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Advancing the blue economy through sustainable mariculture: the prospect of pearl oyster and sponge farm cultivation in St. Vincent and the Grenadines

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WORLD MARITIME UNIVERSITY

DISSERTATION

ADVANCING THE BLUE ECONOMY THROUGH SUSTAINABLE MARICULTURE:

THE PROSPECT OF PEARL OYSTER AND SPONGE FARM CULTIVATION IN ST. VINCENT AND THE GRENADINES

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A dissertation submitted to the World Maritime University in partial fulfilment of the requirements for the award of the degree of Master of Science in Maritime Affairs

2023

DECLARATION

I certify that all the material in this dissertation that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this dissertation reflect my own personal views, and are not necessarily endorsed by the University.

(Signature): .....

(Date): 25th September, 2023.

Supervised by: **Professor Francis C. Neat**

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ABSTRACT

Title of Dissertation: **Advancing the Blue Economy through sustainable mariculture: The prospect of pearl oyster and sponge farm cultivation in St. Vincent and the Grenadines**

Degree: **Master of Science**

The Blue Economy is estimated to be worth over USD 2.5 trillion annually, or almost 3% of the world's GDP in 2020. Additionally, the economic service potential of marine ecosystems is at least USD 24 trillion. St. Vincent and the Grenadines (SVG) in the Caribbean region, has a vast and rich marine space that is heavily underutilised. In view of SVG's Blue Economy potential, this study explored the feasibility of pearl oyster and sponge farming to advance the country's Blue Economy through sustainable mariculture. The study employed a qualitative approach through a literature review and thematic analysis of data gathered from semi-structured interviews with governmental ministries and Non-Governmental Organisations (NGOs), and focus group discussion with local fisherfolk.

The researcher assessed the environmental conditions of four species of pearl oysters and eight species of sponges that are commercially farmed. In addition, an area feasibility assessment was conducted in the islands of SVG which gave rise to four possible locations. As a result of the literature review, it was found that the *Pinctada imbricata* oyster specie and *H. lachne* sponge species are the most suitable for cultivation in SVG coastal waters. These species are native to SVG and the wider Caribbean region. Thus, avoiding risk of introduction of invasive species which may pose ecological and economic detriments to SVG and the Caribbean region. The area feasibility assessment showed that Union Island was the most suitable site for pearl oyster and sponge farming.

In conclusion, the study suggests there is real potential pearl oyster and sponge farming in SVG. It is, however, contingent upon the technical capacity, initial financial resources, and long-term commitment to ensure its success and sustainability. It also necessitates careful and sustainable planning and development and local collaboration to promote and sustain economic and social growth. This objective is also contingent upon several factors, including active community involvement, establishment of a comprehensive legal and regulatory framework that incorporates novel finance mechanisms, the implementation of ecosystem-based management practices, and the adoption of marine spatial planning strategies.

KEYWORDS: Blue economy, oyster pearl farming, Saint Vincent and the Grenadines, sponge farming, sustainable development, ecosystem-based management, ocean governance, ocean natural resources.

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LIST OF ABBREVIATIONS

BE	Blue Economy
CMFRI	Central Marine Fisheries Research Institute
CROP	Caribbean Regional Oceanscape Project
EEZ	Exclusive Economic Zone
EU	European Union
FAO	Food and Agriculture Organization
MPA	Marine Protected Area
NASA	National Aeronautics and Space Administration
NGO	Non-Governmental Organization
NOAA	National Oceanic and Atmospheric Administration
OBIS	Ocean Biodiversity Information System
OECD	Organization for Economic Cooperation and Development
PSU	Practical Salinity Unit
RQ	Research Question
SIDS	Small Island Developing States
SDG	Sustainable Development Goals
SVG	Saint Vincent and the Grenadines
UN	United Nations
UNCTAD	United Nations Conference of Trade and Development
TCMP	Tobago Cays Marine Park
WMU	World Maritime University

1. Introduction

1.1 Background

The oceans cover over two thirds of the earth's surface and provide a wealth of opportunities for humanity. It provides many "ecosystem" services that are often classified as regulating, provisioning, cultural, and supporting services, for example; the provision of food and nutrients for billions of people on a day-to-day basis (Koundouri & Giannouli, 2015); carbon sequestration, renewable energy; bio-based products; ecosystems such as sea grasses and corals, which protect coastal cities and homes from destructive force of storms; drugs and medicines derived from its biodiversity (Costello et al., 2010). In addition, the ocean facilitates around 90% of global trade (UNCTAD, 2022a) as well as laying of submarine telecommunication cables at ocean floors, which supports 98% of global communication (United Nations, 2016).

Noting the importance of the ocean, the United Nations (UN) encourages the sustainable use of marine resources through its Agenda 2030 and the Sustainable Development Goals (SDGs). In 2015, the UN Member States adopted SDG 14, entitled "Life Below Water," which calls for the conservation and sustainable utilization of marine resources, seas, and oceans for sustainable development, and calls upon global cooperation to bring back the oceans in balance (UN, 2022). In recent years, there has been a growing discourse regarding sustainable use of the oceans; this has been termed the "Blue Economy". The European Union (EU), the World Bank, the Organization for Economic Cooperation and Development (OECD) and the UN have all used this term to explain the relationship between sustainability, economics, and the oceans. Even more so, the UN recognized that the Blue Economy is precisely what is needed for the implementation of the aforementioned SDG 14 (UN, 2022).

According to UNCTAD (2022b), the anticipated value of ocean-based trade, or the "Blue Economy," in products and services is at least $2.5 trillion annually, or almost

3% of the world's Gross Domestic Product in 2020. Additionally, it is estimated that ocean-based economic potential, such as the services provided by marine ecosystems, is worth at least $24 trillion but does not currently have markets (Commonwealth of Nations, 2023).

The term Blue Economy was first mentioned by Gunter Pauli, an economist, entrepreneur, and author who created the blue economy model. He defined the blue economy as "*the regeneration of ecosystems in a logic of abundance and autonomy*" (Pauli, 2011) using nature as a source of inspiration to take what is required and work in harmony with it (Sakhuja, 2015). Notably, at a summit in 2012, the United Nations established the term "Blue Economy" and emphasized sustainable management, arguing that healthy marine ecosystems are more productive (UN, 2022). However, there is no agreement on the precise definition, and there is much variation between many states, institutions and scholars (Table 1).

Table 1

Blue Economy Definitions from Different Individuals/Organizations

Author	Definitions
Bari, (2017)	● The decoupling of socio-economic activities and development from environmental degradation and optimizing the benefits which may be derived from marine resources ● Means the use of sea and the use of its resources for sustainable economic development
European Commission, (2021)	● All economic activities related to oceans, seas and coasts ● Covers a wide range of interlinked established and emerging sectors ● Under a sustainable blue economy, maritime and coastal activities reconcile economic development, improved livelihoods, and social inclusion with fighting the climate crisis, protecting biodiversity and ecosystems, using resources responsibly, and achieving the zero-pollution ambition.
Midlen, (2021)	● A way to deliver sustainable ocean development in the context of the sustainable development goals
The Commonwealth of Nations, (2023)	● An emerging concept that encourages sustainable exploitation, innovation and stewardship of our ocean and its life-giving 'blue' resources
UN, (2022)	● An economic term linked to exploitation and conservation of the maritime environment and is sometimes used as a synonym for "sustainable ocean-based economy.
World Bank, (2017)	● A sustainable use of ocean resources for economic growth, improved livelihoods and jobs, and ocean ecosystem health

In the past decades, when the business-as-usual model was dominant, the development of countries' economies only focused on the exploitation of ocean resources and did not give enough consideration to the sustainability of ocean ecosystems (The Commonwealth of Nations, 2023). In addition, many believe that the main objectives of the blue economy are full employment levels and national financial gains (Blažauskas et al., 2015; Fernández-Macho et al., 2016). Meanwhile, to some, Blue Economy is the integration of all maritime activities with a focus on Ocean Management generally, and Marine Spatial Planning (MSP) specifically (Mulazzani & Malorgio, 2017). Santos et al. (2014) emphasized that MSP is the core framework of Ecosystem-Based Management of the Blue Economy.

Some contend that the idea of an ecosystem forms the basis of the blue economy, and they concur the criticality of assessing ecosystem services in order to ensure sustainability, particularly in complex situations where trade-offs must be made between the opportunity cost of the blue economy and efforts to protect the ocean (Jobstvogt et al., 2014). This was supported in a feasibility study of offshore aquaculture locations in the North Sea, where they specifically stressed the importance of the incorporation of ecosystem services as significant aspects in the cost-benefit analysis of blue economy (Jansen et al., 2016).

Despite the varying opinions on the denotation of the blue economy, some factors stand united. Among these are: the immense role the blue economy plays in the lives of humans for seafood, financial gain, energy, coastal protection, transportation, and other marine goods and services; and its power to improve the management of marine ecosystems, reduce emissions, create a more equitable health standard, and contribute to the battle against climate change (UN, 2022).

By challenging conventional wisdom, the blue economy seeks to reconcile the interests of both economic growth and ocean health. It is generally accepted to be a long-term strategy designed to foster sustainable and fair economic growth through ocean-related industries and ventures. The blue economy can be used at several scales, from local to global, and is relevant to all nations. However, it needs to be backed by

a reliable and diverse body of knowledge, as well as management and development tools that encourage and promote innovation, in order to become operational.

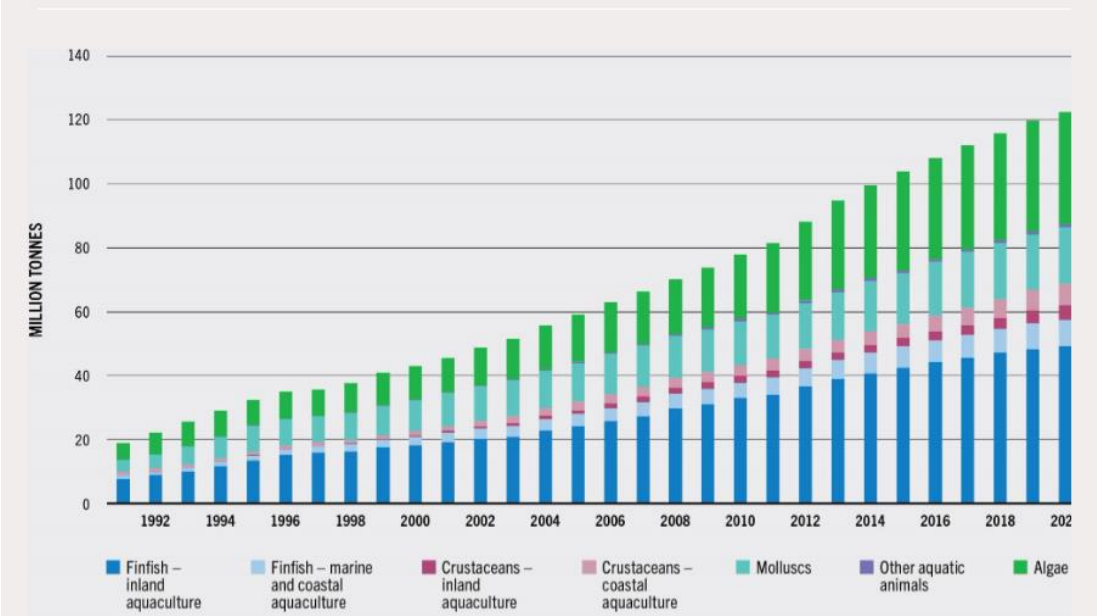
According to Voyer et al. (2018), one of the components of the Blue Economy is mariculture. Oyinlola, (2019) dubbed mariculture as the fastest growing food system in the world. It is likewise confirmed by the World Bank (2016) that mariculture is among the industries that boost the growth of the blue economy. The term "mariculture" refers to the management, cultivation, and harvesting of marine creatures either in their natural habitats (such as estuarine, offshore waters, brackish, or coastal) or in enclosures like pens, tanks, or channels. Seaweed, molluscs, crabs, fish, and echinoderms are just a fraction of the creatures that are grown (Phillips, 2009).

With an increasing global population and growing need for food and resources, mariculture will increasingly become a key producer of aquatic food and goods in coastal areas, as well as a source of employment and money for many coastal communities. Well-planned and maintained mariculture can also benefit coastal environmental integrity (Phillips, 2009).

The FAO (2022) has noted mariculture as a component of the blue economy because it facilitates economic growth, food security, support sustainable resource management, drives innovation and enhance climate change resilience. Notably, in 2020, as presented in Figure 1, the overall aquaculture production was 122.6 million tonnes in live weight, this consisted of 87.5 million tonnes of aquatic animals primarily for human use, 35.1 million tonnes of algae for both food and non-food applications; and 700 tonnes of shells and pearls for decorative use. This represents a 6.7 million-tonne increase from 115.9 million tonnes in 2018. The total farm gate value was predicted as USD 281.5 billion in 2020; an increase of USD 18.5 billion over 2018 and USD 6.7 billion over 2019 (FAO 2022). Mariculture has been practiced in different countries such as Cuba (Betanzos-Vega et al., 2019), Venezuela, Japan, China (MacKenzie et al., 2003), Micronesia and French Polynesia (Cartier & Ali., 2012).

Figure 1

World Aquaculture Production, 1991–2020



Note. From *Aquaculture Production* by Food and Agriculture Organization (FAO), 2022 (https://fao.org/3/cc0461en/online/sofia/2022/aquaculture-production.html).

Of the many different animals that can be cultured, oyster pearls and sponges for cosmetics and pharmacological use are perhaps less well known. While they do not contribute much to global aquaculture production, they are never the less valuable and locally important enterprises. It is with respect to these two types of mariculture that this study is focused within the national context of St. Vincent and the Grenadines in the Caribbean. The species groups were chosen because they are all farmed internationally for various commercial purposes. They are also high value species and require little physical work compared to many other jobs.

1.2 Background of Saint Vincent and the Grenadines

Countries in the Caribbean region are at the forefront of defending and boosting the blue economy's potential because ocean-related tourism accounts for half of the regional GDP and about 40% of employment (Oxenford & McConney., 2020).

Saint Vincent and the Grenadines (SVG) is an archipelagic state located in the Southern Caribbean region (Howell et al., 2019). It comprises 32 islands and cays. Of these islands, nine are inhabited. Islands cover a total land area of 389 square km: the largest island, St Vincent, also known as the mainland, has the largest land area of approximately 345 square km with a coastline of 105 km; and the Grenadines with a combined land area of 44 square km. The island is volcanic in nature and is teeming with an abundance of unique life both terrestrial and marine. The EEZ of SVG is 36, 381 square kilometres. In 2022, the population at SVG is 103,948 (World Data Atlas, 2022) with 92% of the population living on the island. The majority of the population resides within one kilometer of the strip of the coastline. According to a 2012 estimate of poverty, SVG is one of the poorest Small Island Developing States (SIDS), with a high unemployment rate of 20–25% and 42% of the people living in poverty (Howell et al., 2019).

