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Exploring Marine Prospects for Entrepreneurship and Innovation

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Abstract

The marine ecosystem, being both diverse and largely unexplored, presents a fertile ground for innovation and entrepreneurship. This review aims to provide a comprehensive overview of the opportunities available in marine entrepreneurship, focusing on both commercial and research-based avenues. On the commercial side, the review discusses sectors such as aquaculture, global transportation, and eco-tourism, highlighting the need for effective production methods and innovative strategies. In the realm of research-based entrepreneurship, the review explores areas like coral restoration, water desalination, and marine-based product development, emphasizing their potential for sustainable utilization of marine resources. The paper also identifies existing gaps and areas that require further innovation and research, thereby offering a roadmap for young researchers and entrepreneurs. The overarching goal is to promote self-reliance and contribute to the betterment of both nature and humanity through sustainable marine entrepreneurship.

Keywords: Marine System; Marine Entrepreneurship; Innovation Strategies

1 Introduction

The term 'marine' describes a diverse array of ecosystems on Earth. Originating from the French word for sea, the marine ecosystem has traditionally been associated with saltwater bodies, including seas and oceans [1]. Oceans constitute the largest component of the marine environment, covering 71% of Earth's surface [2] and accounting for 97% of Earth's total water [3]. Oceans are further divided into various ecosystems based on zonation. Horizontally, the marine surface water is categorized into neritic and oceanic zones, collectively referred to as the pelagic zone [4]. The neritic zone includes waters near the shore and may consist of ecosystems such as the intertidal zone, rocky shores, and coral reefs [5]. In contrast, the oceanic zone may contain ecosystems like kelp forests. Vertically, the marine system is divided into three major zones based on light penetration: the photic, twilight, and aphotic zones [6]. The photic (0–200m) and twilight (200–1000m) zones are characterized by complete and diffused light penetration, respectively, while the aphotic zone (below 1000m) is devoid of light. These zones host unique habitats for free-floating organisms like plankton and sedentary organisms known as benthos. The aphotic zone is home to deep-sea ecosystems such as hydrothermal vent ecosystems [7].

In addition to these zones, marine ecosystems can also be classified based on salt concentrations, including estuaries, salt marshes, wetlands, and rock pools. Other forms of marine ecosystems, such as mangroves, lagoons, and brackish water ecosystems, also exist but are not easily categorized [8]. A visual representation of these various types of marine ecosystems is provided in Figure 1. Despite its rich biodiversity, only 5% of the ocean has been explored, leaving vast areas yet to be discovered [9].

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Figure 1: Various types of marine ecosystems

Moreover, the extraction of ocean resources, particularly petroleum and oil, has escalated since the onset of industrialization, becoming a significant global enterprise [10]. However, such activities have led to considerable degradation of marine life and ecosystems. Anthropogenic activities, including pollution, further exacerbate the negative impact on marine ecosystems [11]. This situation presents a paradox where marine ecosystems face the risk of destruction by pollution even before they are fully explored. Consequently, there exists a significant opportunity for researchers, entrepreneurs, and innovators to not only explore marine systems for beneficial products but also to develop innovative solutions for the conservation and sustainable management of Earth's most extensive ecosystems. This review aims to summarize various fields of marine entrepreneurship and highlight areas requiring innovation for effective marine ecosystem management.

2 Classification of Marine Entrepreneurship Fields

A considerable amount of work can be undertaken in the marine field. This review proposes to classify this extensive field into two major categories based on market orientation: Commercial-Scale Marine Entrepreneurship and Research-Based Marine Entrepreneurship. A detailed classification of these categories is illustrated in Figure 2.

