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Living Lab Approach to Ocean Citizenship in Sustainable Development of the Blue Economy and Food Security

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Abstract: This article elaborates on different perspectives on the blue economy and suggests the importance of a Living Lab approach to support sustainable blue growth in sectors such as seafood security. This discussion highlights the growing dependence of the world on marine ecosystem services and the need to inculcate key elements of sustainability in ocean ecosystems while deriving socioeconomic benefits. A marine Living Lab serves the purpose of engaging different stakeholders, including professionals, managers, coastal communities, and entrepreneurs, in blue economy projects. For it to function effectively, an inclusive organizational structure and the identification of key goals and performance indicators should be clearly defined. The challenges of delivering outcomes from heterogeneous stakeholders deserve to be addressed to solve these problems and to adopt practically feasible models for specific sectors of the blue economy. Ocean citizens committed to pro-environmental activities will synergize and contextualize their roles in marine sustainability and find a voice to influence policymaking institutions. When acting in sync, the marine Living Lab and ocean citizenship programs can create new knowledge that can be applied to developing a blue economy. The study identified that higher education institutions have the means and resources to co-develop innovations in real-world contexts. The inclusivity expected in the Living Lab projects will increase the familiarity of a broad range of stakeholders with increasingly important areas of emerging technology. This study is intended to address the so-called ‘complexity avoidance’ syndrome constraining the sustainable growth of small-scale ocean-based enterprises. Thus far, the application of such technologies has been limited to academia and a limited number of aquaculture and fisheries industries. This study represents the first attempt to blend the blue economy with seafood security in the Living Lab domain.

Keywords: blue economy, marine living lab, citizen science, ecosystem services, seafood security.

蓝色经济可持续发展与粮食安全中的海洋公民生活实验室方法

摘要：本文阐述了对蓝色经济的不同观点，并指出了生活实验室方法对支持海产品安全等部门可持续蓝色增长的重要性。这一讨论强调了世界对海洋生态系统服务的日益依赖，以及在获得社会经济效益的同时在海洋生态系统中灌输可持续性关键要素的必要性。海洋生活实验室的目的是让不同的利益相关者参与蓝色经济项目，包括专业人士、管理人员、沿海社区和企业家。为了使其有效运作，应该明确定义一个包容性的组织结构以及关键目标和绩效指标的确定。为了解决这些问题并为蓝色经济的特定部门采用切实可行的模式，应该解决从

不同利益相关者那里获得成果的挑战。致力于环保活动的海洋公民将协同和具体化他们在海洋可持续性中的角色，并找到影响决策机构的声音。当同步行动时，海洋生活实验室和海洋公民计划可以创造新的知识，可以应用于发展蓝色经济。研究发现，高等教育机构拥有在现实环境中共同开发创新的手段和资源。生活实验室项目所期望的包容性将提高广泛利益相关者对日益重要的新兴技术领域的熟悉程度。这项研究旨在解决所谓的“复杂性回避”综合症，这种综合症制约了小型海洋企业的可持续发展。到目前为止，此类技术的应用仅限于学术界和少数水产养殖和渔业行业。这项研究代表了在生活实验室领域将蓝色经济与海鲜安全相结合的首次尝试。

关键词：蓝色经济、海洋生物实验室、公民科学、生态系统服务、海鲜安全。

1. Introduction

The blue economy is growing at an unprecedented rate. Enormous benefits will accrue to people and the planet by making blue growth more sustainable, but this requires knowledge-based strategies. The ocean is the next big frontier for investing in the blue economy. However, it can deliver the expected outcomes in good health.

The ocean regulates climate, provides air that we breathe, supplies food and pharmaceuticals, offers jobs, means for livelihood, opportunities for leisure, and many other services that support our survival and well-being. The ocean is home to enormous biodiversity, without which human existence on Earth is not possible.

The total value of ocean assets amounts to US$24 trillion [1]. Globally, the ocean contributes US$ 1.5 trillion annually, making it almost the 8th largest economy in the world, and an ongoing trend suggests that this value will reach US$ 3.0 trillion by 2030 [2].

