Chapter

Sponge Fishery and Aquaculture in Cuba: Impacts and Challenges

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Abstract

Sponges are very primitive multicellular organisms that belong to *phylum Porifera*; they are sessile and live attached to different types of hard and soft substrates. Sponges have different shapes and colours and very varied sizes, from a few millimetres to more than 2 m in height. They inhabit mainly in the marine environment at different depths. This chapter describes the general biological characteristics of sponges, their properties, uses and applications. Moreover, this study discusses a commercial fishery analysis of this natural resource in Cuba during the period 1970–2017, as well as the different characteristics of their natural populations subjected to commercial extraction. The applied techniques for aquaculture, harvest and postharvest processing are reviewed, including those procedures adapted from other countries or locally developed by Cuban fishermen. Finally, this study examines the challenges and perspectives of this productive activity with a long-term eco-sustainable approach.

Keywords: sponges, ecology, aquaculture, production, Cuba

1. Introduction

Sponges are very primitive pluricellular aquatic organisms that belong to *phylum Porifera*; they are sessile species and live adhered to different types of soft and hard substrates. *Porifera* are of diverse shapes and colours and have very varied sizes, from a few millimetres to more than two metres in height. They are found practically at all depths; non-polluted coastal zones and tropical reefs are especially rich in this type of species. The majority of sponges are marine, and only is the family *Spongillidae* known to live in fresh water. Until well into the eighteenth century, the origin of sponges was justified differently as nests of certain marine animals or plants. In 1786, John Ellis, an Englishman, observed retraction and expansion movements of the sponge pores, as well as water currents flowing through their bodies, so he classified them as animal organisms. Nevertheless, sponges lack some characteristics of typical animals, such as not having organs totally differentiated, which in a way could be considered equivalent to sets of specialised cells that pump water through their whole body to obtain oxygen, food, transport waste and reproductive products. Their reproduction is sexual and asexual; this last one is the most common as it occurs at any moment by gemmulation, formation of root-like extensions and fragmentation of the mother sponge. Sexual reproduction can be hermaphrodite with separate sexes in definite or temporal form. Oviparous and viviparous species have also been recorded; in both cases, the eggs or larvae are released through the exhaling water current [1–3].

Close to 9000 sponge species are estimated to exist in the world, but only do a few ones belong to the order *Keratosa* and the family *Spongiidae*, which have been traditionally utilised for commercial purposes [4, 3]. These kinds of sponges are characterised by having a corneal skeleton densely reticulated, free of spicules with a great capacity to retain water, elasticity and durability [5]. The main commercial value of natural sponges is given by their high capacity for water retention and because they can pump 1200 times their own volume per day. *Keratosa* and *Spongiidae* are able to retain up to 90% of particulate organic material, such as plankton, bacteria and even viruses suspended in water besides their resistance to acids and greater easiness for cleaning with respect to the artificial ones [6, 7].

The demand of natural sponges has been growing because of the market preference for natural products and the increase of their use in man's life, such as domestic, cosmetic, biomedicine, pharmaceutical, pottery, art industry, filter, cleaning and industrial purposes, among other uses. The commonly called 'bath sponges' of the family *Spongiidae* have a high price in the market although their offer has decreased due to natural reduction and impact of different natural and anthropogenic factors, among them, increase in frequency and intensity of extreme meteorological events, such as hurricanes, deriving from climate change or variability, pollution, disease incidence and overexploitation of natural populations [8]. The industrial and domestic sponges in Cuba have an international market that rises above 40 million USD annually [9].

Natural populations in sponge zones in the world, such as the Antillean region (Cuba, Bahamas and Florida), guarantee more than 50% of the world production. In Mexico, the Caribbean reefs (Isla Mujeres, QR) and the Gulf of Mexico have great species richness that includes the three classes that integrate *phylum Porifera: Calcarea*, *Hexactinellida* and *Demospongiae*. Nonetheless, no commercial exploitation of sponges exists in Mexico. Although none of the species of this taxonomic group are found protected by the Mexican norm NOM-059, natural sponge populations are located in protected natural areas, national marine parks or biosphere reserves under conservation legislation [3]. On the other hand, the production zones that stand out are the Mediterranean Sea (Syria, Turkey and Greece), the Adriatic Sea (Lebanon, Egypt, Tunisia and Italy) and the North Pacific Ocean (Philippine Sea, Carolina Islands and Marshall Islands) [4, 10].

The species from the Mediterranean are considered as those with the best quality and commercial value, of which those that stand out are the species *Spongia officinalis* or 'Fina' [in Spanish] (the best of all the commercial species; bath sponge), *Hippospongia communis* 'Común' [in Spanish] (of greater abundance; horse sponge), *Spongia zimoca* and *Spongia agaricina* or 'Oreja de Elefante' [in Spanish] (elephant ear; lamella) [4, 5].