For SVG, in the Caribbean region, the coastal and marine resources are the main components of its blue economy. SVG is one of the poorest countries of the eastern Caribbean, and suffers from high unemployment, especially among young adults and women. The nation has jurisdiction over a large body of ocean about 90 times that of its land area and the associated accompanying living and non-living resources. These resources are used mainly for small-scale artisanal fisheries (e.g., conch, lobster), transportation, sea moss-farming, transportation, and conservation-related activities. These resources are vital to the country's economy and the well-being of its people. At present, small-scale fisheries dominates the SVG, making the livelihoods and food

security of its coastal communities dependent on it. Additionally, fisheries contribute significantly to trade and foreign exchange earnings, and have important links with tourism (Oxenford & McConney, 2020).

SVG has rich marine resources, however, the economic potential of the resources in this area remains mostly untapped and underdeveloped (Department of Maritime Administration, 2013). The presence of these resources provides a possible avenue to further develop a sustainable blue economy in SVG. As such, this study aims to facilitate blue growth through sustainable mariculture by assessing the pragmatism of oyster pearl and sponge farm cultivation in St. Vincent and the Grenadines.

SVG is rich in living and non-living resources which contribute significantly to the nation's economy and wellbeing of its people (Howell et al., 2019). However, the economic potential of the resources in this area is largely unassessed and underutilized. The blue economy, which is an important development strategy for SVG comprises transportation, recreation, coastal development, conservation, tourism, surface water management and waste water treatment and disposal, small scale artisanal fisheries, lobster, conch, and small-scale seaweed farming. Howell et al. (2019) further stated in the report that the blue economy is underdeveloped and there is an abundance of untapped potential. To remedy this, Howell et al. (2019) in the CROP report outlined possible new industries for the blue economy, namely: marine mineral extraction; marine renewable energy; biotechnology; subsea cables; biotechnology; marine dredging and disposal; aquaculture/mariculture; and subsea cables.

1.3 Problem Statement

SVG has rich marine resources; however, the economic potential of the resources in this area remains mostly untapped and underdeveloped (Department of Maritime Administration, 2013). The presence of these resources provides a possible avenue to further develop a sustainable blue economy in SVG. As such, this study aims to

facilitate blue growth through sustainable mariculture by assessing the pragmatism of oyster pearl and sponge farm cultivation in St. Vincent and the Grenadines.

1.4 Aims and Objectives

The study aims to assess the potential of pearl oyster and sponge cultivation as a strategic component for Blue Economy development in Saint Vincent and the Grenadines.

1.5 Research Questions

This study intends to answer the following research questions to achieve its aims and objectives.

1 What are the perceptions of the emerging Blue Economy and the potential for mariculture in SVG?

2 What species of pearl oysters and sponges would be suitable for mariculture in SVG?

3 Which areas could sustain viable pearl oysters and sponges?

4 How will pearl oyster cultivation and sponge farming affect local fisherfolk and coastal stakeholders?

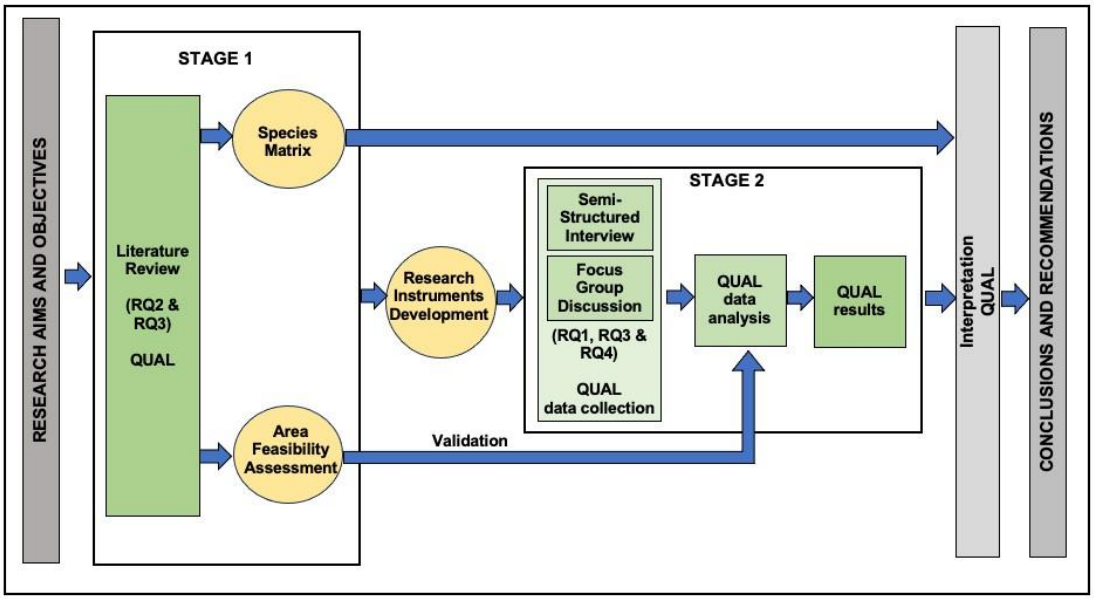
2. Research Methodology

2.1 Methodological Rationale and Approach

A qualitative research method was applied in the study in assessing the viability of pearl oyster and sponge farming in SVG. Specifically, the researcher employed a literature review, and thematic analysis of the data gathered from the semi-structured interview and focus group discussion. According to Patton (2005), qualitative research analyses data from written documentation, open-ended and in-depth interviews, as well as from fieldwork observations. Meanwhile, Aspers & Corter (2019) defined it as a repetitive process that advances scientific understanding by making new and meaningful distinctions as a result of getting closer to the topic being studied. Figure 2 illustrates the general overview of the methodological framework of the study.

Figure 2

General Overview of the Methodological Framework of the Study



2.2 Literature Review

In the first stage, the researcher conducted a literature review to gather biological information about different species of pearl oysters and sponges as well as the environmental conditions necessary for the survival and culturing of the organisms. The researcher scrutinized the relevant documents to answer RQ2 and RQ3. These documents covered national and regional governmental reports on SVG's profile and marine space; authorities with varying responsibilities on the marine space; and local users of that space. Documents relating to pearl oyster and sponge farming, mariculture, and sustainable blue economy expansion were also scrutinized. The literature review resulted in the contextualization of information regarding the pearl oysters and sponges as well as the understanding of suitable areas for its cultivation. The data gathered from the literature review were used to create species matrixes of sponge and pearl oysters and a proposed area which was compared to SVG's environmental conditions and available native species. An area feasibility assessment was also conducted to identify a suitable area in SVG that could sustain the farming of pearl oysters and sponges, thus, addressing RQ2 and RQ3. All results of Stage 1 were then used in developing a research instrument (semi-structured interview questions) which was utilized for the second stage of the study.

2.3 Semi-Structured Interview and Focus Group Discussion

According to Magaldi & Berler (2020), the semi-structured interview is a commonly employed method in the field of social sciences, particularly in qualitative research, to conduct exploratory interviews. It allows exploration and flexibility for the pursuit of different topical paths as the conversation progresses. As such, the researcher used a semi-structured interview to address RQ 1, RQ4 and validate the analysis for RQ3. The interview questionnaire for the ministries and the NGOs are attached as Appendix A and Appendix B, respectively. A total of five actor groups were interviewed in this study.

In addition, a focus group discussion was employed with six fishermen from Union Island in order to gather the perceptions of the local fisherfolks and coastal stakeholders on the effect of pearl oysters and sponge farming on the island. The questionnaire is attached as Appendix C. During focus group discussions, there is a higher likelihood that individuals offer candid comments. The utilisation of moderated discussion in focus groups allows members to enhance and expand upon one another's ideas through a process known as "piggybacking." Consequently, focus groups prove to be highly valuable for the objectives of needs assessment and project evaluation (Leung & Savithiri, 2009).

In this investigation, the regulations and standards of the WMU Research Ethics Committee governing the use of human subjects in data collection were adhered to. When gathering data, the researcher concentrated primarily on responder safety, in accordance with known research ethics norms such as obtaining informed consent, avoiding injuring participants, respecting participants' privacy, and truthfulness. The data was password-protected and securely saved on the researcher’s computer after being treated with the highest security and confidentiality until safely deleted on the award of the degree.

2.4 Participants Groups

All participants were selected based on purposive sampling (Patton, 2001 as cited in Palinkas et al., 2015) and were considered to have the necessary information and skills to drive this research. Table 2 shows the information about the interviewees. Corresponding codes were used in this study to keep the interviewees’ identity confidential.

Table 2

Information About the Actors and the Stakeholders

Interviewee Class	Code Used	Role in Industry
Actors	FA1	Fisheries Officer
	FA2	Fisheries Officer
	NP1	National Parks Authority Officer
	NGO1	Executive Director of local conservation agency, Non-Governmental Organization
	NGO2	Marine and Coastal Project Manager
Stakeholders	FF1	Local Fisherman
	FF2	Local Fisherman
	FF3	Local Fisherman
	FF4	Local Fisherman
	FF5	Local Fisherman
	FF6	Local Fisherman

2.4.1 National Ministries

In this research, various ministries in SVG were targeted to participate in the study. These ministries share overlapping responsibilities regarding the blue economy of the country, however, within their own missions and interests.

2.4.2 Non-Governmental Organizations

NGOs have a growing presence in SVG. They are deeply rooted in the community and they aim for sustainable development and environmental restoration. As a result of this, they were likewise targeted as actors in the study.

2.4.3 Local Fisherfolk

This study surveyed fisherfolk on the island of the proposed site location. The island is dominated by fisherfolk who are at the community level. They are crucial stakeholders in understanding how an activity affects the local community.

2.4.4 Data Collection and Analysis

The semi-structured interview instrument was composed of one section of questions for each category of the targeted audience. The questions presented to the participants guided them to independently expand on their responses to gain holistic insight on their response. The interviews were transcribed and imported into NVivo software for qualitative analysis. The interviews were performed between the period of June 1st and July 8th 2023.

In the second stage, a semi-structured interview and focus group discussion were conducted with the pre-identified stakeholders in order to analyse the effect of pearl oyster and sponge farming on the SVG's local fisherfolk/coastal stakeholders as well as to validate the result of the area feasibility assessment in Stage 1, thus, addressing RQ1, RQ3 and RQ4 of the study. Thereafter, all results of this qualitative study were then interpreted in order to address the research objective of the study.

The data from the semi-structured interviews were analysed using the platform NVivo. This was done to capture the corresponding themes within the interviews. The themes responded to RQ1, RQ3 and RQ4. Individual themes were gathered from each interview response. These themes were compared and then grouped across all interviews to determine major and minor themes. No preconceived themes were used throughout the analysis

3. Results and Analysis

3.1 Pearl Oyster Farming

One of the sectors of mariculture is pearl oyster farming. This section examines the varying views on the history and development of human-farmed pearls. There was also an evaluation of the economic value of pearl oyster farming, in terms of pearl, shell, and meat. Following this, the various uses pearl oysters have in different disciplines are presented. Furthermore, the journey to achieving high-quality pearls and the environmental factors that influence their production are examined. Finally, this section looked into how marine pearl farming has contributed to the sustainable expansion of the blue economy.

3.1.1 History and Development of Pearl Oyster Farming

Pearls were the first jewels discovered by humankind thousands of years ago (Haws, 2002). Natural pearls are generated when the pearl oyster reacts to an irritant by coating it with nacre, the bright iridescent material found on the inside surface of the shell. Natural pearls are often small, of varied colours, and irregular in shape (Haws 2002). Zhu et al. (2019) claimed that pearls are uniquely associated with modern civilization as the only gem produced by humans. It is known as the "queen of jewels" and is a symbol of material prosperity.

Natural pearls are uncommon since only one in every 2,000 pearl oysters contains one (CMFRI, 1987; Haws, 2002). Because of the great value of natural pearls, pearl fisheries have been established in practically every corner of the world where pearl-producing bivalves have been discovered (CMFRI, 1987; Haws, 2002). The majority of these pearl fisheries were short-lived since the natural stocks were soon depleted (CMFRI, 1987; Haws, 2002). As a result, the art of pearl culture, in its rudimentary

form, emerged in the 12th century A.D. in China (Alagarswami, 1987). Table 3 displays the various major pearl shells and natural pearl fisheries across the world.

In the early twentieth century, Japanese researchers devised technologies that brought pearl production under human control. The Mise-Nishikawa system in Japan in the early 1900s is credited with giving rise to modern round pearl farming (Haws, 2002; Zhu et al., 2018). These "cultured pearls" are larger and more consistent in size and colour than natural pearls (Alagarswami, 1987). They are created using a surgical operation known as grafting, which involves surgically implanting an artificial nucleus (shell bead) into the tissue of a pearl oyster. After that, the oyster secretes nacre around the nucleus.

Table 3

Major pearl shell and natural pearl fisheries. Source: Cariño & Monteforte,2009; Strack 2006.

Region	Period	Main species
Marine		
Arabian/Persian Gulf, Gulf of Mannar, Red Sea	since at least 2000 years ago	*Pinctada radiata, P. fucata, P. Margaritifera*
China	2000 years ago	*Pinctada fucata-martensii*
Japan	6th century, intensively in late 19th century	*Pinctada fucata-martensii*
Central and South America	from 16th century onwards	*Pinctada mazatlanica, P. imbricata, Pteria sterna, Pteria colymbus*
Australia, Indonesia, Philippines, French Polynesia	from 19th century onwards	*Pinctada margaritifera, P. maxima*
Freshwater		
China	ca. 8th century	*Unio sp.*

Region	Period	Main species
Central Europe, UK	16th century for Bavaria (Kunz and Stevenson, 1908); Roman times (Scotland)	*Unio sp.*, *Pinctada margaritifera margaritifera*
USA	18th century onwards	*Unio sp.*

Note. From "Sustainability and Traceability in Marine Cultured Pearl Production," by Cartier, L. E. H., 2014, *University of Basel* (https://edoc.unibas.ch/34907/1/THESIS%20for%20PRINT%20Laurent%20Cartier.pdf).

3.1.2 Economic Value of Pearl Oyster Farming

Pearl cultivation presents a substantial opportunity for economic growth in coastal village communities across the spectrum of the more valuable species (Gervis & Sims, 1992). The industry necessitates only minimal capital investment yet provides numerous benefits to producers, coastal communities, and national economies.