Despite its importance, the ocean has endured human impacts, both directly and through climate change, if its health is in serious decline. Biodiversity loss, depletion of natural capital, non-native species, pollution, overexploitation, unsustainable aquaculture practices, warming of sea water, oxygen deficit, and acidification threaten the sustainability of this vital ecosystem.

In recent years, interest in economic growth linked to the ocean. The terms ocean economy and blue economy are often used interchangeably. However, there is a difference between the two. Clarification is required to avoid terminological confusion and incorrect connotations. As the name implies, the ocean economy deals with the economic systems linked to the ocean or the use of the ocean and its resources for economic benefit. The blue economy focuses on sustainability and offers environmental, economic, and long-term societal benefits. In other words, it emphasizes responsible ocean use. Conservation International added another dimension to the blue economy by including non-marketable benefits such as carbon storage, biodiversity, coastal protection, and cultural values [3] in addition to economic uses such as fisheries, aquaculture, pharmaceuticals, energy, mining, and tourism. There is a growing realization of the importance of knowledge-based developments in the blue economy by incorporating advances in science and technology to create value-added, data-driven opportunities and making use of information-sharing tools to inspire solutions to societal needs [4]. Efforts have been made in this article to provide a balanced definition of the blue economy to explain the scope of this presentation. This term "blue economy" refers to the sustainable use of the ocean using knowledge-based approaches that preserve the health and ecosystem services of the ocean to promote economic growth and social benefits.

2. What Roles Can a Marine Living Lab Play?

The Living Lab supports programs that facilitate partnerships, access to infrastructure, expertise, and communication technologies. Its role extends beyond providing incubation support and includes helping start-ups, enterprises, students, and researchers develop projects related to the blue economy. These activities operate in an open innovation ecosystem that welcomes communities and is supported by experimental product trials. The Living Lab creates an avenue for ocean citizens to participate in purposeful research and test innovative approaches for the sustainable development of the blue economy through sustainable fishing, ecological aquaculture, seafood solutions, marine pharmaceuticals, and pollution control, among other areas, to create better conditions for maximizing sustainable benefits accruing from the various marine ecosystem services.

The concept of Living Labs is gaining interest in developing a sustainable blue economy, but multiple

definitions have created some confusion about its real meaning. Some common definitions denote the Living + community network, and academia-community interface. The key words of the Living Lab, such as open innovation, co-creation, real-life setting, and information- and communication technology-driven networks, can, however, be structured in diverse ways to convey the balanced meaning and purpose of the Living Lab.

Typically, a Living Lab is an open innovation system focused on the co-creation process for improving certain products, services, ideas, and designs, potentially leading to prototyping, testing, and scaling up under real-life conditions and making full use of information and communication technology for sharing information about the processes followed and the outcomes generated. In short, the Living Lab brings together researchers, innovators, consumers, users, and the general public with the knowledge required for pooling their efforts systematically to develop solutions. Conducting applied research with business partners or inheritors of traditional knowledge in search of solutions to problems can help Living Lab deliver its responsibilities through appropriate physical facilities, organizational systems, and functional roles aimed at solutions.

The main purposes of the Living Lab, which are also followed by the European Network of Living Labs were elaborated in [5] (Fig. 1). Here, the four main actors forming a Quadruple Helix Model are citizens, the government, industry, and academia.

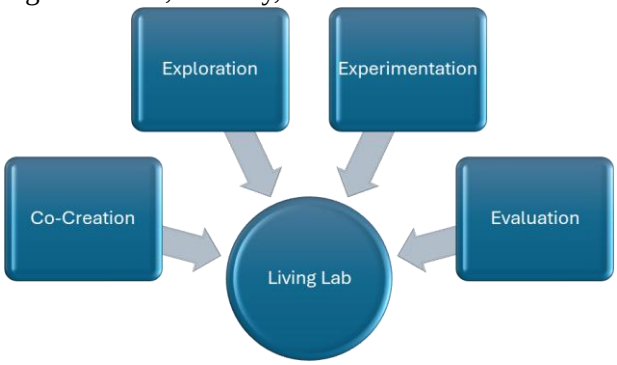

Fig. 1 Living Lab model that delivers its roles through a quadruple helix of actors [5]

As global interest in the blue economy expands with the increasing realization of its significance, research institutions, decision-making bodies, and other stakeholders invest resources in a detailed analysis of various perspectives on this subject [6]. These include not only the economy but also the environment, development, climate change mitigation, education, job opportunities, socio-economic policies, and other aspects. Obviously, knowledge and interdisciplinary perspectives are firmly embedded in the blue economy and blue growth [7]. The results are presented in Table 1.