In the Antillean region, the best commercial sponges have come from Cuba and the Bahamas Islands. Although several species have been reported in Cuba, four species have been the target for capture because of their abundance [1, 11–13]. Of the four species, three of them correspond to those commonly called 'machos' [males] from the genus *Spongia*: *Spongia barbara* (Duchassaing & Michelotti, 1864) called in Cuba 'macho fino' [fine male], *Spongia obscura* (Hyatt, 1877) or 'macho cueva' [cave male] and *Spongia graminea* (Hyatt, 1877) or 'macho guante' [glove male] and the one called 'hembra de ojo' [eye female] or Wool of the genus *Hippospongia* and *Hippospongia lachne* (Laubenfels, 1936), which is the one with the greatest commercial value in Cuba although other species usually show up in capture.

The presence of commercial sponges, as well as their fishing or recollection, has been reported in Cuba since the nineteenth century. During colony times, fishing boats from the Bahamas would reach the coasts of the Caribbean and Nuevitas (northeast of Cuba) to fish sponges with licence from Spanish authorities where more than 150 thousand dozen were fished by Cubans in 1867 [14]. Years later, sponge fishing was developed in southwestern Cuba with fishermen from Batabanó port, and because of their abundance, the two fishing zones in Cuba were established: (1) the northeast zone exploited by boats and fishermen from Caibarién where the Sabana-Camagüey Archipelago is located and (2) the Gulf of Batabanó, in southwest Cuba, exploited by boats from Batabanó fishing port. By 1886 offices in London and Paris were established to commercialise this product [15]. In 1930, the production went beyond 1 million dozen until 1939 and up to 1943 when a disease known as 'tizón' (blight), caused by the fungus *Spoingiophaga communis*, reduced the Cuban, Bahamas and Florida populations. Jointly with this situation, damage caused by a hurricane in 1944 led to a decrease in sponge production in the region to 16,000 dozen in 1947 [16].

This chapter discusses the principal studies and criteria related to commercial sponge fishery and aquaculture advances in Cuba, the main impacting factors that limit their abundance, and the challenges to increase aquaculture production of this important resource sustainably in the long term and with an ecosystem approach.

2. Analysis of the commercial sponge fishery in Cuba

Sponge fishery in Cuba has shown two extraction procedures, in accordance with the characteristics of the extraction zone, fishermen's age and regional traditions [17–19]: (1) by means of hooking implements for sponge recollection from auxiliary (small) boats that are towed by a sponsor, so fisherman immersion is not needed, or (2) by diving in apnoea for detaching or cutting the sponges from the closest part to the fixation substrate. Practically, no evolution in the fishing form has taken place throughout the years. The shallowness of the area where sponges inhabit has determined the fishing system that has followed the traditional method, using a glass bottom bucket and a stick with a double hook or trident to detach the sponge from the substrate (**Figure 1**).

Cuba reached an important commercial sponge production with an average of 166 t in the period from 1910 to 1919; 505 t for 1920–1929 and 391 t for 1930–1939 [20]. From 1939 to 1943, the fungus (blight) disease decimated the populations jointly with the hurricane at the end of 1944, generating lower production levels until 1947 [16, 21]. During the period after 1960, fishery activity was reorganised in Cuba; the fleet was modernised, which decreased the number of sponge boats and fishermen; fishing areas were divided into zones by territories, establishing

Figure 1.
Traditional technique for sponge capture or recollection in Cuba, sponge boat, auxiliary boat and glass bottom bucket. Photography: La Empresa Pesquera Industrial de Caibarien (EPICAI).

two fishing regions (**Figure 2**) in terms of abundance [22, 23]. Currently, commercial sponge fishery in Cuba is regulated by catch quota, and minimum legal sizes have been established for perimetric length: 35.6 cm for *H. lachne* ('Hembra de ojo'), 30.6 cm for *S. obscura* ('Macho cueva') and 20.8 cm for other species, such as *S. pertusa*, *S. barbara* and *S. graminea* [24].

Although current statistics have shown a tendency to increase sponge extractive activities since 1960, Cuba has not been able to reach the production levels previous to 1940. This tendency could have been due to a greater fishing effort. Almost all the fleets of Batabanó and Caibarién ports dedicated themselves to the capture of this resource and utilised boats type 'Balandro' and 'Goleta' with a crew from 14 to 16 fishermen. Before 1944 the fleets operated around 350 boats in the Gulf of Batabanó, which belonged to the Cuban ports of Batabanó, Coloma and Gerona [13, 14]. Production increased from 1960 with the proper fluctuations of a fishery that depended on different natural and human factors. Nonetheless, the average annual capture (40.15 ± 12.8 t) from 1960 to 2017 (58 years) did not go beyond 50 t (**Figure 3**).