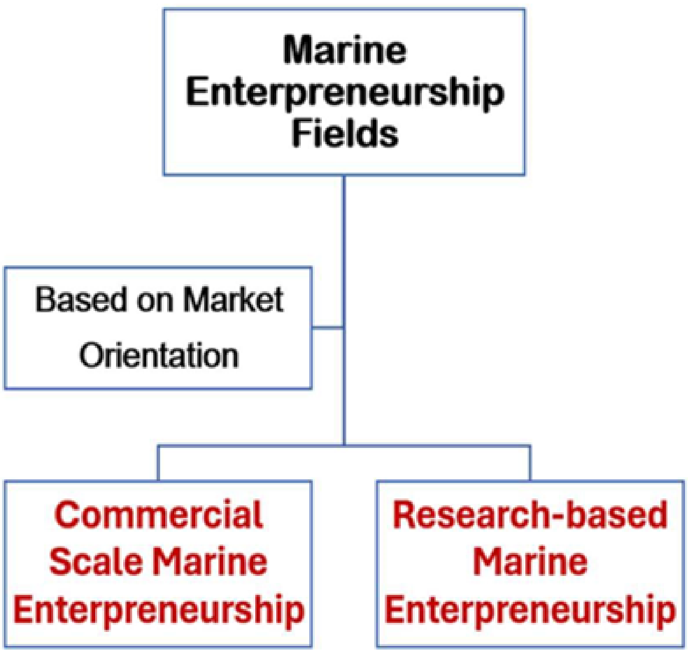

Figure 2: Classification of marine entrepreneurship fields.

2.1 Commercial-Scale Marine Entrepreneurship

Commercial-Scale Marine Entrepreneurship primarily focuses on disciplines that already have a global presence. Significant work is already in progress, and products are being manufactured. A business-oriented mindset is essential for marketing these products to a broader audience. Additionally, innovation is required to establish more effective strategies for the production, processing, and sale of marine products. For example, agar-agar powder, commonly used in making jellies, is already available in the market. In this context, Commercial-Scale Marine Entrepreneurship could focus on strategies to increase sales or reduce production costs. Similarly, seaweed-based essences, perfumes, and cosmetics exist in the market, but their production processes are cumbersome. Groups within this category could work to streamline production and enhance profitability. Common fields within Commercial-Scale Marine Entrepreneurship include aquaculture, the seafood industry, the global transport sector, and tourism.

2.2 Research-Based Marine Entrepreneurship

Research-Based Marine Entrepreneurship necessitates a scientific approach to better exploit marine resources and focus on the restoration of marine habitats damaged over the years due to natural and unregulated anthropogenic activities. A notable example in this category is the Exclusive Economic Zone (EEZ), an oceanic area extending approximately 230 nautical miles beyond a nation's territorial sea. Studies on the EEZ have led to effective strategies for ecosystem protection [10]. Research efforts aimed at simultaneously exploring and protecting deep-sea biodiversity and resources, such as natural gas, also fall under this category. Other fields within Research-Based Marine Entrepreneurship include coral restoration, desalination strategies, and the development of novel compounds from marine microbes.

3 Commercial-Scale Marine Entrepreneurship Opportunities

This section explores various fields under commercial-scale marine entrepreneurship. Figure 3 provides an overview of these fields.

Figure 3: Examples of fields under commercial-Scale marine entrepreneurship.

3.1 Aquaculture

Aquaculture represents an economic human activity conducted in confined areas, aimed at transforming natural aquatic resources into marketable products valuable to society. The scope of aquaculture includes the rearing, breeding, and harvesting of aquatic species such as fish, mussels, and shrimps in controlled environments. The primary objectives are to enhance the growth and survival rates of marine species for both consumption and conservation purposes [12]. Historically, fish were consumed directly from capture. However, it became evident over time that such practices exert stress on ocean ecosystems due to species loss. As a result, aquaculture gained prominence. In the 1990s, the global production of farmed fish was approximately 17 million tonnes. This figure has since increased to around 100 million tonnes [13]. According to 2019 statistics, Asia contributes 92% of many aquaculture products like prawns and shrimps, with China and India being the largest producers [14]. Despite these advancements, aquaculture still accounts for only one-fourth of the fish consumed globally, with the remainder coming from capture [15]. Therefore, there is a pressing need to develop effective strategies to increase production through aquaculture. Additionally, aquaculture water often contains fecal contaminants and nutrient sources, contributing to eutrophication and increasing the risk of harmful algal blooms when released into natural water bodies [16]. Consequently, there is a need for innovative, cost-effective water treatment processes to manage aquaculture water before its release into natural systems.