Table 1 Interdisciplinary knowledge and innovations required for blue growth (Adapted from UN, 2022)

Knowledge	Purpose
Natural Science	To ensure the conservation and sustainable use of marine habitats and species is not compromised by socioeconomic activities but rather enhanced.
Social Sciences	To address inequality and the essential needs of society, create employment opportunities for all, including native communities, women, the younger generation, and impoverished sections of the community.
Interdisciplinary sciences	To ensure that natural and social scientists and economists' efforts create synergies rather than trade-offs.
Innovation by Sector in Blue Economy	To improve the efficiency of ocean-based activities and their ecological viability while reducing their environmental impact.
Sciences supporting marine spatial planning	To mainstream environmental conservation and sustainability in the economic sectors by balancing demands for ocean space with conservation for improved outcomes.
Technological innovation	To promote the use of renewable energy, incorporate means of climate change adaptation and mitigation, and ensure that ocean health is not adversely affected.

The main components of the Living Lab required for its functioning are as follows:

1. Organizational structure with defined roles (for governing all aspects of the Living Lab activities).
2. Innovation initiative management (comprising researchers and user communities for the co-creation of solutions).
3. Technical designs (focusing on engineering or processes that are oriented toward solutions).
4. Monitoring and evaluation (for tracking the progress of initiatives or practices).

These roles can be performed effectively structurally distinct on-campus facilities, such as research incubators.

3. Can Higher Education Institutions Help?

Higher education institutions are among the most suitable places to develop Living Labs. They have interdisciplinary expertise, programs, infrastructure, and other resources to support the objectives of the Living Lab. In a way, universities are a type of microcosm containing representatives of various sections of society. Staff, scholars, and students can mobilize to attain sustainability goals through inclusivity. They can project working models that resonate far beyond campus boundaries and influence society. Academia has an obligation to empower society with current knowledge and to inculcate an understanding of how human activities affect the

ocean, how we are affected by ocean conditions, and what solutions are available to mitigate the health of the ocean for the benefit of people and the planet. Given the deteriorating state of this largest ecosystem on Earth, it is time to make informed choices immediately.

The marine Living Lab is especially useful in coastal zones if there is an institution of higher education with ocean education as one of its flagship programs managed by a research and development center located at the sea front. Such an institutional entity committed to citizen science, willing to embrace emerging technologies, and sharing knowledge with communities can effectively manage the marine Living Lab. Such an arrangement can effectively demonstrate the benefits of 'ocean citizenship' by elaborating on the relationship between the daily life activities of the communities and the health of the coastal and marine environment [8]. It was suggested in [9] to go beyond private and individual environmentally friendly behavior to include public and political efforts to bring about the transformation of human-ocean relationships. These authors have expressed the view that ocean literacy supports ocean citizenship but have emphasized the importance of further exploring the multiple dimensions and complexities of ocean citizenship for influencing marine policy and management to improve the outcomes of ocean health. Although individual actions by responsible citizens are important, social strategies that motivate policy decisions in support of transformative change are also necessary. In this context, the advocacy of a paradigm shift toward the ocean as proposed in [10] is timely and relevant.

The concept of ocean citizenship not only implies a bond between the daily activities of informed citizens and the marine environment but also takes it to a higher level. This serves to emphasize the role of individual citizens in contributing solutions to ocean problems for the welfare of current and future generations. People must understand the connection between their activities and this unique heritage shared among all inhabitants of the world [11]. Generally, people living in coastal areas know very well the significance of the sea in their lives, especially food supply, but they need to be better informed about how their individual actions can affect the health of this ecosystem.

