture fisheries, which provide half of the world's fish for human consumption and livelihoods for millions (Mustafa et al., 2019; Hic et al., 2016; Hasegawa et al., 2019; Be´ne´ et al., 2016).

It is a new and growing industry within the bioeconomy, which focuses on utilizing renewable biological resources from both land and sea. For instance, the growth of seaweed is anticipated to offer sustainable biomass, which supports the advancement of the marine bioeconomy through BG (Froehlich et al., 2019) and is seen as a standard in the industry for achieving a competitive, circular, and sustainable economy with reduced reliance on fossil carbon (Bell et al., 2018). Revamping of food systems is crucial for enhancing resilience, promoting sustainability, and protecting human health, the economy, and the environment (W. Bank, 2020). Fishery by-products, such as seafood waste biomass (SWB), are being recognized for their value and potential to be used in various products like fish ensilage, fertilizer, and animal feed (Mozumder et al., 2022). Maximizing the use of seafood resources efficiently can help prevent environmental problems and increase their commercial value, offering a range of benefits across health, social, economic, and environmental dimensions and leveraging Seafood Waste Biomass (SWB) as a cost-effective and sustainable raw material for industrial components.

Seaweed cultivation plays a significant role in promoting sustainable food production in marine environments. Likewise, the cultivation of seaweed provides ecosystem benefits such as habitats for fish and nutrient appropriation. (Hasselstrom et al., 2018). In response to the growing demand for higher food production due to population growth, seaweed liquid extracts enhance crop health and yields. In accordance with that, many manure and agro-industries are utilizing the benefits of seaweeds, which leads to increased food production (Bharath et al., 2018). Brennan, from McKinsey and Company (2021), stated that cultivated meat and seafood, also known as cell-cultured or cell-cultivated, involves using animal tissue samples to replicate cells on a large scale in industrial settings, resulting in meat that is indistinguishable from the original animals. Scorse, 2021, described there is tremendous opportunity for global seafood production that is truly "blue" and can provide sustainable protein for a growing population without the myriad negative externalities of industrial fishing. The remainder of this brief will outline the three sectors that can meet this challenge: sustainable aquaculture, cultivated seafood, and plant-based seafood alternatives, followed by a short discussion of the policy responses required to accelerate this transition.

Boosting food production from the ocean is seen as a way to improve sustainability and health. However, this potential is being overshadowed by interests in the rapidly growing 'blue economy. The increase in 'blue food' production is expected to enhance food quality and nutrition. Security and mariculture are expected to replace marine capture fisheries. Farmery et al. (2021) suggested research and policies need to address these blind spots to maximize the benefits of blue food and achieve the Sustainable Development Goals. Hall and team (2013) argue that seafood and fisheries should not be viewed simply as commodities, especially in developing countries where traditional fishing activities are crucial for food security. Sustainable management and governance are vital to ensure a steady supply of seafood and maximize the contributions of fisheries to local economies and communities, beyond just ecological sustainability and increasing yields (Costello and Ovando, 2019; Hilborn et al., 2020). In the vision of biologists, blue economy is requiring enhanced observation of marine biodiversity and biology. The reason for this is that the current methods of measuring marine biodiversity and biology lack consistency and thoroughness, preventing informed decision-making on resource use and conservation. The blue economy is a geographical economy that centers on the sea and its assets. This consists of industries like fishing, mining, creating new products, and selling oceanic goods. The blue economy stands out for its focus on fair processes and advantages in ocean industries.

The ocean environment offers natural resources that have important functions in the fields of medicine and biotechnology. Numerous biochemical in nature have been extracted from marine organisms and can provide safer options for cosmetics, anti-fouling agents, medications, and various other goods, including compounds that have anti-cancer properties and potential treatments for COVID-19. The blood of the average horseshoe crab The compound originates from the horseshoe crab, *Limulus polyphemus*, which is utilized for testing injectable medications for microbial contamination (Sigwart et al., 2021). In India, research capabilities of modern marine biology and biotechnology are highly significant due to the presence of wide marine biodiversity and are reserved in a sustainable way. Emphasis on fundamentals of research focusing on applied research of marine biology, marine ecology, and marine biotechnology. Likewise, a variety of scientific disciplines has the ability to generate innovative outcomes of biological molecules and mechanisms related to medications, enzymes, hormones, biodegradable plastics, and metabolic byproducts. It has proven to be a powerful force behind prospective economic expansion and the creation of job opportunities as well as the advancement of sustainable livelihoods for the coastal community (Ninawe, 2017). In India, professionals in scientific and technological fields working within government agencies, research institutions, foundations, and trusts offer lucrative career prospects. Opportunities in the blue economy are being evaluated through research conducted by these highly skilled individuals in accordance with the policies and guidelines of research and development agencies of India, such as the Council for Scientific Industrial Research, the Department of Science and Technology, the Department of Biotechnology, and the Ministry of Earth Sciences, India.