Sponge fishery production decreased in southwest Cuba (Gulf of Batabanó) by fishing region from the beginning of the 2000 decade. Production reported by the enterprise PESCAHABANA (Batabanó) fell from 28.2 ± 3.1 t (2000–2004) to 19.6 ± 1.6 t (2013–2017). A similar pattern was registered for the northeast region (Sabana-Camagüey Archipelago). Production from the industrial fishery (EPICAI) decreased from 25.4 ± 1.6 t (2000–2004) to 14.1 ± 3.0 t (2013–2017). In the case of Caibarién, a greater stability was observed in sponge production during the period 1990–2009 (23 ± 3.8 t). Nevertheless, average capture from the period 2010–2017 was 19.1 ± 9.0 t with a maximum capture (>33 t) in 2010 and 2011, much higher than the historic average (23.5 t) from the period 1972–2017 (47 years). All these data suggested that overfishing occurred during 2010 and 2011 whose consequence was observed several years later with a lower extraction of 15 t, which affected national sponge production. The situation of this region got worse in 2017 (10.4 t) due to the impact of Hurricane 'Irma'.

2.1 Abundance by species and regions

Population density studies developed in the 2000 decade [13] showed a greater sample density in the region of the Sabana-Camagüey Archipelago (Caibarién) with respect to sample data for the region of the Gulf of Batabanó (**Figure 4**).

In both Cuban regions, northeast (Caibarién) and southwest (Batabanó), commercial extraction of the sponges locally known as 'Machos', which belong to the genus *Spongia sp*, was higher than those known as 'Hembras' (*Hippospongia lachne*).

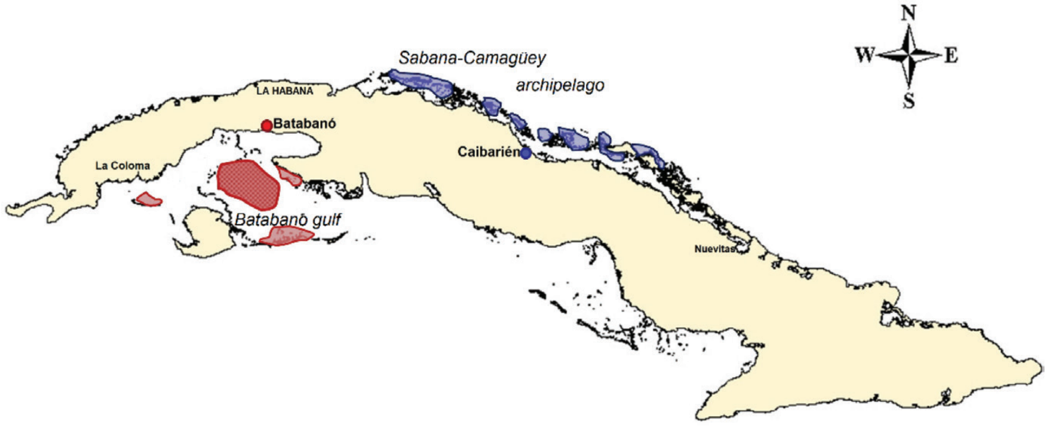

Figure 2.
Distribution of the fishing areas according to zones of major commercial sponge abundance: northeast zone (Sabana-Camagüey Archipelago) and southwest zone (Gulf of Batabanó) Cuba.

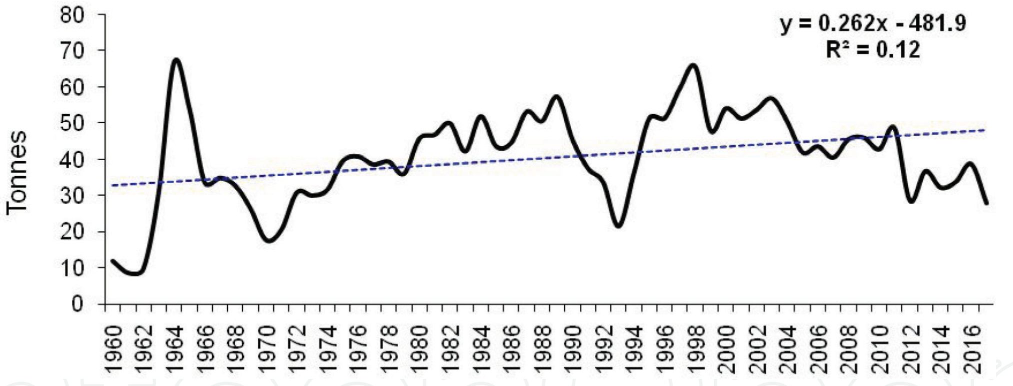

Figure 3.
Interannual variability of commercial sponge annual average extraction for the 1960–2017 period, in Cuba.