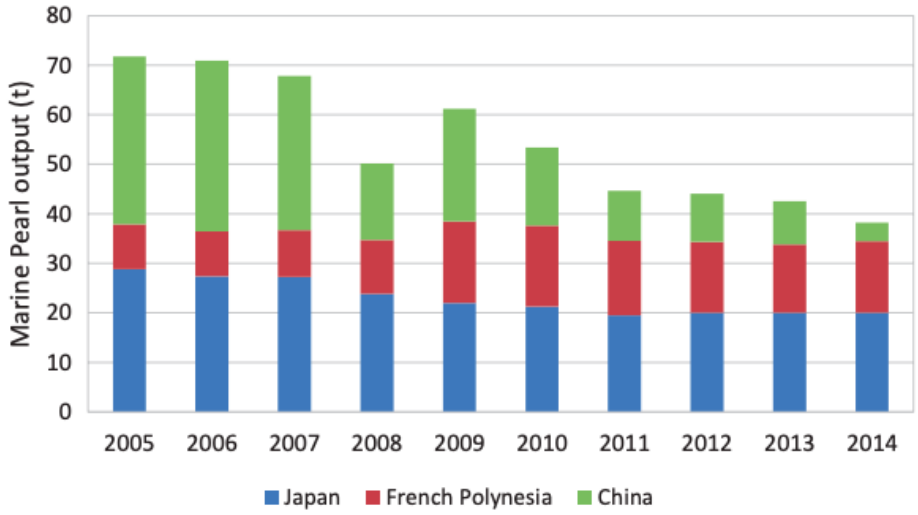
Pearls

Pearls are the ideal export commodity because they are non-perishable, transport costs are minimal, and profitable markets already exist. According to Zhu et al. (2019), more than 30 countries have been producing cultured pearls in the past decades. From 2005 to 2014, based on FAO statistics (FAO, 2022), Chinese pearl production comprised 98% of the world's cultured pearl output, with freshwater pearls comprising 99.5%. On the other hand, Japan, the world's leading marine pearl producer, produced an average annual value of 127 million USD in marine cultured pearls, accounting for 51.6% of the global output value. However, it should be noted that in the past decade, global pearl production decreased by 60% and output value by 39% due to over saturation of low-quality pearl production.

In summary, Figure 3 presents the global production of marine pearls from 2005-2014 of the top 3 leading producers of cultured pearls while Figure 4 shows the total output value of pearl production in the same period.

Figure 3

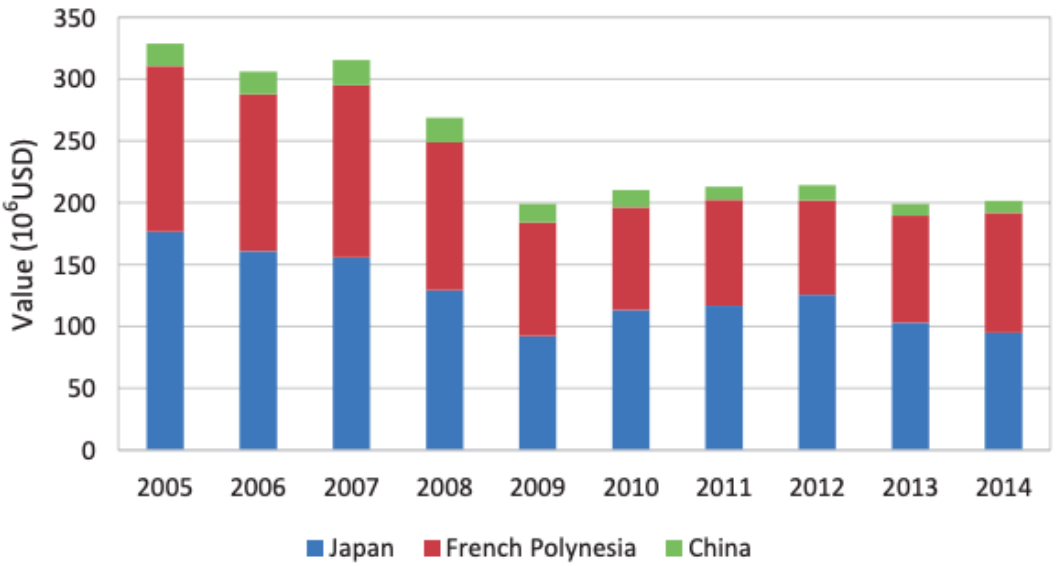
Global Production of Marine Pearls from 2005-2014



Note. From "Production of Pearls," by Zhu, C., Southgate, P. C., & Li, T. in Smaal, A., Ferreira, J., Grant, J., Petersen, J., Strand, Ø. (Eds.), *Goods and Services of Marine Bivalves* (p. 73-93), 2019, Springer Open (https://doi.org/10.1007/978-3-319-96776-9_5). Copyright 2019 by Springer Nature Switzerland AG.

Figure 4

Total Output Value of Global Pearl Production from 2005-2014



Note. From "Production of Pearls," by Zhu, C., Southgate, P. C., & Li, T. in Smaal, A., Ferreira, J., Grant, J., Petersen, J., Strand, Ø. (Eds.), *Goods and Services of Marine Bivalves* (p. 73-93), 2019, Springer Open (https://doi.org/10.1007/978-3-319-96776-9_5). Copyright 2019 by Springer Nature Switzerland AG.

Cartier (2014) presented the production of cultured pearl (both freshwater and marine pearl) per country as shown in Table 4. In general, although China produces the highest volume of pearls with 800-1,000 tons of freshwater pearls and 2.6 tons of marine pearls, Japan is the leading nation in terms of its value amounting to US$ 100 million.

Table 4

Cultured Pearl Production Figure

Country	Freshwater/ marine	Species of pearl oyster	Volume of pearls produced	Value of pearl production	Production since	Source
China	Freshwater and marine	*Hyriopsis cumingii H. schlegelii* and hybrids; *Pinctada fucata-martensi*	800-1000 tons (Freshwater, 2010); 2.6 tons (Akoya, 2013)	n/a (freshwater, 2010); US$ 5 million (Akoya, 2013)	1961 (marine); 1962 (freshwater)	Wiesauer, 2012; Liping and Min, 2013; Sheperd, 2013; Müller, 2013
Japan	Freshwater and marine	*Hyriopsis schlegelii*; Akoya	19 tons (Akoya, 2013)	US$ 100 million (Akoya, 2013)	1916 (marine)	Strack, 2006; Southgate and Lucas, 2008; Müller, 2013
Vietnam	Marine	Akoya	2.8 tons (2013)	US$ 5 million (2013)	1991	Strack, 2011; Müller, 2013
Australia	Marine	*Pinctada maxima*, Akoya	3.75 tons (2013)	US$ 90 million (2013)	1956	Lucas and Southgate, 2008; Müller, 2013
Burma (Myanmar)	Marine	*Pinctada maxima*	1.125 ton (2013)	US$ 24 million (2013)	1960s	Lucas and Southgate, 2008; Müller, 2013
Indonesia	Marine	*Pinctada maxima*	5.45 tons (2013)	US$ 58 million (2013)	1970s	Lucas and Southgate, 2008; Müller, 2013
Philippines	Marine	*Pinctada maxima*	2.1 tons (2013)	US$ 22 million (2013)	1964	Lucas and Southgate, 2008; Müller, 2013

Country	Freshwater/ marine	Species of pearl oyster	Volume of pearls produced	Value of pearl production	Production since	Source
Cook Islands	Marine	*Pinctada margaritifera*	100-150,000 pearls (2010)	US$ 467,000 (2010)	1974	Macpherson, 2000; Strack, 2011; SPC, 2011; Müller, 2013
Fiji	Marine	*Pinctada margaritifera*	9,500 pearls (2011)	n/a	1999	Strack, 2011
French Polynesia	Marine	*Pinctada margaritifera*	14 tonnes (2012)	FCFP 6.9 billion = US$ 76 million (2012)	1963	Domard, 1962; ISPF, 2014
Micronesia	Marine	*Pinctada margaritifera*	2000 pearls (2012)	n/a	1987	Cartier et al., 2012
Mexico	Marine	*Pteria sterna*	3000 pearls (2013)	n/a	1993	Kiefert et al., 2004; D. McLaurin, pers. comm. 2013
U.A.E.	Marine	*Pinctada radiata*	n/a	n/a	2008	M. Al Suwaidi, pers. comm. 2012

Note. From "Sustainability and Traceability in Marine Cultured Pearl Production," by Cartier, L. E. H., 2014, *University of Basel* (https://edoc.unibas.ch/34907/1/THESIS%20for%20PRINT%20Laurent%20Cartier.pdf).

Shells

Pearl shells are another non-perishable and valuable product. Shell is mostly marketed for use as buttons. Notably, they are also used by Korean and Japanese furniture makers in inlay work. They are also used for creating necklaces, earrings, and brooches (Philipson 1989; McElroy 1990 as cited in Gervis & Sims 1992) as well as for producing face creams from shell scraps (Haws, 2002). Haws (2002) outlined that

South Korea and Japan are the two largest importers of pearl shells, with imported tonnage ranging from 1,000 to 1,500 tons per year between 1980 and 1987 (Philipson 1989 as cited in Zhu et al., 2019).

Meat

According to Gervis & Sims (1992), the meat of pearl oysters is highly valued in the Japanese market. However, it is a perishable good and needs to be processed before shipping at a great distance. Typically, the meat is supplied fresh to the sushi industry by large farming operations and Japanese suppliers. Likewise, the pearl oyster fishery in Venezuela also sells almost all oyster meat to consumers for food, which would generate high fishery profit (MacKenzie et al., 2003). Further, Cartier & Ali (2012) also revealed that small-scale pearl farming in French Polynesia and the Federated States of Micronesia market oyster meat as an alternative strategy for maximizing profits.

3.1.3 Production of High-Quality Pearls

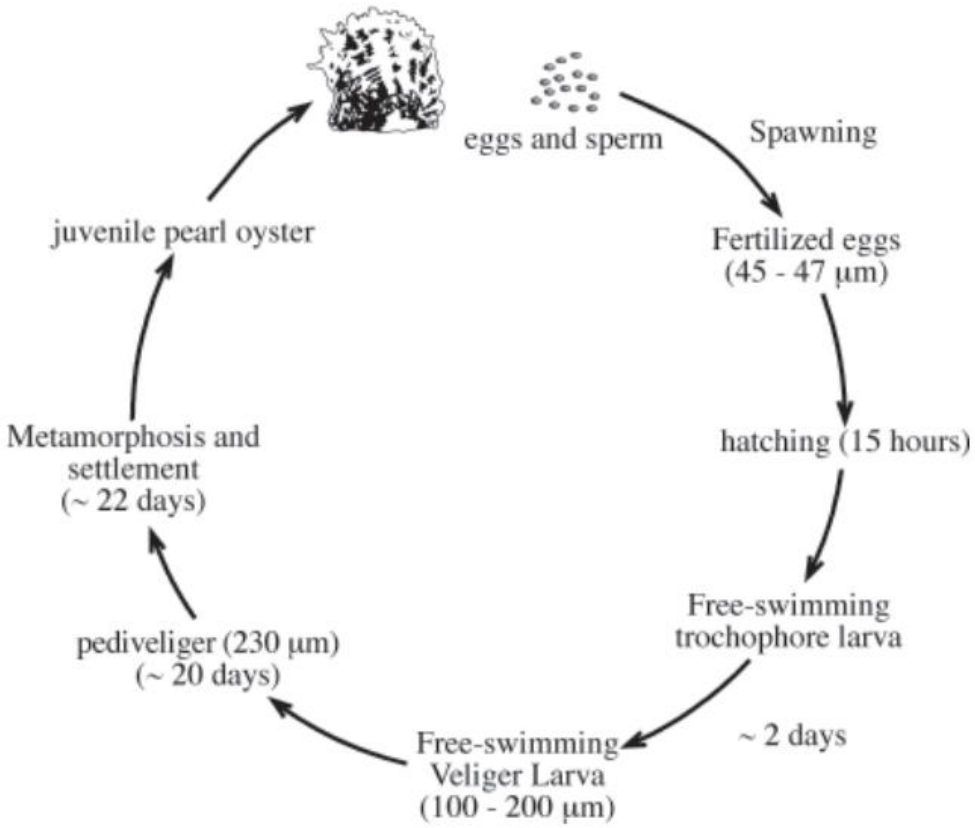
The production of a top-quality pearl is achieved through proper care of the pearl oysters at all phases of farming (Haws, 2002). Haws (2002) also stressed that the competence of the grafting technician is crucial to guaranteeing high-quality pearls. Further, venturing into cultured pearl farming necessitates sufficient funds to establish and operate a farm, a trustworthy and uninterrupted pearl oysters supply, appropriate location, enough revenue to start and run a farm, access to grafting technicians, capacity to commercialize pearls (Alagarswami, 1987; Haws, 2002).

Understanding the life cycle of a pearl oyster is also crucial to maintaining its quality and its continued supply. Figure 5 shows the life cycle of an adult pearl oyster. Gervis & Sims (1992) and Haws (2002) explained that the majority of pearl oysters are protandric hermaphrodites, which means that they are predominantly male before becoming female. Typically, the male phase occurs during the first 2 to 3 years of life,

followed by the transition to the female phase. According to reports, pearl oysters can live up to 25 years (Haws, 2002). Pearl oysters reproduce by dispersing millions of eggs or sperm into the water column, where they are fertilized at random. The larvae remain suspended in the water column for two to three weeks before metamorphosing into a juvenile known as a "spat." The larva acquires an enlarged foot and an eyespot just prior to metamorphosis. After metamorphosis, the foot persists, and the young spat retains the capacity to move for several months after attaching to a hard substrate. Utilizing their byssus, pearl oysters can attach and reattach themselves (Gervis & Sims 1992; Haws, 2002).

Figure 5

Life Cycle of an Adult Pearl Oyster



Note. From *The Basic Methods of Pearl Farming: A Layman's Manual*, by Haws, M. 2002, Center for Tropical and Subtropical Aquaculture (https://www.ctsa.org/files/publications/CTSA_12763167286192394836 81.pdf).

Cultured pearl farming is well documented (Haws, 2002; Cartier et al., 2012; Zhu et al., 2019) (see Appendices D-F). In general, it can be classified into seven major steps, namely: farm selection; oyster selection; nucleus implantation; nurturing; harvesting; pearl processing; and pearl marketing. Haws (2002) explained that young pearl oysters need around two years to mature and are then prepared for grafting, which kicks off the nurturing of a cultured pearl. The pearl oysters stay on the farm for the next 12 to 24 months after a 40-day inspection to assess the outcomes.

3.1.4 Environmental Factors

There are several environmental factors that affect the growth and quality of oyster pearls. Among these include water temperature, depth, salinity, pollution, currents, and spawning season, as discussed below.