Marine Drugs in Blue Economy

Many research findings documented the biodiversity of marine ecosystems is seen as a source of hope for finding new discoveries. Many chemical components, provide a perfect foundation for further screening of marine natural products (MNPs), particularly to confront the increase in disease prevalence and the ineffectiveness of treatments. The marine sources contain a variety of biological properties like anti-inflammatory, antimicrobial, antiparasitic, antiviral, antimalarial, anticancer, analgesic, neuroprotective, and other remedial activities. There are many medications identified from marine invertebrates such as sea sponges, sea stars, sea cucumbers, sea worms, sea urchins, corals, sea worms and sea hares. There are many obstacles that have been confronted in the marine bio-drug discovery sector, investment in drug discovery, and its contribution of new products to the market for the treatment of various human illnesses (Ibrahim et al., 2023). Pandey (2016) stated that demand and supply of drugs are important issues in the healthcare sector, which could be tackled with fresh approaches and progress in pharmaceutical research focused on species that live in the ocean. The finding and limited bioavailability of marine natural products with low absorption characteristics. The intricate organization, along with their manufacturing for initial testing and clinical trials and bringing to market, are linked to exorbitant costs, unmanageable activities, and significant environmental concerns (Papon et al., 2022). All these factors clearly demonstrate the importance of investing in the marine pharmaceutical industry and its importance in the blue economy sector. This financial endeavor provides innovative and efficient medications in the pharmaceutical industry that help improve human well-being by addressing a variety of important illnesses and long-lasting conditions (Sruthi et al., 2020; MBMOR, 2022). Coincidentally, numerous organizations have taken part in this medical industry sector. Moreover, substantial companies are also significant and engaged in partnerships with organizations that enhance their range of products, like product authorizations, agreements, and collaborations (Marine Biotechnology Market MBM, 2022).

Sigwart et al. (2021) reported on investment in marine biopharmaceutical production. The United Nations Decade of Ocean Science for Sustainable Development 2021-2030 has been initiated; it is imperative to undertake intentional and organized measures to enhance the entire marine biodiscovery pipeline and address its existing bottlenecks. Furthermore, the protracted and costly nature of marine drug development underscores the need for sustained strategic investments over the long term. The industrial sector and private finance community must also make a significant and productive contribution to the development of bio-drug compounds from marine resources. The collaborations between industry and academia at every point. Basically, a lead molecule has effective properties, and then the pharmaceutical company plays an essential role in investment in clinical trials. Marine drugs won't be able to reach the market unless supply can be controlled in a way that is both environmentally and commercially feasible. In addition, the government should be responsible for monitoring the terms of resources and security to develop marine pharmaceuticals in terms of resources, security, etc. (Sruthi et al., 2020).

Recently, Atanasov and his team (2021) reported that limited organizations like Michael Popp, Research Institute for New Phyto-Entities Austrian Drug Screening Institute (ADSI), Bionorica Research, and Biocrates Life Sciences AG from Phytovalley Tirol, Austria, leads to rapid up the natural product-based drug discovery. Alternatively, the International Natural Product Sciences Task Force (INPST) has facilitated the exchange of knowledge, technology, and materials between academic and industrial partners. There are 20 medications with marine origins that are being clinically tested. Interestingly, Alejandro M.S. Mayer of Midwestern University in Illinois, USA, maintains a website called The Global Marine Pharmaceuticals Pipeline. The purpose of the website is to record marine natural products and medications, which provides the details of licensed medications and the status of the drugs undergoing clinical trials (Malve, 2016). Taxol was successfully incorporated into contemporary medicine by the U.S. Department of Agriculture (USDA) and the National Cancer Institute (NCI) for more than half a century ago. A team of chemists, pharmacologists, and oncologists had to work for a while before taxol became one of the most successful new cancer treatments. Many marine natural products, like discodermolide, eutherobins, and sarcodictyins, have attained industry curiosity due to developing better compounds (Jordan, 2001). On the contrary, many businesses have found success in the field of marine biotechnology. The industry is thriving, with major players like Abbott Laboratories, Nofima, Lonza Group Ltd., Aker Biomarine, and others forming strategic partnerships to expand their product offerings through product approvals and acquisitions (Marine Biotechnology Market MBM, 2022). The Pharma Sea project focused on researching and developing pharmaceuticals from marine organisms, funded by the European Union under the FP7 programme. It involved 24 collaborators from various sectors, exploring marine genetics, biosynthesis, and chemical structure. Two successful stories include Prialt from cone snails for pain relief and Ara-C from a marine sponge as a complement to radiation therapy for leukemia treatment. The project aimed to provide medical care to those in critical conditions, such as cancer patients (PSC, 2023).