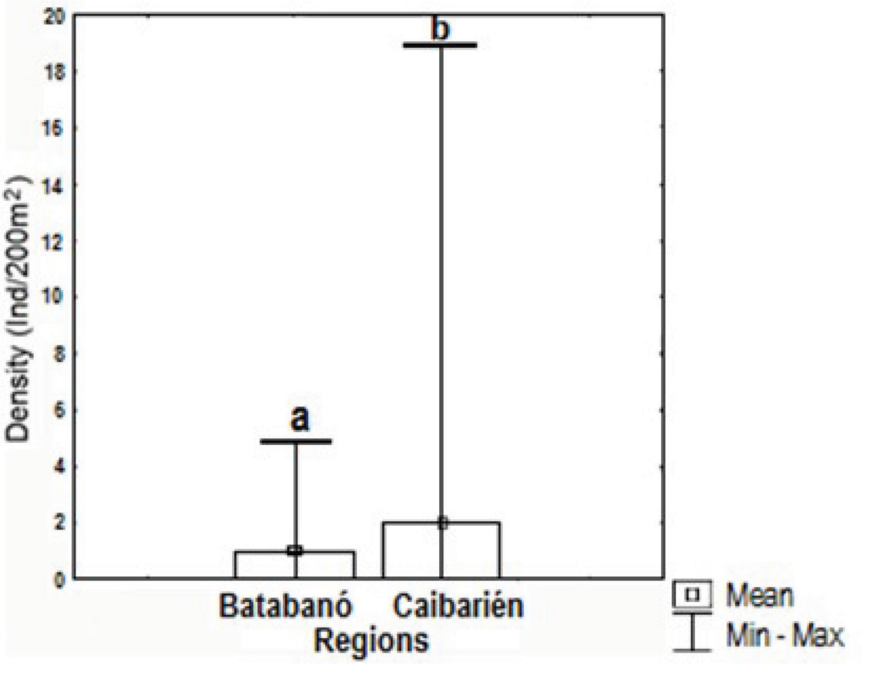

Figure 4.
Sponge density according to southwest (Batabanó) and northeast (Caibarién) regions in Cuba. Different letters indicate significant differences p < 0.05 [13].

On the other hand, regardless of the fishing effort applied in each region, a tendency to decrease was observed in sponge production, which was lower for *H. lachne* species both in extraction data and abundance parameters in both regions [13]. Species extraction of the genus *Spongia* sp. in the northcentral or northeast regions of Cuba was relatively constant during the 2000 decade. A different pattern was found for the same genus in the southern region (Gulf of Batabanó), showing a tendency to decrease, same as those of the species *H. lachne*. This situation was reflected on sample density by species (**Figures 5** and **6**).

In subsequent studies developed in a protected northeast zone of the Sabana-Camagüey Archipelago during 2013 [25], which is under the Special Regime of Use and Protection and in which commercial sponge extraction has not been performed, an average density of 0.457 ind/m^2 was recorded (4570/ind/ha), estimating a potential precautionary capture of 1300 specimens (30% of the total) per hectare per year [25].

Density data obtained were by far superior to those reported by Blanco and Formoso [13] for the extraction zones of the Sabana-Camagüey Archipelago. Furthermore, they were superior to those reported by these same authors for the