Temperature

Temperature thresholds differ between species and are the primary factor affecting their species distribution. The tolerance range across commercially viable species is 18 - 32 degrees Celsius, which varies across each type of pearl oyster. Notably, cold water inhibits growth, hampers reproductive development, and makes pearl oysters more susceptible to illness (Gervis & Sims, 1992).

Salinity

Although most can withstand a wide variety of salinities, pearl oysters prefer fully salinated waters. This is a typical occurrence for species living in the intertidal zone. The salinity tolerance of pearl oysters ranges from 28 to 35 PSU (Gervis & Sims, 1992). However, rapid changes in salinity have the potential to cause harm to pearl oysters (Haws, 2002).

Depth

The depth of the water is a critical factor during the nurturing phase of the pearl farming as it affects the mortality of the oysters. In addition, depth also affects the quality, colour, and growth of pearl oysters (Gervis & Sims 1992). It is suggested that pearl oysters have to be placed in a calm area of the ocean at a 2-3 meters depth after nucleus implantation (Wang et al., 1993 as cited in Zhu, et al., 2019).

Pollution

Pearl oysters like clear, unpolluted waters that are far from sources of contamination including sewage, oil, chemicals, and other types of pollution (Haws, 2002). In order to mitigate it, oyster farms should not be situated near large villages or cities as they typically have some pollution. Such consideration is crucial as pollution affects the mortality rate and the quality of pearl oysters (Gervis & Sims, 1992). Heavy mortality rate can be caused by pollution from the pearl farms themselves such as sludge from pearl bleaching and washing, as evident in the Japanese pearl industry based on the culture of *P. fucata martensii* between 1966-1988 (Gervis & Sims, 1992).

Currents

A current is advantageous to pearl oysters as it keeps its supply of oxygen and nutrients steady; and prevents the accumulation of waste materials beneath the farm which could

lead to issues with water quality (Haws, 2002). Haws (2002) stated that only weak currents can be tolerated by pearl oysters. On the contrary, Gervis & Sims (1992) mentioned that some species of pearl oysters prefer strong currents such as *P. maxima* and *P. margaritifera galtsoffi.*

Spawning Season

Spawning is frequently related to temperature extremes or abrupt changes in the environment (Gervis & Sims, 1992). Although pearl oysters often spawn at lower-level temperatures throughout the entire year, pearl oysters produce eggs and sperms when the water is at the warmest temperature (Haws, 2002). In addition, every species of pearl oyster has different spawning seasons. For instance, *P. margaritifera* typically has a spawning season in winter and summer; *P. fucata* has a continuous spawning season in India, though it depends on temperature; and *P. Maxima* spawns from September/October to March/April in Australia (Gervis & Sims, 1992).

Notably, pearl oysters from temperate locations, like many marine species (Orton 1928; Pearse 1974 as cited in Gervis & Sims, 1992), have more distinct, regular spawning seasons. Spawning in tropical pearl oysters is not restricted to a single season, and prolonged spawning can occur throughout the year.

3.1.5 Marine Pearl Farming for Sustainable Blue Economy Expansion

The cultivation of pearls is created through a complex process that involves a thriving marine habitat, important knowledge and talent, and several years of patience (Cartier, 2014). Based on the three pillars of sustainability - environmental, economic, and social, cultured pearls have proven to be extremely beneficial and sustainable across many nations. On an environmental front, due to their high rates of filtration and capacity for accumulating heavy metals, contaminants, and bacteria, pearl oysters and mussels have the potential to be used in bioremediation in contaminated coastal areas.

With the ability to pump up to 22 L per hour per oyster, marine pearl oysters have strong pumping and filtration rates, removing particles and pollutants (Zhu et al., 2019). Evidence was found by Gifford et al. (2005) as cited in Zhu et al. (2019) that for every tonne of Akoya pearl oysters harvested, 0.5 kilogram of phosphorus, 7.4 kg of nitrogen, and up to 0.7 kg of metals were removed from the water, demonstrating the potential for such bioremediation systems. Additionally, small-scale pearl oyster farming off the coast of Pakin in the Federated States of Micronesia contributes so much to ecosystem health that pearl oyster farming is permitted within marine protected zones (Brodbeck, 2010 as cited in Cartier et al., 2012). Pearl oyster farming is thus one of the components of the Blue Economy that appears to be compatible with marine conservation and protection.

On the other hand, the economic pillar of sustainability was demonstrated in the case of French Polynesia and the Cook Islands where cultured pearl has become their vital source of export revenue and employment (Cartier, 2014). As contained in Cartier (2014) study, in 2010, there were 397 individuals/companies collecting spat (juvenile oysters) and 429 licensed pearl farms in French Polynesia alone (Service de la perliculture, 2010), producing pearls with an export value of $130 million (Müller, 2009). At its peak in 2000, this business employed 7000 people in French Polynesia (Murzyniec-Laurendeau, 2012 as cited in Cartier, 2014). Further, it was argued that black-lip pearl production in the Cook Islands is possible within current systems of (indigenous) social and economic structure (Macpherson, 2000). Socially, pearl oyster farming promotes community engagement and integration. It allows locals the opportunity to create a livelihood they can pass on to future generations.

3.2 Sponge Farming

3.2.1 History and Development of Sponge Farming

Sponges have been used as early as 700 BC (Schippers et al., 2012). Sponges are invertebrate organisms that can be found in freshwater and saltwater environments, from the deep sea to the coast (Liu, Zheng 1997 & Hooper, 2002 as cited in Yi et al., 2005; Friday, 2011; Betanzos-Vega et al., 2019). Sponges are used in bath and beauty, art, medicine, and industry (Ellis, 2008; Schippers et al., 2012; Betanzos-Vega et al., 2019). According to Ellis et al. (2008), these are mostly harvested from the Mediterranean and Caribbean waters. The global source demand for sponges is estimated at USD 35 million per year. However, wild sponge populations are declining worldwide due to overharvesting and disease. To remedy the inconsistent supply and nonuniformity of sponges obtained from the sea and to continuously meet its demand, sponge farming was discovered, which is straightforward, cheap, and produces a homogeneous output (Yi et al., 2005).

Sponges are ancient, sessile invertebrates with a simple cell organization. Their ability to efficiently pump water is due to its complex auriferous structure of channels and chambers (Hooper et al., 2002 as cited in Friday, 2011). The sponge takes in water through inhalant pores called ostia and pumps it in a unidirectional current known as a choanocurrent through a single layer of flagellated choanocyte cells, which delivers nutrients and oxygen to the sponge while expelling metabolic waste into the surrounding water (Osinga et al., 2010).

3.2.2 Economic Value of Sponge Farming

There are over 8000 species of sponges, of which only 6-7 species of sea sponges are of any commercial value (Dobson, 2003; Betanzos-Vega et al., 2019). These are mostly harvested from the Mediterranean and Caribbean waters (Ellis et al., 2008) and used for bathing, cosmetic and medicinal purposes. With regard to cosmetics, a variety

of dried and pounded sponges were utilized as powders, tablets, syrups, and ointments (P van Treeck et al., 2003). *C. reniformis* specie, on the other hand, is used as a source of collagen and other biomedical applications (Swatschek et al., 2002 as cited in Osinga et al., 2010). Regarding medicine, Pronzato et al. (2000) as cited in P van Treeck et al. (2003) asserted that sponges have long been recognised as a marine source of minerals with significant healing potential. Due to their high iodine content of sponges, Spongia species in particular, were used as ash to treat struma and as compresses for blood staining and wound disinfection (Janussen and Hilbert, 2002 as cited in P van Treeck et al., 2003). Additionally, bath sponges are sourced for their antiviral properties. which resulted in the production of Ara-A (active against herpes) and Ara-C (effective in leukaemia treatment) (Schippers et al., 2012). Importantly, sponges are used to create a wide range of anti-cancer and antibiotic drugs. Schippers et al. (2012) indicated that marine sponges have continuously been the most prolific source of newly discovered bioactive compounds, with more than 7000 sponge-derived novel molecules.

The value of sea-based sponge farming is confirmed to be high value (Osinga et al., 1999). However, the existing literature does not provide a concrete figure of its economic value. In a study of Betanzos-Vega et al. (2019) regarding Cuban sponge farming industry, the international market of the country goes beyond USD 40 million annually. On the other hand, Ellis et al. (2008) asserted that the annual worldwide demand for sponges is around USD 35 million. Examples are seen in Zanzibar, Tanzania where farmers earn USD 15-30 / £ 12-24 per sponge (Makoye, 2023).

3.2.3 Production of High-Quality Sponges

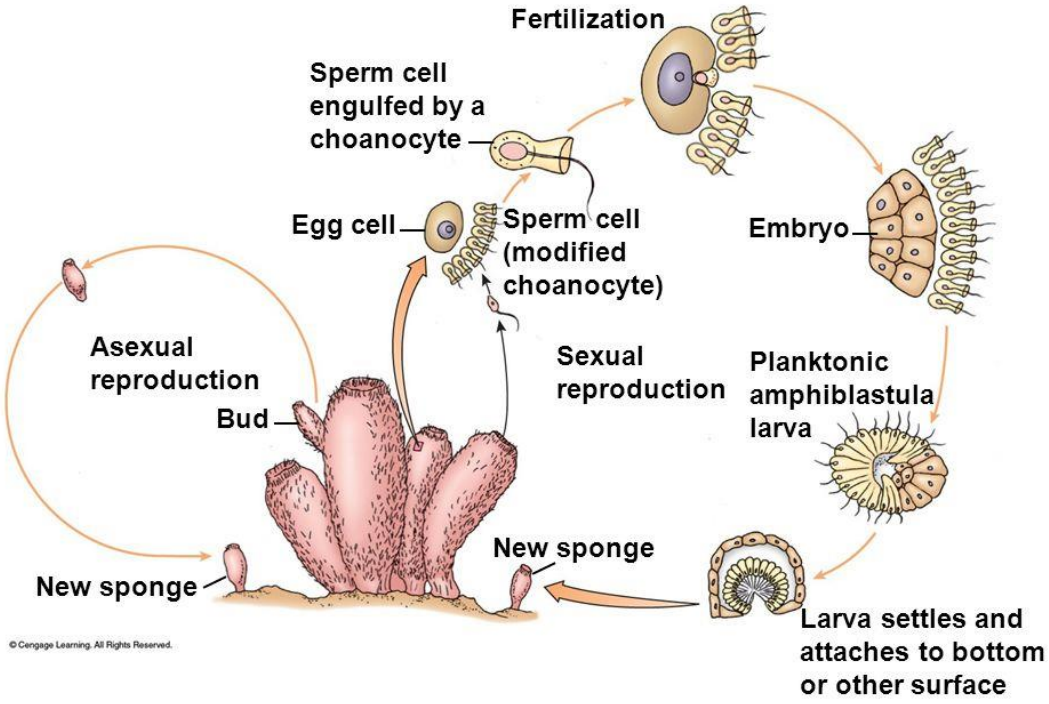
The production of high-grade sponges is achieved with proper care throughout all stages of the farming process. It is also important to understand the life cycle of the sponge intended for farming. From growth to a harvest size of 10-15 cm takes 1.5-3

years, depending on the farm site (Ellis et al., 2008). However, in Zanzibar, Tanzania harvest size is achieved in one year (Makoye, 2023).

Furthermore, understanding the life cycle of sponges is essential to maintaining a quality and continued supply. Sponge reproduction is both asexual and sexual (Ellis et al., 2008; Betanzos-Vega et al., 2019; Bierwirth et al., 2022). The majority of sponges reproduce sexually. Sponges generate sperm and eggs at varying rates. Archeocytes help to convert sperm collected by sponges into eggs (Bierwirth et al., 2022). During the sexual stage, larvae reproduce and are discharged into the water. Figure 6 illustrates sponges life cycle.

Figure 6

Life Cycle of Sponges



Note. From *Sponges (Porifera)*, by Project MA.R.E., 2018 (https://www.marineadventures.org/sponges-2/). Copyright 2023 by Project Marine Adventures Respecting the Environment.

Macmillan (n.d.) provided a manual for a successful venture of commercial sponge mariculture farm. He mentions three major phases: 1) planning; and 2) managing; and 3) harvesting, cleaning, and marketing. Phase 1 includes the identification of suitable location; selection of method for sponge farm grow-out; acquisition of materials; setting up the farm; identification of brood stock; and cutting and attaching sponges. In finding an appropriate location, it was suggested to avoid fresh water, and to consider the depth of the water as well as the tidal changes. During the farm set up, it was recommended that sponges should not touch the seabed to avoid additional cleaning work and that the rope should be put across the current. Further, to maintain

the quality of the sponge, careful consideration must be applied in cutting the sponges. While making the sponge cuttings, it was advised to keep the sponge cuttings in the water; to use razor-sharp knives; and that it should not be squeezed, because this can result in the death of the sponge. Moreover, Ellis et al. (2008) pointed out that farmers may start harvesting the fast-growing sponges after 1.5 years.

3.2.4 Environmental Factors

There are several factors that affect the well-being of sponges. Among these are temperature, salinity, light, oxygen, food, depth, and currents, as discussed below.

Temperature

Sponge growth is sensitive to significant shifts in water temperature (Ellis et al., 2008; Yi et al., 2005; Friday, 2011; Betanzos-Vega et al., 2019). In the natural environment, most sponges encounter only modest temperature changes, but powerful and quick temperature fluctuations. It has been found that sponges can withstand temperature decreases better than temperature increases (Yi et al., 2005). In addition, it should be noted that temperature affects the growth of sponges. Sponges grow slower in cold temperatures, and are more resilient in hotter temperature (Makoye, 2023).

Salinity

Sponges are osmosis-alterable species that can control osmosis to some extent. Sponges appear to achieve ionic equilibrium in salinity-varying environments through ion regulation and the start-up or closure of free amino acids (Yi et al., 2005). Although knowledge on how salinity affects sponges is very limited, it is hypothesized that sponges are sensitive to low salinities because it interferes with their ability to maintain a balanced water content (Osinga et al. 1999 as cited in Friday, 2011).

Light

Yi et al. (2005) noted that some sponges have photosynthetic endosymbionts. As a result, light is an energy source that supports the sponge's organic food source. According to some accounts, UV radiation from the sun may also inhibit the growth of sponges.

Oxygen

The availability of sufficient dissolved oxygen is essential to sponges. The supply of oxygen often becomes a limiting factor for the maximum overall volumetric productivity. Respiration rates per cubic centimeter of sponge volume have been found to vary from 0.2 to 25 μmol O_2 per hour. Oxygen supply should be enough for sponge consumption at high oxygen transfer (Dobson, 2003; Yi et al., 2005).