The marine biotechnology industry is growing with fluctuating growth patterns affected by supply chain and inflation is awaited to protect in the future (MBMOR, 2022). The worldwide marine biotechnology market was worth 5.9 billion dollars in 2022 and is projected to grow at a CAGR of 7.09% from 2023 to 2032, reaching 11.7 billion dollars. The market for marine pharmaceuticals was valued at 26.5 billion dollars in 2020 and is expected to grow to 48.1 billion dollars by the end of 2027, with a CAGR of 8.5% over 5 years. The market for drugs sourced from marine organisms is expected to grow from 2.1 billion dollars in 2020 to 38.9 billion dollars by 2027, with a CAGR of 8.8% from 2021 to 2027 (Marine Biotechnology Market MBM, 2022). GlaxoSmithKline partnered with Life Mine Therapeutics to develop a fungi-based drug to create three potential candidates. FDA approved tisotumab vedotin-tftv in September 2021 for treating recurrent or metastatic cervical cancer. GlaxoSmithKline, a drug development industry, partnered with Life Mine Therapeutics for a $70 million deal in March 2022 to leverage Life Mine's fungi-based drug development engine to create three potential candidates. FDA approved tisotumab vedotin-tftv in September 2021 for treating recurrent or metastatic cervical cancer.

ALGAE IN BLUE ECONOMY

Seaweed farming is a growing industry worldwide, established as a way to bring in foreign currency and income for marginalized coastal communities. Seaweeds are rich in the South Indian marine environment, comprising enormous bioactive compounds and providing an unlimited supply for many pharmaceutical industries (Bharath et al., 2020). International agencies promote seaweed cultivation as a poverty-alleviation strategy for rural coastal areas (Buschmann et al., 2017; Campbell et al., 2019; Rimmer et al., 2021). The short growth period of seaweed and affordable farming techniques lead to generous economic benefits. Despite the vast marine ecosystems suitable for seaweed cultivation across 132 countries, only around 37 to 44 nations are actively involved in seaweed production. All over the world, seaweed has been used for food, fertilizer, and other industry sectors. (Froehlich et al., 2019; García-Poza et al., 2020).

The seaweed industry is booming worldwide, and the production exceeds 32.4 million tonnes, tripled since 2000, due to the promising economic returns (FAO 2020). Recently, Ahmed et al. (2022) documented that Bangladesh is currently focusing on promoting blue growth and sustainable development in the seaweed sector. The blue economy industry is emerging in Bangladesh, with seaweed cultivation identified as a key focus for enhancing economic growth in coastal communities. Seaweed farming shows promise in improving the livelihoods of women, with farmers utilizing methods such as the long-line technique for cultivation. While there are challenges hindering the progress of the seaweed industry, establishing a well-structured value chain can support its growth and contribute to the advancement of Bangladesh's blue economy. The diverse capabilities of seaweed, emphasizing its role in carbon sequestration and potential in the blue carbon economy, were reviewed by Saravanan and team (2023). They noticed that the development of a blue carbon economic model is significant to replacing fossil fuels with sustainable alternatives, such as renewable fuels and also food from marine ecosystems, has led to. Seaweed plays a crucial role in this model by storing carbon and offering various benefits, including aiding in climate change adaptation and mitigation. Seaweed also has potential as a resource for human consumption, cattle feed, biofuels, and other applications. Many scientific publications and organizations highlight how seaweed can contribute to a carbon-friendly economy and address the challenges of climate change. Cultivating seaweed offers promise in alleviating global issues and promoting economic growth and sustainable livelihoods.