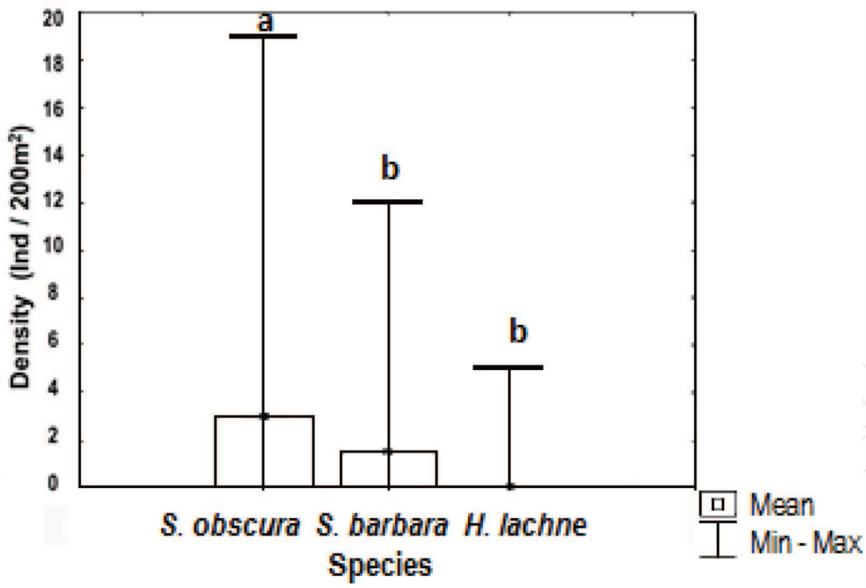

Figure 5.
Commercial sponge density by species on the natural banks of northeast Cuba (Sabana-Camagüey Archipelago). Different letters indicate significant differences $p < 0.05$ [13].

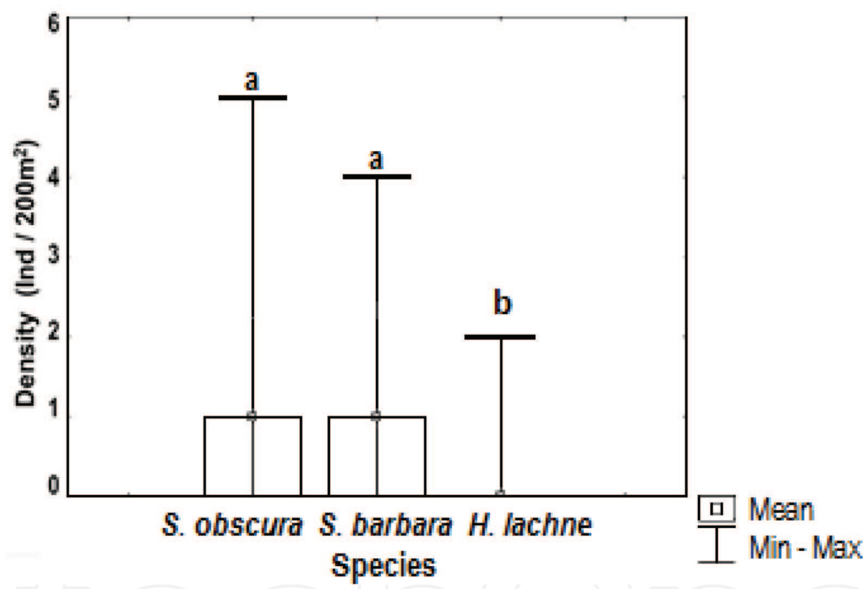

Figure 6.
Commercial sponge density by species found on natural banks of southwestern Cuba (Gulf of Batabanó). Different letters indicate significant differences $p < 0.05$ [13].

Gulf of Batabanó in the 2000 decade, which evidenced, among other causes, that fishery was also an impact factor.

What is more transcendental data from recent studies is that the 'Hembra' sponge *H. lachne* showed greater abundance in the zone assessed from the protected area in 2013. Just because of its greater economic value, it is one of the first species to decrease in abundance, and it also evidenced that a decrease in production is expected due to commercial exploitation and improvement of extractive methods [25].

3. Main impact factors in sponge populations in Cuba

As previously mentioned, one of the main causes of abrupt decrease in sponge populations in Cuba was related to the disease known locally as 'Tizón' (smut or blight) caused by the fungus *Spoingiophaga communis* during the period 1939–1945 [17, 20, 21]. After 1945, no significant outbreaks of this disease were reported. Because of the capture decrease in the Gulf of Batabanó, studies were performed in 2005, but no proofs of the existence of pathogenic organisms (fungi and bacteria), which could cause sponge death and subsequent decrease in production, were detected that year [26].

Solar radiation, illumination and temperature are factors that regulate sponge distribution, colonisation and success in their natural reproductive processes. Although they can withstand extreme temperature (10–36°C) values in short periods, the optimum values for their sexual proliferation is from 23 to 29°C [27, 28]. In Cuba the southern sponge zones of the Gulf of Batabanó showed water temperature average of 28.03°C, while in the northern zone of Sabana-Camagüey Archipelago, average temperature was 27.33°C in Sabana and 28.32°C in Camagüey [29].

Even though these values are permissible for commercial sponges in Cuba, high temperatures (>30°C) can also favour the proliferation of bacteria and fungi. In coastal water bodies and bays in the inner part of the Camagüey Archipelago, extreme maximum temperatures up to 35°C could occur due to shallowness and limited water renovation [29]. Because of the shallowness from 3 to 7 m in the Gulf of Batabanó and from 2 to 8 m in the Sabana-Camagüey Archipelago, in which the greatest abundance of Cuban commercial sponges inhabit, they are very vulnerable to natural physical impacts.