Food

Sponges consume food by filtering microscopic plants, animals, and dissolved nutrients from the ocean water as it passes through their body (MacMillan, n.d.; Yi et al., 2005; Schippers et al., 2012). They also highlighted that the majority of these food particles are so tiny that not even a basic microscope can view them. In general, a sponge will develop more quickly if there are more food particles in the water around it.

Depth

The depth of the water is likewise an important factor on the growth and quality of sponges. McMillan (n.d.) suggested that the water at the sponge farm should be kept for a minimum of five feet deep at low tide. This is to protect the sponges from the harmful effects of sun exposure and to prevent the lines from being snapped by passing motorboats. Additionally, Friday (2011) explained that when the farm water is

shallow, it will have more exposure to sunlight, which will lead to more biofouling, UV radiation, and wave shock. All of which can make sponges less healthy.

Currents

Most sponge biological activities (such as feeding, reproduction, and gas exchange) are completed and controlled by the current (Wu, 1995 as cited in Yi et al., 2005). Water current also plays an important role in maintaining the placement of sponge positions in the farm. MacMillan (n.d.) suggested that a 1/4-inch support ropes should be positioned either across or perpendicular to the flow of the current, if there is a current present in the farm location. By putting the ropes across the current, the test lines with sponges tied to them will point in the same direction as the current. This makes it less likely that a sponge will break off when there are big tide changes and strong currents.

3.2.5 Sponge Farming for Sustainable Blue Economy Expansion

Sponge farming requires time and knowledge to properly execute this lucrative market (Aguilo-Arce et al., 2023). Based on the SDGs, marine sponge farming provides scientific growth and action. Furthermore, it adds variety to blue economy production, which increases aquaculture supply and supports the development of innovative aquaculture methods, particularly those with low environmental effects (Aguilo-Arce et al., 2023). Numerous jobs are created, both directly and indirectly, providing a source of income for the local population. An example of this is the sponge farming in Zanzibar, Tanzania where women in the local community earn USD 15-30 per sponge (Makoye, 2023). Sponge farming also combats decreasing biodiversity loss and poverty, using marine resources sustainably, and encouraging environmentally sustainable economic development (Aguilo-Arce et al., 2023; Makoye, 2023). Importantly, the outlined environmental and economic potentials of marine sponges are critical to the attainment of the mariculture sector's role in sustainable social development. Further, it is confirmed in a study by Betanzos-Vega et al. (2019) that

the development of economically viable and sustainable alternatives to fishery production, such as sponge culture, contributes further to environmental sustainability.

In Zanzibar, Tanzania, the prospect of oyster and sponge farming was examined (Oakland, 2013). It was found that their combined presence is beneficial to the environment's health. It was also clarified that there was no indication of any detrimental effects to their collaboration on the environment, animals or human life and wellbeing.

3.3 Evaluation of Sustainable Mariculture for Natural Populations Production in SVG

This section presents the findings and analysis regarding marine pearl oysters, sponges, as well as the identified suitable location for its cultivation. The data that were collected and analysed came from the existing literature and the semi-structured interviews.

3.3.1 Evaluation of Candidate Species of Marine Pearl Oysters

Based on the literature review, Table 5 presents the list of major commercial pearl oysters for marine cultivation including their environmental requirements. As can be gleaned from the table, there are four (4) viable commercial marine pearl oysters, namely: *Pinctada imbricata*; *Pinctada fucata/martensii*; *Pinctada maxima*; and *Pinctada margaritifera*. This study did not assess commercial species other than the aforementioned ones due to lack of credible and complete data in the existing literature.

Table 5

Main Commercial Oysters for Marine Round Pearl Cultivation

Scientific Name/ Commercial Name	Fishing Area	Use	Water Temperature (°C)	Depth Interval (m)	Growth Duration (months)	Diameter (cm)	Salinity (PSU)	Source
Pinctada imbricata (Atlantic Pearl Oyster)	Western Atlantic region (Caribbean region, Gulf of Mexico)	Commonly used	20.5-29.1	0-23	-	7.7-8.8	-	(SeaLifeBase, 2023a)
		-	20-30	0-30	-	-	30-35	(OBIS, 2021)
	-	-	-	-	12-24	-	-	(Haws, 2002)
Pinctada fucata/martensii (Akoya pearl oyster) (Japanese pearl oyster)	Western Atlantic region (Caribbean region, Gulf of Mexico), Western Pacific Ocean (Korea, Japan, southern China and Australia) to the Indian Ocean, including the Red Sea and Persian Gulf	Most commonly utilised for commercial pearl production	17.9-28.9	3-46	-	8	-	(SeaLifeBase, 2023b)
	-	-	20-30	20-40	-	-	30-35	(OBIS, 2017)

Scientific Name/ Commercial Name	Fishing Area	Use	Water Temperature (°C)	Depth Interval (m)	Growth Duration (months)	Diameter (cm)	Salinity (PSU)	Source
	-	-	-	-	12-24	-	-	(Haws, 2002)
Pinctada maxima (the gold or silver-lip pearl oysters)	Indonesia, northern Australia, Philippines, Malaysia and Myanmar	Largest and most valuable	24.4-29.1	0-60	-	20-30	-	(SeaLifeBase, 2023c)
	-	-	20-30	20-30	-	-	30-35	(OBIS, 2023a)
	-	-	-	-	12-24	-	-	(Haws, 2002)
Pinctada margaritifera (black-lip pearl oyster)	Indo-Pacific: from Mexico to Tanzania and the Red Sea to French Polynesia	Second largest of the pearl oysters, produces black pearls	26-33	0-20	-	9.8	-	(SeaLifeBase, 2023d); (OBIS, 2023b)
		-	20.30	0-30	-	-	30-35	(OBIS, 2023b)
	-	-	-	-	12-24	-	-	(Haws, 2002)

The table illustrates the necessary living conditions of each species in terms of water temperature, depth, and salinity. All the assessed species fall within the sea surface temperature range of 17.9-33 degrees Celsius. Except for *Pinctada fucata/martensii*, the three (3) other species can be farmed in less than a meter deep below the seawater surface. Regarding tolerance of depth, all subjects can be farmed within 3-20 meters however, *Pinctada maxima* can be farmed in water depth up to 60 meters. All species have the same growth duration of 12-24 months.

3.3.2 Evaluation of Candidate Species of Sponges

Based on the literature review, Table 6 summarizes the list of eight (8) main commercial sponges as well as their ecosystem requirements for optimal survival. Most of the commercial sponges can be found in the Mediterranean, Caribbean region, and Gulf of Mexico. Their temperature range is 14.3-30 degrees Celsius. The literature outlines varying depth tolerance for the assessed species of sponges. For instance, for the specie of *Hippospongia communis*, the range of 0.5-30 m was observed in FAO (1990) while SeaLifeBase (2023e) gave a range of 5-80 m. The diameter of the sponges varies in a range of 12-100 cm. Most are within the range of 25-30 cm, while *S. officinalis mollissima* and *S. graminea* are 15-20 cm and 12-25 cm respectively, and *Spongia agaricina* with a diameter range of 50-100 cm. All species can comfortably survive a salinity range of 30-35 PSU.

Table 6

Main Commercial Sponges

Scientific Name/ Commercial Name	Fishing Area	Use	Water Temperature (°C)	Depth Range (m)	Harvest Time (years)	Diameter (cm)	Salinity (PSU)	Source
Hippospongia communis (Horse Sponge, Honeycomb)	Mediterranean	Cosmetic/ domestic (bath sponge)	-	0.5-30	-	-	-	(FAO, 1990)
	Eastern Central Atlantic	-	15.2-21.6	5-80	-	30	-	(SeaLifeBase, 2023e)
	-	-	15-25	-	-	-	30-35	(OBIS, 2014)
	-	-	-	-	1.5-3	-	-	(Ellis et al., 2008)
H. gossypina (Velvet)	Western Central Atlantic: USA, Belize and Honduras	Bath sponge	26.1-28.3	14-15	-	-	-	(SeaLifeBase, 2023e)
	-	Bath sponge	25-30	0-20	-	-	30-35	(OBIS, 2023c)
	-	-	-	-	1.5-3	-	-	(Ellis et al., 2008)
H. lachne (Wool, Sheepswool)	Gulf of Mexico, Caribbean	Bath sponge	-	2-10	-	30	-	(FAO, 1990)

Scientific Name/ Commercial Name	Fishing Area	Use	Water Temperature (°C)	Depth Range (m)	Harvest Time (years)	Diameter (cm)	Salinity (PSU)	Source
	-	-	26.3-28.1	5-15	-	28.7	-	(SeaLifeBase, 2023f)
	-	-	-	-	-	-	30-35	(OBIS, 2023d)
	-	-	-	-	1.5-3	-	-	(Ellis et al., 2008)
Spongia agaricina (Elephant ear)	-	Decoration, polisher	14.3-21.6	5-60	-	50	-	(FAO, 1990)
	Northeast Atlantic and Mediterranean	-	-	4-60	-	100max		(SeaLifeBase, 2023g)
	-	-	15-20	-	-	-	30-35	(OBIS, 2023e)
	-	-	-	-	1.5-3	-	-	(Ellis et al., 2008)
S. barbara (Yellow sponge)	Florida Keys	Bath sponge	-	2-15	-	25	-	(FAO, 1990)
	Western Central Atlantic: from Belize south to Panama, north to Bahamas and east to British Virgin Islands	-	-	7-45	-	-	-	(SeaLifeBase, 2023h)

Scientific Name/ Commercial Name	Fishing Area	Use	Water Temperature (°C)	Depth Range (m)	Harvest Time (years)	Diameter (cm)	Salinity (PSU)	Source
	-	-	25-30	1-10 & 40-50	-	-	30-35	(OBIS, 2023f)
	-	-	-	-	1.5-3	-	-	(Ellis et al., 2008)
S. graminea (Glove, glass)	Gulf of Mexico, Caribbean	Little use, very soft	-	2-5	-	12-25	-	(FAO, 1990)
	Western Central Atlantic: USA, Cuba and Honduras	-	-	1-20	-	-	-	(SeaLifeBase, 2023i)
	-	-	20-30	-	-	-	30-35	(OBIS, 2023g)
	-	-	-	-	1.5-3	-	-	(Ellis et al., 2008)
S. officinalis adriatica (Bathing sponge) (Other name: Spongia officinalis Linnaeus, 1759)	Mediterranean (Greek Waters)	Bath sponge, rare and expensive	-	0.5-40	-	35	-	(FAO, 1990)
	-	-	15-30	0-50	-	-	30-35	(OBIS, 2021)
	-	-	-	1-100	-	-		(Azzopardi, 2021)

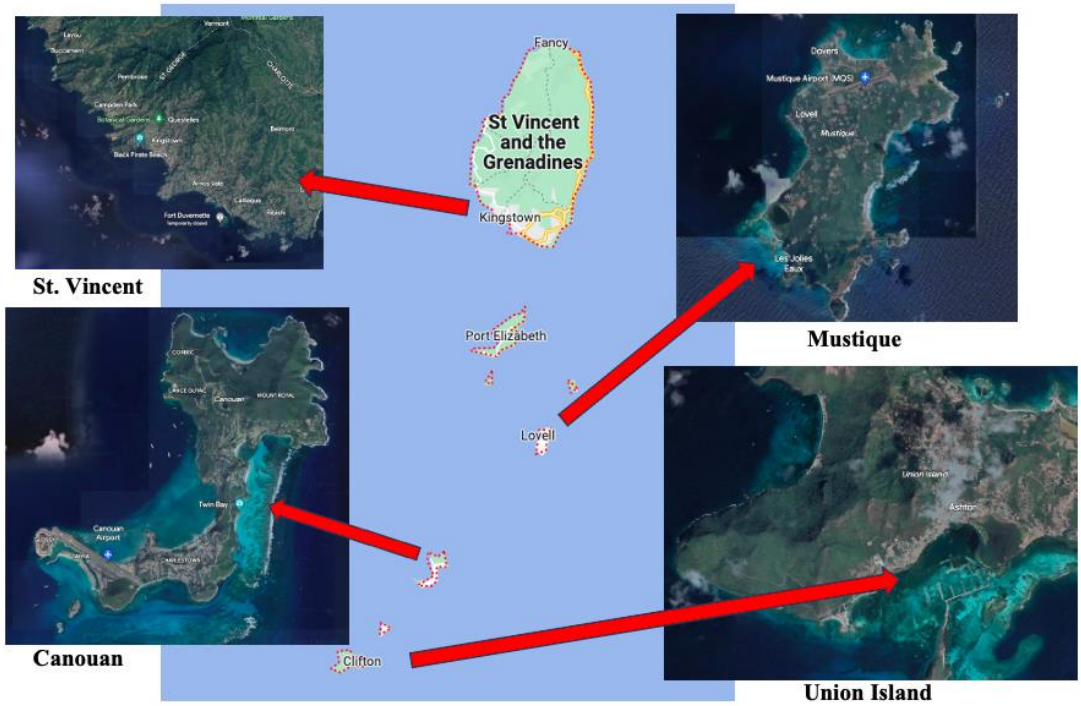
Scientific Name/ Commercial Name	Fishing Area	Use	Water Temperature (°C)	Depth Range (m)	Harvest Time (years)	Diameter (cm)	Salinity (PSU)	Source
	-	-	-	-	1.5-3	-	-	(Ellis et al., 2008)
S. officinalis mollissima (Turkey cup, Turkey solid)	Mediterranean	Bath sponge	15-25	10-30	-	15-20	-	(FAO, 1990)
		-	15-25	0-10 & 40-50	-	-	30-35	(OBIS, 2019)
	-	-	-	-	1.5-3	-	-	(Ellis et al., 2008)

3.4 Evaluation of Potential Locations for Mariculture

Based on the environmental requirements for both sponges and pearl oysters farming, numerous locations across SVG were assessed. This gave rise to four main locations, namely: St. Vincent; Mustique; Canouan; and Union Island as shown in Figure 7. The four areas presented were scrutinised on the basis of species requirements for sponge and pearl oysters such as island population densities, island pollution, area usage, salinity, temperature, currents, depth, and security of area from theft.

Figure 7

Assessed Locations in SVG



Note. From Google Earth, 2023 (https://earth.google.com/web/@12.83694732,-61.19583449,55.36122349a,160627.60781558d,35y,0.00000083h,0t,0r).

After evaluation of the environmental conditions of the potential locations, it was found that all locations have the similar temperature range from 27.2 °C to 29 °C (SeaTemperature, 2023) and salinity for 30-35 PSU (NASA, 2015).