3.2 Seaweed Culture

Seaweed encompasses all forms of macroscopic algae that flourish in marine water, typically along seashores [17]. Remarkably, seaweeds contribute to 50% of global oxygen production [18]. They are broadly classified into three groups based on pigmentation: Chlorophyceae (green), Rhodophyceae (red), and Phaeophyceae (brown) [19]. Seaweeds have diverse applications, including in the fields of medicine, food, fuel, agriculture, and cosmetics [20]. They are consumed as delicacies, serve as additives in various dishes, and are a rich source of vitamins and minerals. Seaweeds have been shown to reduce the risk of diabetes, cancer, and cardiovascular diseases. They are also used in cosmetic products like face washes, face masks, and anti-aging creams. Furthermore, seaweeds are part of next-generation projects such as organic farming, bioremediation, water mass cleaning, bioplastics, biofuels, and nanotherapies [21]. Seaweed culture involves the cultivation of commercially valuable seaweeds in either natural or artificially induced habitats, such as open oceans or specialized aquatic sites. These sites could be lakes, wells, or areas excavated and filled with water. The water should be non-stagnant, and the ideal temperature should range between 25–30°C. The site should also be protected from heavy rains and winds [22]. Artificial sites must be prepared to be conducive for seaweed growth, which includes the removal of barriers and other vegetation [23]. No fertilizers, pesticides, or insecticides are required for seaweed culture.

Site preparation also involves the collection of materials like nylon threads, digging bars, stakes, and boats [22]. Seaweeds for cultivation can be sourced directly from the sea and propagated vegetatively [24]. Various methods are employed for seaweed cultivation, including the fixed-bottom method, floating raft method, and longline method [22]. Currently, 42 countries, including India, engage in seaweed production. Asia leads in seaweed culture, with China, Korea, and Japan contributing over 80% of global seaweed cultivation [25]. India, with its 7500 km coastline, is a hub for diverse seaweeds with unique potential. Economically valuable species like Sargassum, Porphyra, and Gracilaria have been identified for cultivation along the Indian coastline [26]. Given that many people living near the coastline depend on marine activities for their livelihood, India has the potential to meet global seaweed demand and generate significant revenue.

3.3 Global Transportation

Transportation between countries primarily occurs through three routes: airways, waterways, and land routes. While land routes are not universally applicable, airways and waterways serve as the main options [27]. Airways are often expensive and offer limited capacity due to payload restrictions. Consequently, maritime transportation emerges as the most viable option [28]. Maritime transportation has a long history, dating back to 3200 BCE along the Egyptian coasts. By the 10th century, Chinese merchants had established trade routes. Currently, approximately 55,000 commercial vessels are registered under global maritime shipping industries. In recent years, the Asia-Europe route has seen the establishment of numerous commercial linkages [29]. Maritime transportation is generally classified into four categories based on the type of goods or passengers being transported: passenger vessels, bulk carriers, general cargo ships, and Roll-On/Roll-Off (RORO) vessels. Passenger vessels transport people, bulk carriers handle goods in large quantities, general cargo ships carry lighter weight goods (below 10,000 deadweight tonnage), and RORO vessels are designed for transporting cars and other vehicles [29]. Entrepreneurs and innovators can engage in any form of this global transportation to start a business. However, several challenges require attention, including slow transport services, tracking difficulties, damage during transport [30], and environmental concerns such as oil spills and leaks contributing to marine pollution [31]. There is an urgent need for solutions to make maritime transportation more efficient and environmentally sustainable.

3.4 Eco-tourism Services

Eco-tourism focuses on travel that promotes and supports natural ecosystems, including forests, waterfalls, and oceans [32]. While many travel services offer eco-tourism to wildlife sanctuaries, forests, and hilly regions, only a few specialize in marine-based eco-tourism. Various sources suggest that eco-tourism services present a promising startup opportunity [33, 34]. Additionally, the development of innovative infrastructure designs that minimize environmental impact is a valued sector in this field [35].

3.5 Scuba and Water Sport Centres

Water sports such as swimming, surfing, and scuba diving are popular activities for tourists visiting coastal areas. People are often willing to spend money on these activities, making the establishment of businesses in this sector a viable option. Scuba diving, in particular, has evolved into a multibillion-dollar industry [36]. Entrepreneurs interested in this field can focus on maintaining high safety standards to build a profitable and trustworthy business [37].

4 Research-Based Marine Entrepreneurship Opportunities

This section delves into various fields under research-based marine entrepreneurship. Figure 4 offers an illustrative overview of these fields.