Blanco [23] pointed out hurricanes as a cause of impact on sponge populations, above all on those that inhabited the Gulf of Batabanó due to a greater frequency and intensity of cyclonic disturbances after 1996. Hurricanes generate strong currents and surge of great height and intensity that provoke sediment in suspension besides the fracture and dragging of fragments or complete organisms. It occurs to sponges themselves due to their sessile condition that makes it impossible for them to escape from the energetic movement that occurs in waters, which makes the effect greater on the genera *Spongia* and *Hippospongia* because they are very susceptible due to their high tissue density [30–32].

The increase of anthropogenic activities, such as tourism development in keys and islands, above all in the Sabana-Camagüey Archipelago, adds contamination and increase in water turbidity; dragging and landfill for construction and repairing roads that link the coast of Cuba to these keys have led to periodical turbidity events that have affected seawater quality [33]. The excess of small particle solids suspended in the water column has caused clogging of the inhaling pores in commercial and noncommercial species, more so in those that have fine pores, causing them inadequate development, including death [1, 26]. The increase of siltation due to coastal erosion has been another impact additional to hurricanes, which has been derived from logging bordering mangroves, maritime construction and increase of average seawater level, as it has occurred in several coastal segments in the southwest region of the Gulf of Batabanó.

On the contrary, organic contamination at intermediate degrees seemed to have caused certain stimulation to sponge development and diversification, but it also reduced species diversity in reefs dramatically and, in extreme cases, has a greater decrease of their biomass [34]. Contamination has also brought as a consequence the disappearance of marine grass rich in commercial sponges and its substitution for muddy bottoms with turbid water loaded with sediments that do not favour *Porifera*. This situation has occurred in wide zones of the Sabana-Camagüey Archipelago [34].

Finally, fishing activity itself could constitute an additional impact when resource exploitation goes beyond its recovery capacity since uncontrolled extraction levels lead to overfishing patterns. Blanco [23] points out a tendency of sponges to decrease, above all, the species *Hippospongia lachne*, associated to the high exploitation rate to which it has been subjected for years, among other factors, due to its high commercial value.

4. Sponge culture in Cuba

The development of sustainable and economically viable fishery production alternatives, such as sponge culture, constitutes an additional contribution to environment sustainability. It is a working alternative for fishermen to create new community employment sources and generate income of foreign currency besides the need of moving from a predatory recollection activity to a productive aquaculture work, as a step in economic and cultural fishery development in the country [8].

Sponge culture offers a safe and predictable production of a superior quality product to that offered by natural capture besides its elevated price according to the market, quality and species. Besides the easiness of their collection in their natural environment because they are sessile organisms that are generally found in shallow waters, they do not need additional food to that filtered from their environment. This is the reason why its culture requires low investment cost and availability to schedule a tiered harvest. Moreover, its culture reduces fishing pressure on sponges in their natural medium, constituting a sustainable repopulation alternative to increase natural banks surrounding the aquaculture farms because of their larval contribution to the environment [35].

Initial sponge culture in Cuba goes back to several decades. A variance of sponge culture suspended in vertical lines was tested in Cuba in 1965 and described by García del Barco [36, 37] in a sponge culture handbook. The method of vertical suspended lines allowed using a greater area vertically taking advantage of the zone in a greater depth and avoiding being affected by surge as it occurs in lower zones where they traditionally inhabit.

Complete experimental cycles included sponge collection from their natural environment, seeding, harvesting and reseeding from seeds obtained from the same culture, cleaning process and commercialisation. Aquaculture procedures were performed with the assessment of scientific institutions, such as Centro de Investigaciones Pesqueras de Cuba [38, 39].

Although sponge culture was not consolidated to a commercial level, important conclusions were obtained from these studies:

- Cultured sponges showed less osculation density and diameter, increasing solid surface and weight per volume unit.
- They showed less mechanical damage during recollection.
- Cultured sponges were harvested in total absence of foreign materials.
- They showed spherical shapes which reduced process expenses and wastes.
- Cultured sponges reached a similar or greater size to those in their natural environment, in equal period, but with better and more rounded shape.
- ‘Seeds’ for a nondependant aquaculture could be obtained from their natural environment if not harvesting a part of the cultured sponges and allowing them to naturally grow for about 3 years to get a ‘mother sponge’.

The technical and scientific knowledge and field experiences derived from these experiments allowed editing a handbook of work procedures and operations for small sponge farms attended by the same extractive fishery crew [40]. Research and development has continued, and two culture methods have been tested during the last decade, which are briefly described below.