Polysaccharides are essential for maintaining the structure of macroalgal cell walls in marine environments. Derived from green algae, ulvans, agar, carrageenans, and porphyrans are common in seaweeds. Red algae contain fucoidan, while brown algae produce laminarin and ascophyllan. Seaweed extracts, particularly carrageenans, are in high demand but limited supply, leading to higher prices. Carrageenans are widely used in dairy products as emulsifiers and stabilizers, as well as in meat products like hams, sourced mainly from Indonesia and the Philippines. The universal carrageenan market is expected to cross US$1 billion by 2024. (Campbell and Hotchkiss, 2017; Pereira, 2020). Agar, a thickening agent derived from red algae like *Gelidium* sp. and *Gracilaria* sp., is gaining popularity in the industrial sector as a sustainable and biodegradable biomaterial. It is used as an eco-friendly alternative for packaging, in addition to carrageenan (Choudhary et al., 2021). Alginates, derived from brown seaweeds like *Laminaria* sp., *Macrocystis* sp., *Lessonia* sp., and *Ascophyllum* sp., bind ingredients together. Calcium plays a key role in spherification, with lactate or calcium chloride commonly used. The blue economy is expected to reach $214.98 million, with the alginate market valued at USD 923.8 million and the fucoidan market projected to peak by 2025 (360 market updates, 2020; Grand View Research, 2020; Choudhary et al., 2021). Biopolymers derived from microalgae have widespread applications in medical, pharmaceutical, and food industries globally. The market is forecasted to reach around USD 35.47 billion by 2022 with a growth rate of 12.5% (Zion Market Research Report, 2018b). Furthermore, microalgae are crucial in the blue economy and sustainable development goals, playing a key role in generating natural resources and eco-friendly bio-products for human and environmental benefits (Pant et al., 2019).

AQUACULTURE IN BLUE ECONOMY

Estuaries are important for supporting various fish species, impacting the economy and ecosystem. Factors like temperature, pH, salinity, and oxygen levels affect fish distribution in the estuary. Proper conservation and improved management of estuaries are essential to increase the fish community, which helps increase the economic status of the local societies (Suganthi et al., 2018). However, previous reports indicate that the aquaculture industry has been achieved significant success, particularly in the cultivation of species like carps, tilapias, and catfish Pangasius. *Pangasius*. This success can be attributed to innovative artificial breeding methods and diverse aquaculture technologies. There are numerous opportunities to explore in cultivating brackish and aquaculture fish species, with yields ranging from 60 to 230 kg per hectare per crop through semi-intensive methods. The industry has moved toward onshore, land-based farming and offshore cage culture, with potential for expansion in artificial breeding and farming techniques. Technologies can be further developed and applied for the benefit of various fish species, including marine ones like mullets, pomfrets, grouper, and marine eels (Hossain et al., 2014; Choudhary et al., 2021).

Approximately 3.1 billion individuals depend on oceans for 20% of their animal protein supply. The sea supplies nourishment through fishing, aquaculture, and seaweed cultivation. Over the past five decades, the worldwide macro algae industry has experienced remarkable growth. It increased at an average annual rate of 8.13% in volume and 6.84% in financial worth from 2003 to 2012. In 2012, aquaculture generated around 23 million tons of macroalgae (dry weight), valued at over 6 billion USD. The ocean offers a range of value-added products such as agar, alginate, carrageenan, ecteinascidin, salinosporamide A, antifouling agents, developmental luminase, ambergris, animal feed and fertilizers, and carotenoids. The blue economy is crucial for economic development and job creation while also protecting ocean health. However, challenges like harmful algal blooms, global warming, and plastic pollution threaten its sustainability. To ensure the long-term success of the blue economy, reducing carbon emissions and limiting plastic waste are essential steps to safeguard marine life for future generations (Narwal et al., 2024). Recently, in 2023, Fattouh and coworkers documented the sustainability of Manzalah Lake, Egypt. The fisheries are being threatened by pollution and dehydration, leading to a significant decline in fish catch and productivity. In 2017, the Egyptian administration implemented an action plan to revitalize the lake, with the NIOF research team conducting a study to assess long-term fish catch patterns, particularly focusing on tilapia, catfish, and mullet species. His team revealed that there was a gradual decline in overall fish catch, but also unexpected increases in reported catches of the primary species. Their findings suggested a need to increase the number of licensed boats and improve the accuracy of catch-effort data to support the livelihood of fishermen and enhance total income from fishing activities in the lake. Moreover, the study emphasizes the importance of protecting fishermen's territory from unauthorized intrusions and ensuring sustainable fishing practices to preserve the ecological, social, and economic aspects of fisheries. Alternatively, the integration of algae with carnivorous fish boosts income for sea farmers, supporting Sustainable Development Goals (Ahmad Ansari et al., 2020).