The marine Living Lab can motivate individual citizens to enhance their ocean health contributions. Historically, single individuals have not been on board, perhaps because of their view that they can do little for such a vast body of water. According to [12], the reasons could be individuals' lack of interest, belief that their ability to act is limited, or inability to find a voice or appreciation for their efforts. These authors also attribute this trend to coastal and marine programs that focus on local, national, regional, or international levels with little direction for inculcating individual roles, personal responsibility, and social justice for individual contributions. Many countries have local governance structures for community welfare. Such institutions should initiate awareness programs to involve all individuals in the community in one way or another, depending on their age, capabilities, and societal norms.

4. Food Security Solutions

The contribution of seafood harvested from the ocean to food security is one of the most discussed topics and is complex and critical. Capture fisheries and aquaculture are the main seafood production systems that make complementary contributions to food and nutrition security [13]. Globally, the total fish production by the two sectors is 184.3 million tons, out of which the capture fisheries and aquaculture sectors make up 91.1 million tons and 93.2 million tons, respectively, with a trade value of US$ 188.5 billion [14]. By 2032, aquaculture is projected to contribute 55% of total fish production, but on average, the capture fisheries sector will stay at around 92 million tons annually [15]. Obviously, when the projected fish demand reaches 21.2 kg per capita [15] from the current value of 20.4 kg, additional supplies will come from the expansion of aquaculture. Despite the stated aquaculture potential, the sustainability of capture fisheries is vital despite mounting pressures. In recent years, there has been an increasing level of interest in these food-producing sectors in terms of national policies and development planning. Because catch fisheries are based on natural stocks where biodiversity and ecosystem functioning is important, these factors are inseparable from the overall seafood security context. Mitigating and restoring the aquatic ecosystems that supply seafood and developing aquaculture methods that do not produce any significant ecological footprint, and in some ways shaping these sectors to be able to contribute to environmental regeneration, are challenges that should be addressed. The rising demand for seafood due to the growing population, affordability and nutritional value can be met by integrating sustainability practices into capture fisheries and aquaculture and fostering synergies between these two sectors. Such an approach will not only protect the environment but also ensure socioeconomic benefits for people reliant on seafood production. Every step in the production process should be based on environmental compatibility and best management practices.

The blue economy and food security are topics that inherently involve multiple stakeholders. The active participation of ocean enterprises in the multifaceted concept of Living Labs is required to generate new growth for food security. Ocean citizenship contributes to ensuring the environmental sustainability of growth enterprises that use marine ecosystem services. This unique platform requires mechanisms for addressing

the complexities of the collaboration of researchers, traditional coastal communities, and industry. A social innovation model that bridges the inter-stakeholder gap, as developed in this article, will lead to the co-development of innovations and end-user toolkits for intensive practical engagement.

As outlined in [16], several ecological benefits to the ocean can be accrued from sustainable aquaculture development (Fig. 2). The list will increase with additional investments in science and technology, leading to diversification in aquaculture and its related disciplines.

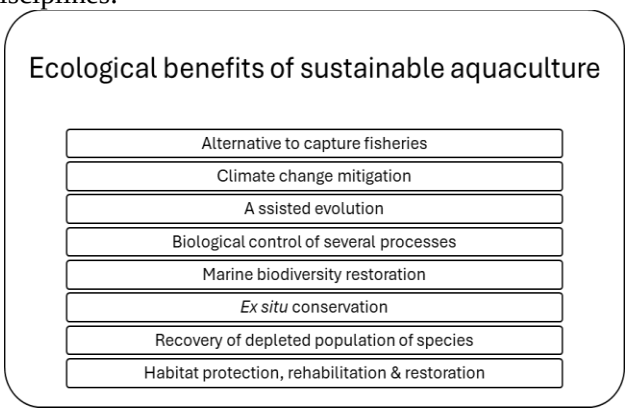

Fig. 2 Ecological benefits of sustainable aquaculture [16]