4.1 Free sponge method

An experimental farm was projected by the Centro de Estudios y Servicios Ambientales (CESAM, its abbreviation in Spanish for Centre for Environmental Studies and Services) of Villa Clara, Cuba. It was sponsored by funding partners of the United Nations Development Programme for Global Environmental Finance (Small Donations GEF-PNUD). The sponge farm was located in a marine zone in the surroundings of the town Carahatas (Sabana-Camagüey Archipelago) north-central coast of Cuba. One-hectare culture fences were built and installed in the sea. Metallic poles were buried in the seabed as basic support and plastic mesh cove to restrict access to predators. The 'free' sponge method was used in those subdivided 1-ha lots, planting a density of 1 sponge/4 m^2 (**Figure 7**).

Starting from the contribution of the project GEF/PNUD/'Protección de la biodiversidad en tres sectores productivos del Archipiélago Sabana-Camagüey' [Biodiversity protection in three productive sectors of the Sabana-Camagüey Archipelago], fishermen from the Caibarien Basic Enterprise Unit (EPICAI) built a farm in a northeast shallow marine zone with the advice from Centro de Investigaciones Pesqueras.

Recollected sponges were cut in 4–5 cm^3 pieces named as 'propagules' that were used for 'seeding' and deposited in the substrate (approximately 2500 seeds/ha), at the mercy of currents and other natural water dynamics, until they reached a commercial size. A total of 12 ha seeded were obtained, which should provide 1 t of sponge in a year at a quote of more than $15,000 USD in the world market [41].

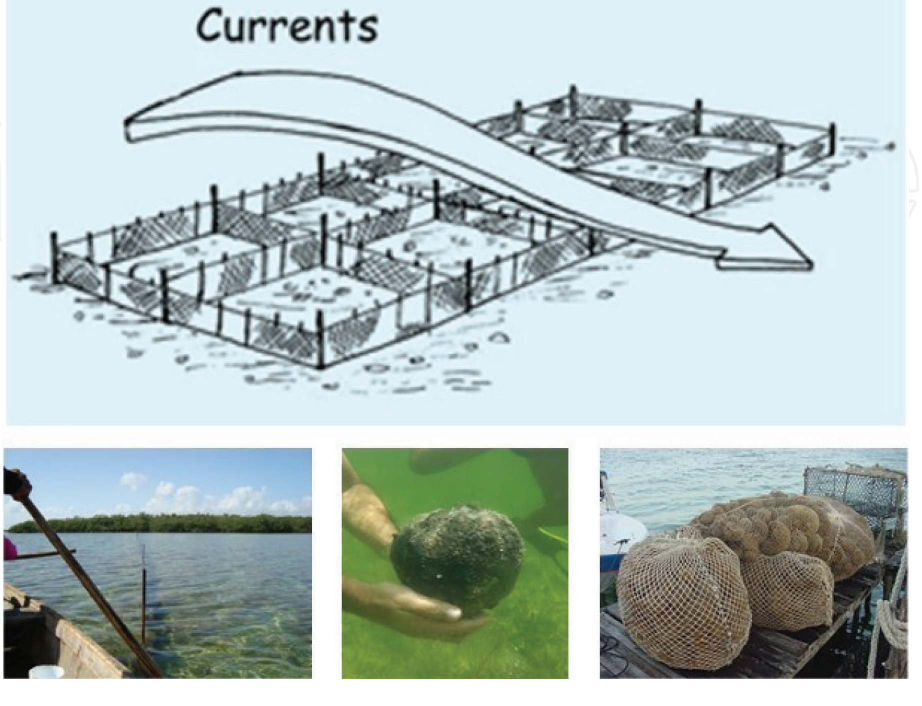

Figure 7.
Experimental sponge farm in Carahatas, Sabana-Camagüey Archipelago, Cuba. Free sponge culture in lots. Graphic art and photography: [41].

4.2 Trials and tendales method

This method uses rope 'tendales' in a horizontal pattern, which is commonly identified in aquaculture as 'suspended long-line' method. Briefly, metallic poles are buried in the seabed as support for nylon-braided rope (long lines 1/4″), elevated 20–30 cm off-bottom. Two long lines support horizontal several tendales of nylon monofilament (150 lb) for sponge suspended aquaculture. Mother sponges are cut in propagues (5 to 8 cm^3) to obtain sponges seeds. Propagues are tied to tendales in a collar-shape pattern using monofilament nylon lines (50 lb). In this way, sponge 'seeds' hang vertically to horizontal tendales with a separation of 30 cm between each one, during all the grow-out period (**Figure 8A**). Alternatively, sponge seeds can be put directly in the nylon tendales (**Figure 8B**).