Figure 4: Examples of fields under research-based marine entrepreneurship

4.1 Isolation of Novel Marine Bacteria

Marine systems are renowned for their biodiversity, ranging from the Antarctic blue whale to microscopic marine viruses. These ecosystems also contain small live cells of bacteria and archaea that play a crucial role in the cycling of carbon and nitrogen in the ocean [38, 39]. The ocean surface contains approximately 10^5 to 10^6 cells per ml, while the deep ocean has 10^3 to 10^5 cells per ml [40]. Marine bacteria may belong to various genera such as Pseudomonas, Alcaligens, Flavobacterium, and Bacillus, and can generally be isolated directly from seawater or sediments [41]. Marine microbes typically exhibit characteristics like small size (1–2μm), proteolytic activity, pleomorphism, motility, and slow growth. About 95% of marine bacteria are Gram-negative and predominantly pigmented [7]. These characteristics open avenues for diverse applications, such as the discovery of novel enzymes with higher stability than plant- and animal-based enzymes [42], biosurfactants, and bioremediation [43]. Marine bacteria can also produce pigments; for example, Streptomyces ruber and Vibrio ruber produce red-colored prodigiosin, while Pseudoalteromonas luteoviolacea and Chromobacterium vioaceum produce violet-colored violacein [44]. Research is also needed to formulate new types of culture media and innovative strategies to increase the culturability of marine microbes.

4.2 Coral Restoration

Coral reefs are often referred to as the rainforests of the ocean [45]. Found in approximately 100 countries, they are primarily located in two distinct regions: the Wider Caribbean and the Indo-Pacific [46]. Coral reefs are among the Earth's oldest ecosystems and exist in three geomorphic categories: fringing reefs, barrier reefs, and atolls. They support an extraordinary diversity of species and act as natural barriers to protect shorelines from erosion [47]. At least 500 million people depend on coral reefs for food, coastal protection, and livelihood [48]. However, marine pollution and global warming have led to the continuous degradation and death of coral reefs. Over recent decades, around 20% of corals, particularly in the Caribbean Sea and Southeast Asia, have been severely degraded [49]. Efforts are underway globally to restore corals, but they take hundreds of years to form. Current initiatives include the removal of invasive species that harm corals and the artificial implantation of sponges to maintain coral-dependent diversity [50, 51]. However, more innovative ideas and efforts are needed in this sector. Researchers, entrepreneurs, and innovators are encouraged to contribute solutions to this pressing issue.

4.3 Water Desalination Strategies

The increasing population and depletion of freshwater resources have made seawater desalination increasingly essential. Seawater typically has a salinity of 35 parts per thousand (ppt), whereas drinking water requires a salinity below 0.5 ppm [52]. Various techniques for desalination are in practice, including reverse osmosis, Multi-Stages Flash desalination, Multi-Effect Distillation, electrodialysis, ion exchange, and liquid-liquid extraction [53, 54]. However, these methods are often expensive and may not be affordable for the general public. Therefore, more cost-effective desalination strategies are needed. Innovations in this field include solar thermal-based desalination methods [54] and nanoporous graphene membranes for desalination [55]. Innovators and investors are encouraged to develop practical protocols and cost-effective solutions for water desalination.

4.4 Restoration of Dead Zones

Dead zones are areas in the ocean where biodiversity is almost entirely lost due to complete oxygen depletion [56]. These zones are created when the environment becomes sealed off from the atmosphere, usually in deep ocean waters far from gas dissolution and lacking ocean current flow [57, 58]. Excess fertilizers can lead to hypereutrophic conditions, causing algae to form films on the surface water. When these algae die, the dissolved oxygen is consumed for decomposition, leading to the formation of dead zones [59]. Examples of such zones include the Baltic Sea, Oregon coast, and the Black Sea [60]. Although ongoing projects aim to restore these zones, more effort and innovation are needed to prevent nitrogen-rich runoff into the ocean [61]. Extensive research is also required to identify microbes, plankton, and macro-forms that can help revive dead zones.

4.5 Marine Taxonomists

Taxonomists are individuals who analyze and classify organisms based on their characteristics, placing them into biological groups. The marine system is rich in both micro and macro-organisms, many of which are either newly discovered or yet to be discovered. Proper classification of these organisms will facilitate systematic study and contribute to the understanding of marine biodiversity. Recently, DNA barcoding has been gaining wide attention. Many companies and researchers are developing mobile sequencers that help identify organisms at field sites with minimal samples [62]. Similar software designs and tool developments are also needed to carry out DNA barcoding of these marine forms. Such innovations can make big business and ease the identification of marine life forms.

4.6 Marine-based Product Development

Various marine-origin products are available in the market, including pharmaceuticals, nutraceuticals, and chemicals like agar and alginate [63, 64]. However, numerous products still require exploration and testing before commercialization. For example, bioactive compounds such as Okadaic acid from Gambierdiscus and superoxide dismutase from Porphyridium microalgae are known for their antifungal and antioxidant properties [65]. The constant discovery of marine-based products provides opportunities for entrepreneurs in drug testing, bioinformatics analysis, and animal model studies, as well as for innovators in product synthesis and cost reduction.