The marine Living Lab approach to issues such as food security can lead to transformative changes. It is a matter of global priority in international policy and a top-ranking target [17]. Food security represents the health and well-being of society and positively reflects the level of government commitment to meeting citizens' basic needs. Aquaculture is one of the fastest-growing food production sectors and is likely to maintain this trend in the future. Production statistics provided by [14] are interesting: globally, aquaculture production accounts for 87.5 million metric tons, whereas seafood harvest from ocean-captured fisheries accounts for 90.5 million metric tons. When the seaweed production of 36 million metric tons is added, the total seafood is 214 million metric tons. As much as 97% of the seaweed comes from farming. This increases the contribution of aquaculture to a level that exceeds that of capture fisheries landings. Aquaculture has therefore been correctly identified as a key sector of seafood security. This is evident from the [18] projection that current aquaculture production (53%) will surpass capture fisheries (47%) in terms of the relative contribution to seafood supply by 2030. However, food security expectations cannot be met if ocean health declines. This realization has motivated an interest in developing methods that are not harmful to the marine ecosystem and should contribute to reducing the impacts of other activities on the ocean. Sustainable aquaculture reduces the pressure on the sea food supply by increasing the availability of fish and other products to consumers. For these reasons, environment-friendly aquaculture has emerged as a major area of vital importance for global food security and the blue economy.

Although only UN SDG 14 (target 14.7) out of the 17 global goals of development mentions aquaculture development, aquaculture may contribute to all 17 SDGs [19]. In an earlier publication [20], the contribution of sustainable aquaculture to all 17 SDGs was elaborated.

Many aquaculture practices have been criticized for their impact on the marine environment [21]-[23]. These include eutrophication (excessive nutrient loading), disease transmission, the release of antibiotics and harmful chemicals used to treat fish diseases, the introduction of exotic species and their adverse consequences for wild populations in the event of their escape to the sea, genetic modification, competition for food and space, alteration in behavior, degradation of habitats, oxygen depletion, formation of dead zones, and loss of biodiversity. Many aquaculture practices have a significant ecological footprint on ocean ecosystems through the overexploitation of prey fish to feed on farmed fish. A sustainable blue growth and blue economy that it supports would require continuous attention toward the protection and restoration of the ocean to maintain its productivity, capacity to maintain ecological services, and resilience to withstand pressures such as those from climate change.

For aquaculture to carry sustainability labels, alternatives to fish-based diets need to be explored. This will avoid a paradoxical situation where the growth of aquaculture will be at the cost of the other food security sectors (the capture fisheries), curtail food supply to low-income populations in many coastal areas, and result in impairment of marine food webs [20], [24]. The scope of the problem can be imagined by the fact that more than 20 million metric tons of the fish harvested are not used for human consumption. Out of this amount, over 16 million metric tons (or 81%) are reduced to fish meal and oil, mainly used as aquaculture feed [14]. Almost 90% of the small pelagic fish, including anchovies, sardines, and scads, which are turned into aquafeed are suitable for human consumption. This has become a food security issue, especially for coastal communities, in addition to being an adverse consequence for the marine ecosystem.

Although aquaculture has made significant advances and many methods have been documented for practical application, their use in farming communities is limited. There are several reasons for this gap in the development of technology and its mainstreaming into farming systems. Most of the scientific publications were for a scientific audience, and the technologies developed required the training of farmers and a support system for their acquisition. With environmental challenges constraining production, scientists and farmers must work together to adapt methods to the changing environment, especially climate. Such an interaction should occur on an appropriate platform. An aquaculture incubator as part

of the marine Living Lab can serve this purpose. A structured approach was proposed in [20] under a social innovation model (developing and applying solutions to problems to support social progress in sustainable ways) for aquaculture (Fig. 3) with algorithmic functions for researcher-farmer cooperation.

Aquaculture is a kind of activity that can engage the whole family unit in one way or another. It weaves into the fabric of coastal communities and strengthens their voices, facilitates the exchange of know-how, builds confidence to explore knowledge empowerment avenues, and demonstrates the strength of using collective wisdom to develop aquaculture entrepreneurship.