St. Vincent, which is the mainland of SVG, has a condensed population in the coastal areas. As such, anthropogenic activities along its coast could potentially pollute the coastal waters. It was noted in the previous section that pollution affects the mortality rate and quality of pearl oysters (Gervis & Sims, 1992) and sponges (Dobson, 2003; Yi et al., 2005).

Mustique Island is a private island. Although the entire island is a conservation area, surrounded by pristine white beaches, and has the lowest population in SVG, this island has many coastal activities such as mooring of yachts and beach goers. In addition, Mustique is the second largest employer in SVG after the government of St. Vincent. Taking into account such activities, there is a possibility of pollution within its coastal areas. Moreover, the island is exposed with strong winds and currents, making it not suitable for the intended mariculture.

Canouan Island is another small island in SVG, measuring 1,251 square kilometers, which is surrounded by white beaches and untouched nature. One side of the island is covered with a coral reef in shallow water for over a mile while the other side caters high yacht traffic. In addition, strong winds and currents are also present around the island and there are few sheltered sites suitable for mariculture.

Union Island is located in the southernmost part of the Grenadines and has a surface area of 9 square kilometers. Although this island hosts some beaches, the area is a Marine Protected Area (MPA). In addition, part of this island is sheltered from storms, strong currents, and wave action. Moreover, the island has many modes of

transportation, both locally and internationally, for passengers and products. in 1994, the MPA and Ashton lagoon was used by a foreign investor who had started foundation work for a hotel, marina and golf course. The pillars, which were inadequately sized, experienced structural failure, resulting in the obstruction of tidal flow within the 10-acre (4-hectare) lagoon. An increased mortality rate among mangrove trees was observed. The transparent water underwent a transformation, becoming contaminated and assuming a yellowish hue. The lagoon, which was once renowned for its high ecological diversity within the surrounding area, underwent a transformation into a desolate and visually unappealing landscape, serving as a breeding habitat for mosquitoes. The Valdetarro Construction Company declared bankruptcy in less than a year after dredging, this left the area damaged (Kentish, 2022).

The local conservation agency Sustainable Grenadines (SusGren) and its collaborating entities currently perceive Ashton Lagoon as being completely rehabilitated, as the survival rate of the mangroves planted within the lagoon exceeds 90% (Kentish, 2022). The foundation structure from the field project is still present as can be seen in Figure 8. It could provide protection for the pearl oysters and sponges from heavy weather conditions. In addition, it could help the aquaculture by serving as structural support for the lines and cages.

In view of this assessment, it can be concluded that Union Island is the most suitable area for pearl oyster and sponge farming in SVG.

Figure 8

Aerial Photo of Prospect Site in Union Island

Note. 2004 aerial photo from Michelle Kading/Birds Caribbean. From The Caribbean Mangrove Forest that Defied Destruction, by Kentish, J. A., 2022 (https://www.bbc.com/future/article/20220329-how-a-caribbean-community-restored-its-dying-mangrove). Copyright 2022 by BBC.

3.5 Stakeholders views and perceptions

3.5.1 Conceptualization of Blue Economy in SVG

In order to gain in-depth understanding about the concept of the Blue Economy in SVG, interviews were conducted with different stakeholders. The emerging themes from the interviews are presented in Table 7. All of the respondents highlighted the underutilised potential of SVG in terms of Blue Economy. It was expressed that aside

from small-scale artisanal fisheries, conch, lobster and transportation and marine tourism, there is potential in areas that could be explored such as oil, gas, and minerals in the seabed. However, it manifested in the interview that there are large industries of conch and lobster fishery in SVG however, it was found unsustainable due to increasing fishing efforts to attain the same catch amount. Nevertheless, mariculture could also be developed which may include sea moss, sponges, sea cucumbers, and pearl oysters. Underdeveloped transportation in SVG was also stressed by the respondents. They highlighted the need for faster, comfortable and efficient inter island boats in order to sustain the promotion of the Blue Economy in the country. Finally, all respondents highlighted the lack of monitoring and management of current MPAs due to lack of resources and scientific capacity. These MPAs account for 0.22% of SVG's Exclusive Economic Zone. Such challenges in managing MPAs affect the blue economy expansion of the country.

Table 7

Perceptions on SVG's Current Blue Economy

Themes	Exemplary Data
Underutilised potential	*"I think there's a lot of underutilization of our marine space... And there's a huge potential there." - (FF1)*
	"It is very underused. And a big part of it is because of a lack of awareness and scientific capacity."- (NC1)
	"So, in my opinion, blue economy, in terms of SVG is still a little underutilised. We still focus a lot on basically just fisheries and use in the marine resources in terms of tourism, transportation. But yet, we haven't even, you know, began scratching the surface of the potential that blue economy offers us here in SVG." - (FA1)
Unsustainable small-scale artisanal fisheries	*"Fisheries is really important to food security and livelihoods. And that importance is sometimes dwarfed in comparison when you look at the potential for revenue generation when you're looking at oil and gas, for example. So, there's a huge potential for us." - (NGO2)*

Themes	Exemplary Data
Unsustainable conch and lobster fishery	*"...talking about lobster hatchery…for St. Vincent or even Grenada except for Bequia used to have a well not really like a hatchery… just was a holding space at Paget farm" - (NGO1)*
Underdeveloped transportation	*"The existing ones are the conventional ones with regard to marine transport." - (NGO2)*
Insufficient conservation scheme	*"We have to look at the space. So, there's limited space around your coastal areas." - (FA2)*
	"…the National Parks, Rivers, and Beaches Authority would have had the national parks and protected areas system plan. I think they're currently reviewing it this year trying to update it" - (FA1)
	"...there is the Caribbean challenge initiative…I think MPA was supposed to be originally 20% by 2020 and I think [it was adjusted to] 20% by 2030." - (FA2)
	"So, I know one of the things they had several areas that were slated for designation, one of which they're looking at that marine space on the leeward side, they're looking at Leeward Coast marine manage area, which is supposed to be from I think, like Larikai down to old woman's point in Edinburgh. So I think that is something that the country is seeking to do under to basically get our numbers up in terms of our commitment to increase in protected areas." - (FA1)

3.5.2 Critical Enablers for Blue Economy Development in SVG

During the interview, the respondents were asked about the critical enablers for the development of the Blue Economy in SVG, four overarching themes came out, namely: 1) regulatory framework; 2) environmental development; 3) social development; and 4) economic development as presented in Table 8 including the identified sub-themes and some of the exemplary data from the interviews. These emerging themes came up across all governmental ministries and NGOs (actors).

Table 8

Critical Enablers to Blue Economy Development in SVG

Overarching Themes	Themes	Exemplary Data
Regulatory framework	Regulation and legislation	*"We currently don't have legislation, that's what we, you know, we hope into to get done through the TNC project. And also, at least some sort of zoning and, you know, plan for best areas that could that could sustain mariculture moving forward." - (FA1)*
		"...to standardise the materials, price zone, the area, and the processing, there should be a national policy" - (NGO1)
		"...it must be regulated through the fisheries sector. And must include the management of marine resources, fishery fishing, the collecting collection, and the protection of these marine organisms. The law should be based on the principles of sustainable development and ecosystem preservation." - (NP1)
	Licensing and registration scheme	*"One of the things that the [Organization] which I work with is trying to actively work with St. Vincent is come up with a licensing and registration scheme for mariculture farmers...essentially determining who is allowed to use what space…" - (NGO2)*
	Marine spatial planning / zoning	*"Number one would be the zoning of that. So, coming up with a zoning scheme that allows and sets aside space to allow for it [sustainable mariculture]." - (NGO2)*
		"You would also need to consider marine spatial planning, and everything because there's so much potential…" - (FA2)
		"I think there's a huge potential for it. But again, as we look at it, we have such a small coastal space, limited space, and the importance of tourism. And we're all competing for that limited space, especially along the coastline where mariculture currently happens. That's something that we need to look at and look at carefully. I think what we need to be looking at also to is potentially looking at mariculture, maybe in offshore areas not so close to the

Overarching Themes	Themes	Exemplary Data
		coastline, where we actually have a lot of our tourism assets, because no one wants to see, especially the way sea moss farming is done." - (NGO2)
Environmental development	Location /environmental consideration	*"We need to balance entrepreneurship with conservation to effectively control environmental development." - (NGO1)*
Social development	Capacity building	*"They learned something new and people can get trained again, but it has to be done holistically. Not just we train people…but it has to be from start to finish." - (NGO1)*
		"It's basically a matter of our own capacity building…" - (NP1)
		"So, if you could have young people come from school and get involved in something that is beneficial, where they learn a skill dive in, where they could operate a boat captain, they could, you know, form a business around that." - (NGO1)
	Stakeholders' engagement	*"So, I think blue economy also has to do with having the right stakeholder involved and the human capacity to really propel it." - (NGO1)*
	Local engagement and education	*"So, if you could have young people come from school and get involved in something that is beneficial, where they learn a skill dive in, where they could operate a boat captain, they could, you know, form a business around that." - (NGO1)*
		"So, if we are looking at Union Island, then so when you think about family, it is our way going forward. This is best practice for fisheries, we look at getting community involvement, maybe some NGO involvement." - (FA1)
	Cultural and regional differences	*"The role of the local and indigenous knowledge in managing and conserving the marine resources is very important for sustainability." - (NGO2)*

Overarching Themes	Themes	Exemplary Data
Economic development	Governmental support	*"Government support and better decision making is crucial."* - *(NP1)*
		"...ensure that you have the full support and endorsement of the government..." - *(NGO2)*
	Innovation	*"We need to look at innovative ways of utilising marine minerals...But I think when exploring those, we need to ensure that we don't negatively impact on the livelihoods and the resources that we already have..."* - *(NGO2)*
	Economic viability	*"...to become economically viable when you start producing poles that you could sell, there's that lag time. So, you need to make sure that your business models allow for that constraint. There's got to be a learning curve."* - *(NGO2)*
	Market access	*"Make sure you have your market secured before you go in into that because you don't want to have to produce a product and there's nobody to buy"* - *(NGO2)*

3.5.3 Mariculture's Role in the Blue Economy

In the context of mariculture as one of the components of the Blue Economy, the respondents underscored its diverse role in the Blue Economy. All respondents recognized that mariculture generates revenue; provides sustainable livelihood which has a great impact especially to single parent households; and diversifies the fishery sector. On the other hand, 3 or 60% of respondents acknowledged that mariculture provides ecosystem services such as water filtration and nutrient management.

3.5.4 General Mariculture Awareness of Sponges, Pearl Oysters, and Sea Cucumbers

The eleven interviewees were questioned on their awareness of sponges, pearl oysters, and sea cucumber cultivation. All of the ministries and NGOs (actors), which account

for forty-five percent of all respondents, were entirely or partly aware of the aforementioned cultivations. However, they mentioned sea moss farming as a mariculture activity performed in SVG. The remaining respondents (stakeholders), who were all fishermen, were unaware of the mentioned species. Additionally, all of the ministries and NGOs (actors) noted their agreement with sponges and oyster farming being done in SVG when asked.

3.5.5 Social and Economic Effects of Pearl Oyster and Sponge Farming on SVG

Table 9 outlines the derived themes from government, NGOs, and fisherfolk regarding the economic and social impact of pearl oyster and sponge farming in SVG. The themes were: 1) employment opportunities, 2) emerging industries, 3) revenue generation; and 4) economic growth. All were raised by both the actors and stakeholders except economic development, which only was raised by the actors. The value of *n* is the representation of the number of respondents for each theme.

Table 9

Economic and Social Impact of Pearl Oysters and Sponges Mariculture in SVG

Themes	Exemplary Data
Employment opportunities *(n = 11)*	*"I think that's a good way to get our youth involved, because a lot of people are coming out of school without skills. So, for example, we have a coral restoration programme, where we train guys to be certified divers…" – NGO*
	"It's something that we should definitely look at, personally, growing up and being on an island and knowing what seamoss farming has done for a lot of livelihoods, especially for families, single parent families, female and households, and those things are important. So, I think there's a huge potential for it." - (NC1)
	"I think it will affect us good. it would be more jobs for everyone." (FF1)
	"Yes, my family and friends would be interested once it will provide jobs…" (FF5)

Themes	Exemplary Data
Emerging industries *(n = 11)*	*"…the benefits far outweigh the cons…it will literally develop a new industry for the nation…even on a tourism base…" - (FA1)*
	What I have learned about mariculture similar to aquaculture being the concept, the cultivation of aquatic animals and plants in a natural control environment, specifically marine environment…it also helps with the diversification of the fishery sector in St. Vincent and the Grenadines" - (NP1)
	"Those things are not done in SVG so that's new ways survive by." (FF3)
	"You're opening locals to a whole new avenue of revenue earnings in terms of the blue economy and not just only fishing, tourists, tours…" - (NP1)
Revenue generation *(n = 11)*	*"The cultivation of aquatic animals and plants in a natural control environment, specifically marine environment, I believe that this would help to increase revenue generation in SVG…" - (NP1)*
	"It would give our family additional income…So, I'd be glad if this idea would come into reality..." - (FF5)
Economic development *(n = 5)*	*"So, people would be more inclined to read about the country and it might even stimulate more investors as well." - (FA2)*
	"I personally believe that mariculture as a whole can play an important role for the economic growth and development in SVG and also for food security," - (NP1)

Employment opportunities

It was explained by the respondents that the mariculture of pearl oysters and sponges in SVG may create a sustainable livelihood for the local communities. The involvement of youth was likewise highlighted. It was stressed that a lot of people are graduating school without skills. The respondents viewed that pearl oysters and sponge farming could be an avenue for them to acquire new skills by training them as certified divers. They also explained the need for locals to see the value and potential in such ventures such as job opportunities, skills training, and financial returns.

Emerging industries

With the implementation of pearl oysters and sponge farming at SVG, various emerging industries may also arise such as marine tourism, fisheries and aquaculture advancement, renewable energy, marine biotechnology, and improved marine conservation and research. These industries should be developed on the basis of sustainability.

Revenue generation and Economic development

It would provide economic growth and revenue generation by supporting the fisheries sector in processing, distribution, and tourism. Through promoting pearl oyster and sponge farming, SVG will enhance economic growth and improve the wellbeing of the coastal communities. However, it was reminded that the achievement of the success of this venture requires robust business strategies with effective operational and marketing plans.

4. Discussion

4.1 What are the perceptions of the emerging Blue Economy and the potential for mariculture in SVG?

The interviewees suggested that there is untapped and underutilized potential in SVG's blue economy. In addition to small-scale artisanal fishing, the sectors of conch, lobster, transportation, and marine tourism suffered from a lack of effective management and zoning, available workforce, and scientific capacity. The respondents also emphasized the issue of underdeveloped marine transportation in SVG, which necessitates further improvements to support the advancement of the Blue Economy within the nation. All participants emphasized the insufficiency of environmental conservation schemes as the primary factor contributing to the inadequate monitoring and administration of existing marine protected areas (MPAs).