Fisheries goods and fish play a significant role in the lives of people in the area. Currently, global fisheries harvest around 80 million metric tons annually. The majority of productions in South Asia come from the Bay of Bengal. About half of the fish are caught in India (1.2 million tons annually) and Myanmar (1.1 million tons annually). Sri Lanka and the Maldives catch 0.6 million tons of fish a year, 0.12 million tons annually, and 0.16 million tons annually, respectively, in comparison to India, Myanmar, and Bangladesh (Bari, 2017). Global fisheries today land approximately 80 million metric tons (mmt) every year, employing some 30.6 million people. The marine capture for 2018 was 84.4 mmt based on data from the Food and Agriculture Organization of the United Nations. Up to 10% of the global population relies on fisheries for livelihoods. Mariculture produces over 38.6 mmt of seafood or US$67.4 billion annually, and this is growing quickly, with the potential for 700 times more production in the future. Similarly, global coral reef tourism is valued at US$35.8 billion annually and is expanding (Gaines et al., 2019).

Role of Chemical Products in the Blue Economy

Over 20,000 chemicals are present in various aquatic organisms that have been acquired from the past fifty years (Papon et al., 2022). Marine shells, barnacles, and oysters are natural sources of adhesive. They secrete proteins and adhesives that allow them to adhere to seabeds and rocky surfaces. (Foulon et al. 2018). In addition, sea mussels produce adhesive properties of protein 3,4-Dihydroxyphenylalanine (DOPA) constructed by catecholic functional groups, and hydrogel contains the chemical substance 3,4-Dihydroxyphenyl-lalanine acrylamide-polycaprolactone (L-DMA–PCL). Nowadays, these chemical substances are used in various medications, like bone joining, painkillers, sensing strains in biometrics, healthcare monitoring, and dental therapies (Yuvaraj et al. 2021; Zhang et al. 2021). Formerly, Maoka, (2011) recorded over 250 bioactive chemicals, such as fucoxanthin, alloxanthin, and tedaniaxanthin, derived from marine algae and animals. These marine carotenoids exhibit potential biological properties like antioxidant, wound healing, anti-inflammatory, antiproliferative, etc. In addition, marine-derived carotenoids are used as cosmeceutical and nutraceutical agents to protect the skin from UV and other oxidative stress-related disorders (Galasso et al. 2017; Berthon et al. 2017). Recently, the most prominent substance, hexadecanoic acid, isolated from brown seaweed possesses significant biological properties like antioxidant and anticancer activity (Bharath et al., 2021).

Chitin/chitosan and collagen are crucial bioactive compounds used in pharmaceuticals, veterinary medicine, nutraceuticals, cosmetics, and biomaterials. By using bycatch and invasive species from non-edible fish and shellfish components, a sustainable circular economy show (Vieira et al., 2023). Previously, few biologists were reported that a business plan for chitin and chitosan production in Ecuador has been developed. Global demand for chitosan has been examined. Hence, a method to utilize all components of shrimp waste has been introduced, and based on its potential, shrimp waste is being exported to China. Environmental and economic aspects of chitosan production in Ecuador have not been addressed in existing literature

(Berrezueta, 2014; Andrade, 2013; Changoluisa, 2016; Chavez, 2009). Riofrio et al. (2021) concluded that chitosan production in Ecuador has a relatively low impact on the ecosystem compared to other industrial activities. The production of chitosan in Guayas, Ecuador, shows economic viability with significant profits and quick returns on investment. Costs in Ecuador are economical compared to other studies, making the industry competitive on a global scale. Marine invertebrates, fish bones, and fins are rich sources of essential minerals and nutrients like hydroxyapatite, calcium, phosphate, zinc, selenium, and iron. Fish bones contain about 66% of these minerals, providing 234 grams of calcium per serving. These minerals have various health benefits, including promoting growth and metabolism, accelerating bone healing, and serving as supplements or additives in various industries (Bruno et al., 2019; Nawaz et al., 2020; Jung et al., 2016; Łabowska et al., 2019).