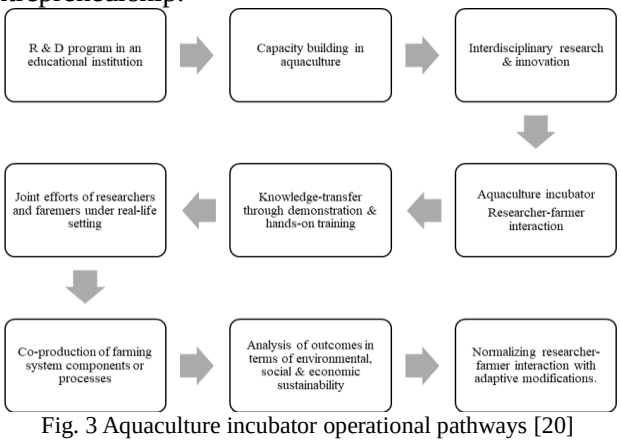

Fig. 3 Aquaculture incubator operational pathways [20]

Aquaculture operations in Malaysia are labor-intensive, and many are interlinked, leading to the formation of personal bonds and social cohesion. The interdependence it develops in society nurtures relationships that can bind the community, influence cultural practices and social dynamics and promote gender inclusiveness and a collective resolve toward solutions [25]. Such an enterprise is a model for social innovation.

It should be accepted that such social innovations can cause transformations in aquaculture through concerted efforts and deliberate changes in the socioecological systems of enterprises to mitigate environmental impacts and enhance the well-being of society [26]. Integrating aquaculture into the socioecological system helps to recognize its role in food systems.

In addition to setting up a physical entity and functional mechanisms, much more effort is needed to achieve social innovation. It requires thorough interaction among the researchers, farmers, and other stakeholders through various stages, including identification of problem(s), level of interest, commitment to accept change, and intense coordination across the full phase of the aquaculture cycle [27]. Findings of [20] comply with the views of [27] that social innovation in aquaculture should be accepted as a process as well as an outcome.

The marine Living Lab attaches immense importance to nature-based solutions (NbS) to aquaculture problems. The reasons for this are that nature has been the main source of learning for most traditional communities. There are cost-effective solutions, and in many cases, these can enhance environmental resilience. By collaborating with communities, academia can explore and address barriers to increasing the effectiveness of NbS in sustainable aquaculture. Researchers have the knowledge to identify indicators of growth through NbS to convince stakeholders, increase investment in aquaculture, and create opportunities associated with sustainable production and blue growth. Affiliation of the marine Living Lab with seed-producing hatcheries and aquaculture incubators will create a better understanding of the practical value of NbS. The stakeholders can experience real-life case studies and get to know real-life data.

The blue transformation pathway developed by [14] envisions an increase in aquatic food production as a part of a Strategic Framework 2022-2031 to enhance the contribution of aquatic food to food security and acts as a driver of employment, economic growth, societal welfare, and environmental recovery, which are consistent with the UN Sustainable Development Goals.

5. Conclusion

A sustainable blue economy seeks to address some major challenges facing the human population and the global environment. As interest shifts toward the ocean, new avenues are being explored for their potential to offer solutions. Global food insecurity is an issue that requires urgent attention. This is a complex problem that requires the active involvement of multiple stakeholders and key professional roles. The relatively new concepts of the marine Living Lab and ocean citizenship are among the aspects that can contribute to this effort. The marine Living Lab should have roles specifically carved out in a way that makes this entity distinct from other initiatives in the past that claimed to be open, inclusive, and user-centered but lacked understanding of the real-world environment and could not deliver. The ocean citizenship program affiliated with the marine Living Lab will have to ensure that the blue growth aimed at food security is consistent with the triple bottom lines of sustainable development. The strength of the stated alliances envisaged in the Living Lab approach will determine the beneficial outcomes expected of blue growth. The wide range of experiences, ideas, and initiatives in the Living Lab approach will create interest in academia in design science research aimed at purposeful outcomes. The mechanism of multi-stakeholder involvement presented in this paper generates new knowledge and interest in identifying pathways for stimulating information flow across the boundaries of disciplines and experiences. It has the potential to transform the practice of research

and promote the use of modern knowledge, especially digital technologies, in ways that go beyond academia and developed enterprises to support the digital revolution in the blue economy, food security, and ocean sustainability that are of interest to all societies and the planet.

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