The underutilization of SVG's potential in the blue economy that was revealed in the study is consistent with various existing literature from the Caribbean region (DMA, 2013; Howell et al., 2019; Oxenford & McConney, 2020). Although there are some drawbacks found such as underdeveloped transportation and insufficient environmental conservation in SVG, the underutilised potential still implies that there is room for further expansion of the Blue Economy in the country.

Mariculture, as among the components of the Blue Economy, was recognised by the respondents as having an essential social, environmental, and economic contribution in SVG. They specifically viewed that mariculture generates revenue; provides sustainable livelihood; diversifies the fishery sector; and can provide ecosystem services such as water filtration and nutrient management. As such, all actors and stakeholders from the interviews acknowledged the growth potential of mariculture in SVG. The expansion of mariculture in SVG would boost the nation's blue economy

which is consistent with the views of Phillips (2009), the World Bank (2016), and FAO (2022).

4.2 What species of pearl oysters and sponges would be suitable for mariculture in SVG?

The potential of SVG in terms of mariculture has led the researcher to examine the marine species that are possibly viable for mariculture farming in the country - the pearly oysters and sponges. By reviewing the existing literature, the researcher was able to evaluate the suitability of various commercial pearl oysters and sponges, based on their environmental requirements.

4.2.1 Pearl Oysters

There were four pearl oysters found in the study that could be commercially farmed, namely: 1) *Pinctada imbricata*; 2) *Pinctada fucata/martensii*; 3) *Pinctada maxima*; and 4) *Pinctada margaritifera*. The assessed environmental conditions in SVG meet all the necessary conditions required for the successful cultivation of all the aforementioned pearl oyster species. Various literatures identified the pearl oyster specie *Pinctada imbricata* as endemic to SVG and the Caribbean region. In addition, to avoid out-competing natural species, it was determined necessary to utilize a naturally occurring species rather than introduce an invasive one. Invasive species possess the capacity to induce extinctions of indigenous flora and fauna, diminish biodiversity, engage in competition with native creatures for finite resources, and modify environments (NOAA, 2023). Due to these reasons, one species (*Pinctada imbricata)* was identified from the four as the most ideal specie for pearl oyster cultivation.

4.2.2 Sponges

Eight species of sponges were examined in this study, namely: 1) *Hippospongia communis*; 2) *H. gossypina*; 3) *H. lachne*; 4) *Spongia agaricina*; 5) *S. barbara;* 6)

S. graminea; 7) *S. officianalis adriatica;* and 8) S. *officianalis mollissima*. Out of the eight species, three species appeared to be suitable for mariculture farming in SVG. Based on the literature, both *H. gossypina* and *S. barbara* require a minimum temperature of 25 °C, which falls below the minimum average sea surface temperature of SVG by 1.3 °C. They both require a maximum of 30°C, which is within the scope of the average sea surface temperature of SVG. The literature also pointed out that both species are found in the Caribbean region and Gulf of Mexico, areas that are known to have similar environmental conditions to SVG. On the other hand, *H. lachne*'s minimum required temperature is 26.3 °C, which is the closest to the minimum average sea surface temperature of SVG (27.2°C) of all assessed species. The maximum temperature for *H. lachne* is 28.1°C, which falls below the maximum sea surface temperature of SVG (29°C). Additionally, *H. lachne* is endemic to SVG and Grenada, as identified in the literature. This makes it a priority as opposed to introducing an invasive specie that may out-compete natural sponge species found in SVG. Notably, literature points out that in warmer months and in times of bad weather conditions, sponge lines can be lowered further into the water to achieve colder temperatures and protection.

4.3 Which areas could sustain viable pearl oysters and sponges?

An area feasibility assessment was carried out using existing literature and actors and stakeholder's perspectives. This gave rise to four main locations: St. Vincent; Mustique; Canouan; and Union Island. It was found that the average sea surface temperature (27.2 °C to 29 °C) and the salinity (30-35 PSU) are the same across all areas. However, there is competing usage for many of the locations from other sectors such as tourism, fishing and maritime.

St. Vincent's mainland has a condensed population in its coastal areas, which could lead to pollution and affect pearl oyster and sponge mortality rates. Mustique Island, a private island with pristine white beaches, has the lowest population but is exposed to

strong winds and currents, making it unsuitable for mariculture. Canouan Island, a small island with a coral reef and high yacht traffic, is also not suitable for mariculture due to strong winds and currents. Union Island, a Marine Protected Area, is the most suitable area for pearl oyster and sponge farming in St. Vincent. Interviewed actors likewise confirmed Union Island's potential for pearl oyster and sponge farming and also highlighted St. Vincent as a potential site.

Figure 9 presents the identified location at Union Island that could sustain viable pearl oysters and sponge farming as found in the study. Aside from being included as MPA, this site is protected against bad weather conditions in view of its location, prevailing currents and bay shape. A total area of 204,030.56 meters square as illustrated in Figure 9 is proposed to be used for both pearl oyster and sponge cultivation. The literature identified various sponge and pearl oyster cultivations being performed in marine protected areas due to their low impact and high benefit on the environment. In terms of security, farming in a marine protected area directly limits users to the area thus making the area less vulnerable to security threats of theft and vandalism.

Figure 9

Identified Site at Union Island

Note. From Google Earth, 2023 (https://earth.google.com/web/@12.58982093,-61.43300934,1.19624651a,3500.65671784d,35y,0h,0t,0r).

4.4 How will pearl oyster cultivation and sponge farming affect local fisherfolk and coastal stakeholders?

Stakeholder participation entails the dissemination of comprehensive information to stakeholders regarding sustainable management practises, as well as actively soliciting and incorporating their perspectives and apprehensions regarding the execution of optimal measures that provide reciprocal economic, environmental, and social advantages (FAO, 2014). Within the realms of environmental and development sectors, the primary significance of involving local stakeholders revolve around

democratic and equity objectives that encompass 1) mitigating the marginalisation of individuals who are underrepresented in the decision-making process, 2) enhancing stakeholder trust and their capacity to take action based on decisions, 3) acknowledging the diversity of values held by different stakeholders, and 4) fostering social learning wherein stakeholders acquire knowledge from one another, establish fresh connections, and generate novel insights (Reed, 2008, Fritsch and Newig, 2012, Young et al., 2013a, Birnbaum et al., 2015 as cited in Sterling et al., 2017).

In view of the importance of stakeholder engagement and the benefits that it gives, the stakeholders (fishermen) from Union Island were interviewed as a focus group to gather their perspectives relative to possible pearl oysters and sponges farming on the island. The results of the discussion showed that the stakeholders displayed awareness and understanding of the MPA on the island, which is a no fish zone. Thus, there would be no detrimental effect on them having a project there. Notably, the practise of small-scale pearl farming in the vicinity of Pakin Island in the Federated States of Micronesia likewise played a significant role in promoting the well-being of the ecosystem, to the extent that it is authorised within marine protected areas (Brodbeck, 2010 as cited in Cartier et al., 2012). Pearl farming is considered a constituent of the Blue Economy, demonstrating apparent compatibility with the principles of marine conservation and protection.

With new activities like pearl oyster cultivation and sponge farming, fisherfolks highlighted that their families can benefit from financial gain through jobs. An example of this is evident in the commercial seaweed farming industry of Zanzibar, Tanzania where women from poor communities earn regular income for their households (Msuya, 2013). Furthermore, there is also a sponge farming in Zanzibar established by a Swiss non-profit organization known as Marine Cultures since 2009 that supports the livelihood of 13 women (single and divorced mothers) in the local community (Makoye, 2023). A notable example is the experience of one farmer who

was able to purchase a piece of land and built a 3-bedroom home. It was noted that because of the rising sea surface temperatures, some women in Zanzibar begun growing sea sponges over seaweeds because of its high financial gain of USD 15-30 per sponge, and resilience to pollutants and warm water temperatures. Additionally, the cultured pearl sector in French Polynesia, which accounted for USD 76,846,195 in 2017, provided employment for approximately 5,000 people as the largest country-based aquaculture industry in the Pacific (Johnston et al., 2019).

The stakeholders also highlighted that pearl oyster and sponge farming being a new industry in SVG can play a role in economic development and revenue generation. They noted it can also spark other industries to emerge as well, such as marine tourism, fisheries and aquaculture advancement, renewable energy, marine biotechnology, and improved marine conservation and research. This is consistent with the study of Betanzos-Vega et al. (2019) where they shared that the sponge farming industry in Cuba has played a significant role in fostering the emergence of sustainable and commercially viable alternatives for fishery production. It created new job sources and generated revenue for the community.

Aside from social and economic contributions of pearl oysters and sponges, it also provides an alternative to fishing reducing pressures on natural resources and protects the environment against climate change by breaking down silicon, controlling the ocean's carbon cycle, and reducing the greenhouse effect (Makoye, 2023).

4.5 Research Limitation

- It was not possible to travel to SVG to have in-person interviews with the stakeholders. Additionally, the sample size of stakeholders was small due to the busy schedule of the fishermen.

5. Conclusions and Recommendations

5.1 Conclusions

Although the definition of the Blue Economy varies from one country to another, there is little doubt it has great environmental, social, and financial potential. With this, the researcher proposes a working definition for the Blue Economy of SVG as the harmonized growth and development of its marine space and marine resources with economic gain, social wellbeing advancement and effective management of anthropogenic activities for overall sustainability. The study explored knowledge and perspectives of the environmental and economic background of SVG and found that despite the considerable number of marine resources available, the Blue Economy remains underutilized. As such, this research has explored the advancement of its Blue Economy through sustainable mariculture by examining the viability of pearl oyster and sponge farming cultivation in SVG.

Pearl oyster cultivation and sponge farming can be part of SVG's Blue Economy and promote employment opportunities for the local communities. The study identified some candidate species and one specific location, Union Island that may be suitable. Thus, the prospect of pearl oyster and sponge farming is possible for SVG, but it comes with the need for technical expertise, start-up capital and long-term commitment to ensure its success and sustainability. It also requires careful and sustainable planning and development and local collaboration to develop and sustain economic and social growth. Achieving this is also dependent on community engagement, comprehensive legal and regulatory framework including innovative financing mechanisms, Ecosystem-based management, and Marine Spatial Planning.

5.2 Recommendations

In order to ensure sustainable development of the Blue Economy in SVG, it is recommended for the policy or decision makers of the country the following:

- **Regulatory Framework.** There is a need for comprehensive legislation and regulation of the blue economy to ensure environmental preservation, benefit sharing and protection. There is also a need for a systematic approach to zoning schemes, and licensing and registration schemes for mariculture farmers.
- **Capacity building.** Awareness of sustainable Blue Economy potential and markets is necessary. There is also a need for training in mariculture techniques, marketing, compliance, and other value-added practices to ensure a competitive advantage in the international market.
- **Stakeholder Engagement.** Further promotion of stakeholder engagement would enhance trust and would reduce the marginalisation of individuals who are underrepresented in the decision-making process. It will also foster social learning wherein stakeholders acquire knowledge from one another, establish fresh connections, and generate novel insights.

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Appendices

Appendix A: Semi-Structured Interview Questionnaire for the Ministries

Semi-structured interview questions about Advancing the Blue Economy through Sustainable Mariculture: The Prospect of Oyster Pearl and Sponge Farm Cultivation in St. Vincent and The Grenadines

Thank you for agreeing to participate in this semi-structured 30-minute interview. Your responses will contribute toward my MSc Dissertation, tentatively titled "Advancing the Blue Economy through Sustainable Mariculture: The Prospect of Oyster Pearl and Sponge Farm Cultivation for Natural Population Production in St. Vincent and the Grenadines."

The Wider Caribbean is heavily dependent on coastal resources, most notably small-scale fisheries that are critical for supporting coastal community livelihoods and food security. Fisheries for high-value species, such as tuna, conch, lobster and shrimp, also contribute significantly to trade and foreign exchange earnings, and have important links with tourism. These are currently the main components of the Blue Economy for St. Vincent and the Grenadines (SVG) and are worth millions of dollars a year. Mariculture, however, is less well-developed in the region, but has a lot of socioeconomic potential and is predicted to be one of the fastest-growing elements of the Blue Economy. This study focuses on innovative industries in mariculture, specifically oyster pearl and sponge farm cultivation, to enhance the growth of SVG's Blue Economy. I wish to evaluate the perspectives, insights and expertise of stakeholders (fishers, coastal communities, tourism operators, and marine regulators) in a specific case study (Union Island) where mariculture could be a viable enterprise. I seek to be as inclusive as possible so as to be in a position to fully evaluate the development of effective national initiatives such as mariculture, that could play a key role in the future of the blue economy in SVG.

GENERAL QUESTIONS

Respondent name: _____
Date: _____
Affiliation: _____
Position: _____
E-mail/contact: _____

Interview questions
1. What is your position and responsibilities?
2. What do you think of SVGs blue economy?
3. What do you think about mariculture as a component of the blue economy?
4. Have you heard of sponge, pearl or sea cucumber mariculture?
5. Are there any such mariculture projects ongoing in SVG?
6. What is needed for mariculture to be sustainably regulated in SVG? License, EIA requirement???
7. Do you think there is a possibility for pearl and sponge farming in Saint Vincent?
8. What about specifically for this area (Union Island) – map of site will be shown.
9. Do you know if there are any special habitats or species that live in this area?
10. How do you think the locals will feel about this type of mariculture?
11. Would you be supportive of developing this type of mariculture? If yes, why?
12. What advice would give to entrepreneurs interested in starting this type of mariculture?

Map of site area

Appendix B: Semi-Structured Interview Questionnaire for the NGOs

Semi-structured interview questions about Advancing the Blue Economy through Sustainable Mariculture: The Prospect of Oyster Pearl and Sponge Farm Cultivation in St. Vincent and The Grenadines

Thank you for agreeing to participate in this semi-structured 30-minute interview. Your responses will contribute toward my MSc Dissertation, tentatively titled "Advancing the Blue Economy through Sustainable Mariculture: The Prospect of Oyster Pearl and Sponge Farm Cultivation for Natural Population Production in St. Vincent and the Grenadines."