Bioenergy in the Blue Economy

Bioenergy is a sustainable form of energy derived from various natural sources such as energy crops, biomass, wastes, by-products, microalgae, seaweeds, and aquatic plants. It has the potential to substitute fossil energy. Therefore, sustainable bioenergy is expected to have a significant impact on the future economy by aiding in the decarbonization of energy systems and reducing greenhouse gas emissions (Lago et al., 2019). Constant and esteemed efforts of biologists towards sustainable alternatives for fossil fuels are highly venerated. They found microalgae from marine sources to be a promising feedstock for biodiesel production. However, challenges such as high costs for drying and extracting lipids from the biomass hinder large-scale production. As a remedy for that, biologists followed transesterification of the wet microalgae biomass to reduce the production cost (Fazril et al., 2020). Recently, biologists have been highlighting the potential of converting marine waste into bio-based products like bioenergy, edible goods, and nonedible items. This sustainable alternative to fossil fuels is being emphasized by researchers and policymakers, with a focus on producing biofuels such as ethanol and bio methane.

Factors affecting the blue economy

The increase in focus on marine technology for developing new drugs has boosted the expansion of the blue biotechnology market in Europe, with significant growth in the Asia-Pacific region as well, although it is still not widely utilized in other sectors. Insufficient knowledge regarding the utilization of marine microorganisms and their potential applications is impeding the market in this area (Pramanik et al., 2022). Generally, changes in the marine environment lead to alternation in the distribution, wealth, composition, and well-being of marine life in ways we are, as it were, starting to get it, an anxiety of the then anxieties of the blue economy and related administrations required by society. Wells and Karson (2018) documented their changes in marine plankton and benthic communities in coastal and offshore areas due to climate change, impacting harmful algal blooms. Future climate variations may further affect the distribution and frequency of these blooms, potentially increasing their toxicity and biomass. At present, with the gradual increase of industries, CO_2 concentrations have increased due to the burning of fossil fuels, leading to global warming. In 2012, the global mean surface temperature is 0.85 degrees Celsius, with projections of an increase of 2.6 to 4.8 degrees Celsius. The worst-case scenario, Representative Concentration Pathway, predicts high temperatures in summer lead to extensive coral bleaching and disease (Berkelmans, 2002). In addition, the rise of increased CO_2 in the marine environment results in acidification. It may lead to reduced pH, reduced taxonomic diversity, reduced harvests of some bivalve shellfish species, cultural disturbance and revenue loss, and world fishing production, affecting adult maturation, recruitment, and economic value (Cooley et al. 2015). Therefore, physical (e.g., temperature and salinity) and biogeochemical (e.g., oxygen, inorganic, and dissolved organic carbon) factors have a vital role in marine ecosystems to enrich the biodiversity of fish and distribution of phytoplankton biomass (Miloslavich et al., 2018; Suganthi et al., 2020).

CONCLUSION

Marine biotechnology has diverse applications in agriculture, health, industry, and environmental sectors. It can lead to the development of new products, create jobs, and promote sustainability in different industries, ultimately boosting the blue economy. However, it has global implications; its success hinges on tailored strategies at the local level that consider each region's unique characteristics. By balancing conservation and development, a sustainable blue economy can help address climate change, promote sustainable development, and protect biodiversity. The estimation of accurate market value of marine biotechnology products and services is challenging due to sector variations. There is a need to effectively analyze outputs; a shared definition of marine biotechnology is crucial, along with the creation of economic indicators for comparative purposes across nations and time periods. The diverse range of marine biotechnology products and services makes it challenging to estimate their market value accurately due to variations across different sectors. There is a need to establish suitable indicators of inputs and outputs in marine biotechnology; it is essential to have a shared understanding or definition of this field. It is essential to create economic indicators and metrics to analyze marine biotechnology outputs in different countries and sectors for comparative purposes across nations and periods. However, the knowledge of this topic is currently limited. Therefore, the government and industrial sectors have a prominent role in the blue economy; their support and collaboration are much needed for the biologist to make a successful blue growth economy in a sustainable manner.

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