4.7 Models to Reduce Marine Pollution

Marine pollution results from the introduction of harmful chemicals or particles into the ocean. Often, potentially toxic chemicals adhere to tiny particles, which are then ingested by marine organisms and move up the food chain [66]. The primary sources of marine pollution include plastics, solid waste, fertilizers, heavy metals, oil, sewage, and radioactive waste, most of which are anthropogenic [67]. Various strategies have been employed to address this issue, such as reducing agricultural runoff, promoting reusable substances [68], raising public awareness, and implementing strict policies [69]. Solutions or clean-up projects in this area can attract significant funding and potentially form lucrative businesses.

4.8 Preparation of Anti-biofouling Agents

Biofouling refers to the undesirable accumulation of various life forms, including microorganisms, plants, algae, and animals, on surfaces [70]. This phenomenon poses significant challenges in marine technology, affecting shipping and industrial aquatic processes. Marine biofouling specifically refers to the growth of marine organisms on immersed artificial structures like ship hulls, jetty pilings, navigational instruments, aquaculture net cages, and seawater intake pipes [71]. The primary taxa associated with biofouling include arthropods, mollusks, annelids, chordates, and seaweeds. Current approaches to prevent and remove biofouling are physical, chemical, and biological. Physical methods involve mechanical removal, chemical methods use materials like silicone elastomers and metals, and biological methods employ metabolites from seaweeds [72, 73]. However, these methods are not entirely convenient and have a limited effective duration. Thus, the development of more effective anti-biofouling agents is needed.

5 Discussion and Future Research

Marine Entrepreneurship offers new funding opportunities and fosters collaborations for expertise and technology to enhance trade cooperation. This sector provides solutions and technologies that support green trades. Tidal devices, underwater robots, automated ships, underwater internet systems, bioplastics from seaweed, artificial intelligence for image analysis, marine compounds for cosmetics, alternative feed sources, and marine-based fertilizers play a crucial role in the global economic progression of the maritime sector [74]. Specifically, in the realm of research-based marine potentials, various renowned institutes are making significant contributions.

These include the Woods Hole Oceanographic Institute and Scripps Institute of Oceanography in the United States, Plymouth Marine Laboratory in the United Kingdom, Institute of Marine Environment and Resources in Vietnam [75], and Institute of Marine Research in Europe [76]. In India, the Central Marine Fisheries Research Institute in Kochi, Kerala [77], CSIR: National Institute of Oceanography in Goa [78], and CSIR: Central Salt and Marine Chemicals Research Institute in Bhavnagar, Gujarat [79] are making advances in marine-based fields. Commercially recognized marine-based companies like ORPC in Alaska [80], Oceaneering Internationals in the USA [81], A.P. Moller–Maersk Group in Denmark, and CMA CGM Group in France [82] also contribute to the sector. Marine Entrepreneurship is rapidly becoming one of the leading and fastest-growing investment sectors globally. Entrepreneurs and researchers entering this field early are likely to reap significant rewards in the near future.

6 Conclusion

The marine system is a vast and complex domain that offers a plethora of opportunities for entrepreneurship, innovation, and research. As this review has highlighted, the scope for marine entrepreneurship is broad, ranging from commercial scale ventures such as aquaculture and global transportation to research-based initiatives like coral restoration and water desalination strategies. Effective production methods and innovative strategies are not merely optional but essential for the development of sustainable and productive marine products and services.

Marine entrepreneurship is particularly significant for standardizing best practices across various sectors within the marine ecosystem. This standardization is crucial for ensuring that all stakeholders operate according to a common set of trade and environmental guidelines, thereby promoting sustainability and ethical practices. Furthermore, marine entrepreneurship has the potential to be a game-changer for developing countries. It can serve as a robust source of revenue, create employment opportunities, and contribute to foreign exchange earnings, thereby having a multiplier effect on economic development.

In summary, the marine system is a fertile ground for entrepreneurial activities that can yield both economic and environmental benefits. As the sector continues to grow, it is imperative for entrepreneurs, researchers, and policymakers to collaborate closely. Such partnerships will be key to unlocking the full potential of marine resources while ensuring their sustainable management for future generations.

Declaration of Competing Interests

The authors declares that she has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Author Contribution

Shwetakshi Mishra: Conceptualization; writing—original draft preparation, reviewing, and editing

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