The Wider Caribbean is heavily dependent on coastal resources, most notably small-scale fisheries that are critical for supporting coastal community livelihoods and food security. Fisheries for high-value species, such as tuna, conch, lobster and shrimp, also contribute significantly to trade and foreign exchange earnings, and have important links with tourism. These are currently the main components of the Blue Economy for St. Vincent and the Grenadines (SVG) and are worth millions of dollars a year. Mariculture, however, is less well-developed in the region, but has a lot of socioeconomic potential and is predicted to be one of the fastest-growing elements of the Blue Economy. This study focuses on innovative industries in mariculture, specifically oyster pearl and sponge farm cultivation, to enhance the growth of SVG's Blue Economy. I wish to evaluate the perspectives, insights and expertise of stakeholders (fishers, coastal communities, tourism operators, and marine regulators) in a specific case study (Union Island) where mariculture could be a viable enterprise. I seek to be as inclusive as possible so as to be in a position to fully evaluate the development of effective national initiatives such as mariculture, that could play a key role in the future of the blue economy in SVG.

GENERAL QUESTIONS

Respondent name: _____
Date: _____
Affiliation: _____
Position: _____
E-mail/contact: _____

Section 1
1. What is your position and responsibilities?
2. What do you think of SVGs blue economy?
3. What do you think about mariculture as a component of the blue economy?
4. Have you heard of sponge, pearl or sea cucumber mariculture?
5. Are there any such mariculture projects ongoing in SVG?
6. What is needed for mariculture to be sustainably regulated in SVG? License, EIA requirement???
7. Do you think there is a possibility for pearl and sponge farming in Saint Vincent?
8. Is it possible specifically for this area (Union Island) – map of site will be shown.
9. Do you know if there are any special habitats or species that live in this area?
10. How do you think the locals will feel about this type of mariculture?
11. Would you be supportive of developing this type of mariculture? If yes, why?
12. What advice would give to entrepreneurs interested in starting this type of mariculture?

Map of site area

Appendix C: Focus Group Questionnaire for the Fisherfolk

Semi-structured interview questions about Advancing the Blue Economy through Sustainable Mariculture: The Prospect of Oyster Pearl and Sponge Farm Cultivation in St. Vincent and The Grenadines

Thank you for agreeing to participate in this semi structured 30-minute interview. Your responses will contribute toward my MSc Dissertation, tentatively titled "Advancing the Blue Economy through Sustainable Mariculture: The Prospect of Oyster Pearl and Sponge Farm Cultivation for Natural Population Production in St. Vincent and the Grenadines."

The Wider Caribbean is heavily dependent on coastal resources, most notably small-scale fisheries that are critical for supporting coastal community livelihoods and food security. Fisheries for high-value species, such as tuna, conch, lobster and shrimp, also contribute significantly to trade and foreign exchange earnings, and have important links with tourism. These are currently the main components of the Blue Economy for St. Vincent and the Grenadines (SVG) and are worth millions of dollars a year. Mariculture, however, is less well-developed in the region, but has a lot of socioeconomic potential and is predicted to be one of the fastest-growing elements of the Blue Economy. This study focuses on innovative industries in mariculture, specifically oyster pearl and sponge farm cultivation, to enhance the growth of SVG's Blue Economy. I wish to evaluate the perspectives, insights and expertise of stakeholders (fishers, coastal communities, tourism operators, and marine regulators) in a specific case study (Union Island) where mariculture could be a viable enterprise. I seek to be as inclusive as possible so as to be in a position to fully evaluate the development of effective national initiatives such as mariculture, that could play a key role in the future of the blue economy in SVG.

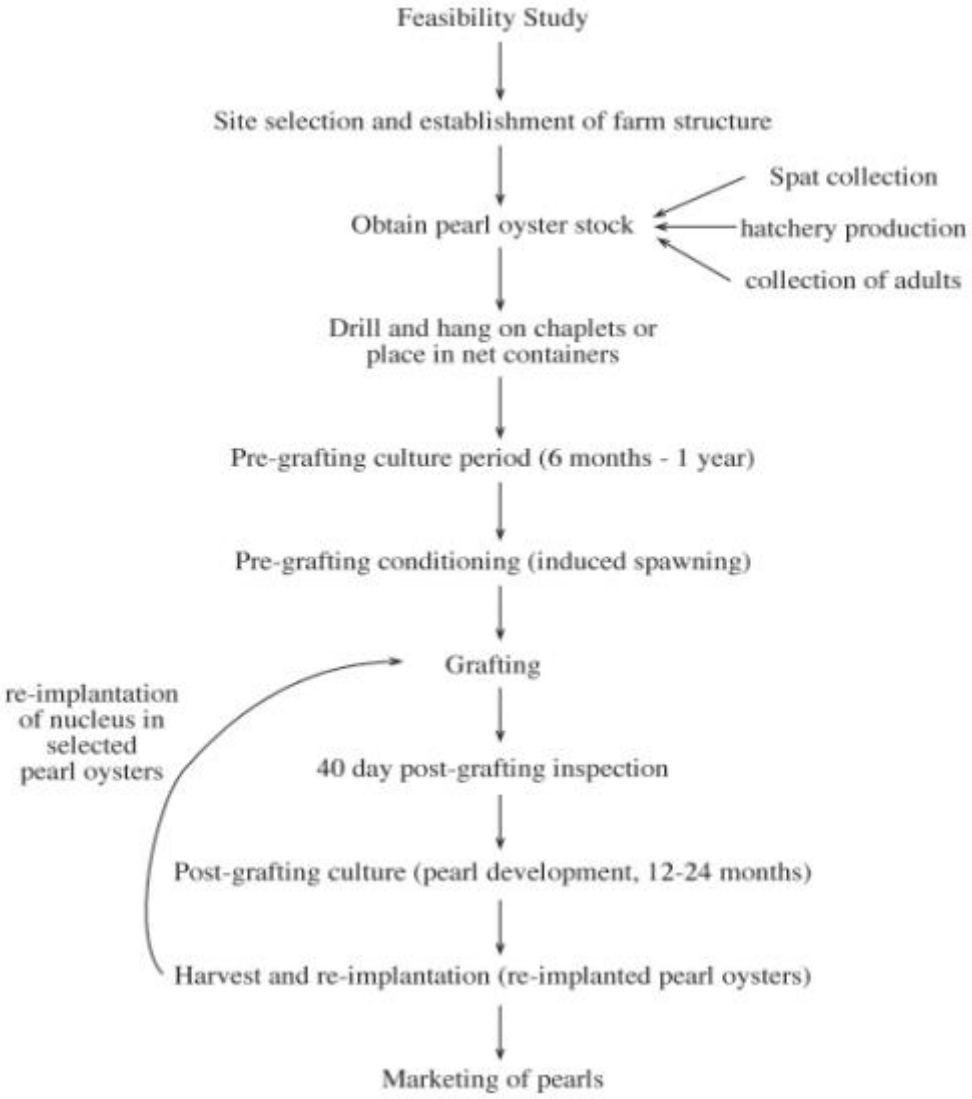
GENERAL QUESTIONS

Respondent name: _____
Date: _____
Affiliation: _____
Position: _____
E-mail/contact: _____

Section 1
1. Are you a registered fisherman?
2. What type of fish do you catch?
3. Do you fish in this particular area? (Refer to map below) If so, what kind of fish?
4. Can you mark on the map where you use the area and what you catch where?
5. How often do you fish there?
6. Do you use this area for any other reasons?
7. Do you see any other activities happening in this area?
8. Do you ever come into conflicts with other users?
9. What is your average catch per week/month from this area and over all areas? Kg or $
10. Have you heard of the term blue economy?
11. Do you know much about mariculture? 12. Specifically growing sponges, pearls or sea cucumbers
13. What effects do you think such a development can have on your livelihood if you could no longer access it or if you could only access certain areas
14. Would you or your family members be interested in jobs associated with mariculture?

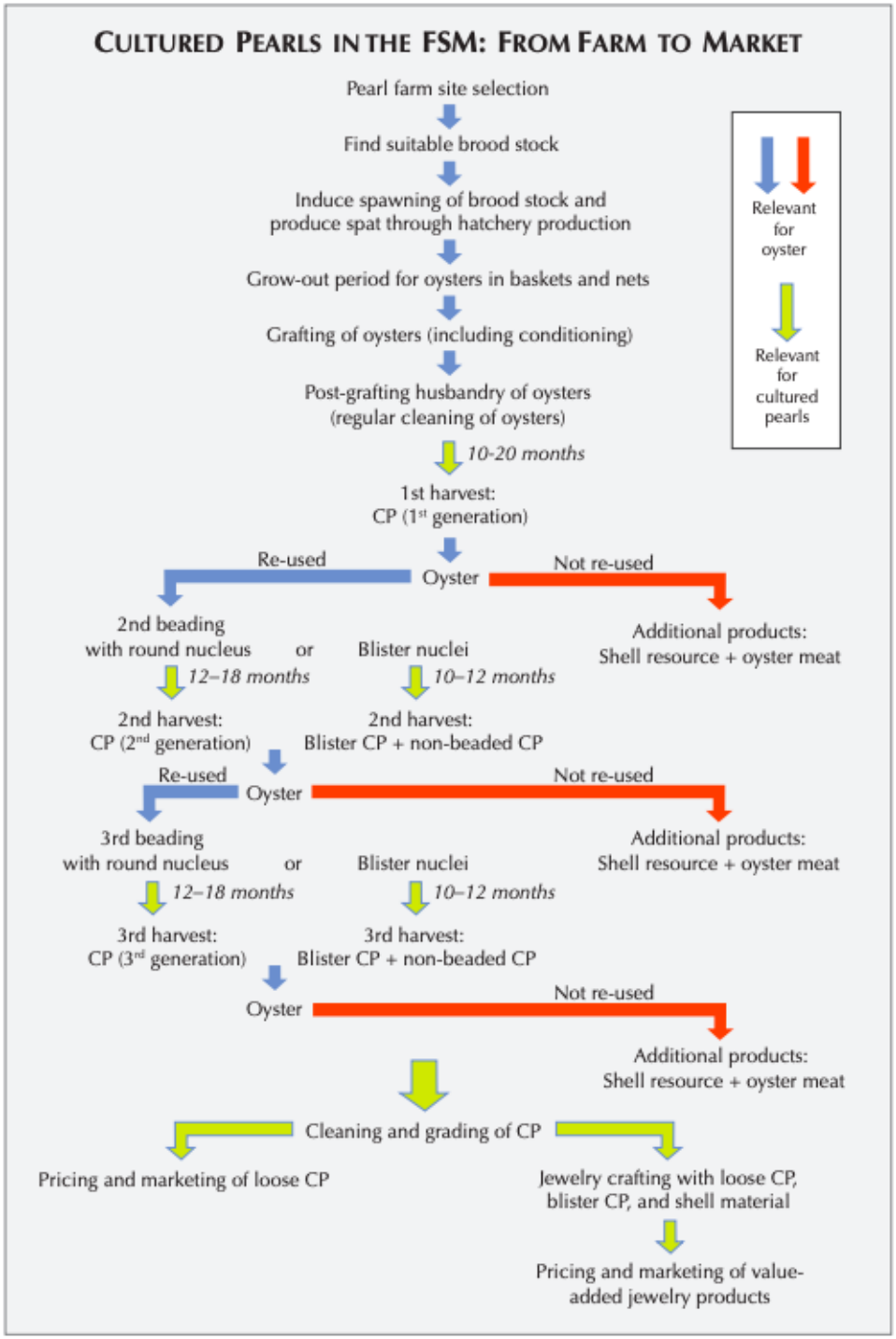
Map of site area

Appendix D: Steps in Pearl Farming by Haws (2002)



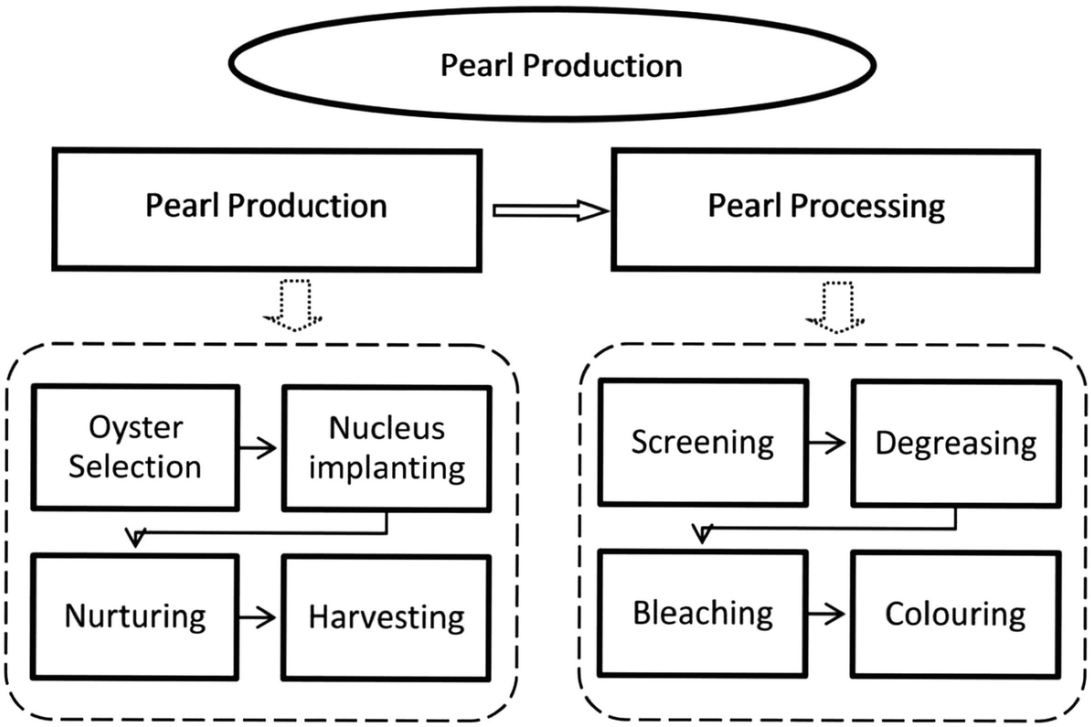
Note. From *The Basic Methods of Pearl Farming: A Layman's Manual*, by Haws, M. 2002, Center for Tropical and Subtropical Aquaculture (https://www.ctsa.org/files/publications/CTSA_12763167286192394836 81.pdf).

Appendix E: Steps in Pearl Farming by Cartier et al. (2012)



Note. From "Cultured Pearl Farming and Production in the Federated States of Micronesia," by Cartier, L.E., Krzemnicki, M. S., & Ito, M., 2012, *Gems & Gemology*, *48*(2), p. 108–122 (https://doi.org/10.5741/gems.48.2.108).

Appendix F: Diagrammatic representation of the stages of pearl production



Note. From "Production of Pearls," by Zhu, C., Southgate, P. C., & Li, T. in Smaal, A., Ferreira, J., Grant, J., Petersen, J., Strand, Ø. (Eds.), *Goods and Services of Marine Bivalves* (p. 73-93), 2019, Springer Open (https://doi.org/10.1007/978-3-319-96776-9_5). Copyright 2019 by Springer Nature Switzerland AG.