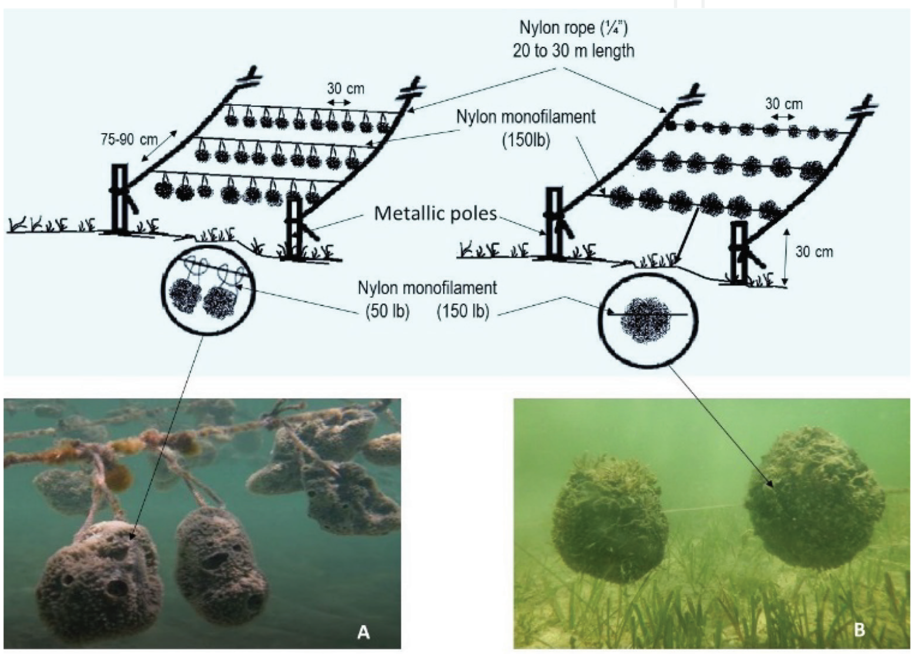

Figure 8.
Suspended line culture. System designed for the experimental farm in Caibarién, Sabana-Camagüey Archipelago, Cuba. Graphic art: M.A. Avilés-Quevedo. Photography: Empresa Pesquera Industrial de Caibarien (EPICAI).

After a grow-out from 15 to 18 months, 80% of planted sponges were obtained with acceptable commercial size (18–23 cm in diameter). Part of the recollection of this farm was used as 'mother sponge' to obtain new lots of 'seeds' for a second project with 130 suspended lines (trails), each one with 33 sponges for a total of 4290 cultured sponges [42].

All these projects, efforts and intentions to boost sponge cultivation in Cuba have remained at the stage of demonstrative experiments without scaling up to allow expansion to a systematic and eco-sustainable production level with an economic profitable income. The causes of this limited development have been related rather than beyond the indisputable potential of marine waters to human factors related to the will of introducing, developing and consolidating sponge culture, which could promote a regional socioeconomic progress.

5. Challenges

Gradual reduction of natural sponge banks at national and global levels has been evident, and that risk situation could get worse due to the problems deriving from climate change. Sponge culture, besides being a sustainable production, constitutes an alternative in foreign currency with commercialisation prices according to Cuban commercial species from $4 to $74 USD/kg, depending on their quality classification.

The main challenges to develop and generalise sponge culture in Cuba are:

1. Link and implicate fishery enterprises and coastal communities to develop sponge culture projects.

2. Assess and select ideal sites for priority species, according to value and abundance of the natural resources, to implement a viable economical and eco-sustainable aquaculture.

3. Apply a differential price and payment policy to fishermen, according to natural and cultured sponges. It is essential although clearly established policies exist for the development of marine aquaculture in Cuba.

4. In other terms, cultured sponges should have more attractive prices to motivate their introduction and boost technologic development and generalisation or the activity.

5. The economical-environmental feasibility that fishermen themselves combine natural sponge extraction with aquaculture production may not be viable in practice due to their extractive tradition, timing annual fishery operations and compliance demand for official production plans or goals, among other subjective factors.

6. Facing the decrease in sponge capture and abundance, it shall be essential to reduce fishing effort on natural populations, diverting fleet and fishermen that are currently dedicated to sponge extraction towards aquaculture production.

7. Those challenges will imply economic and logistic support from state institutions until the first results have been reached, and after that first goal, a second step of continuity will be necessary to improve and continuously enhance this productive activity.

Acknowledgements

This study was financed by Public Sectorial Research Fund for Education of México, Basic Science project Conacyt No. 258282 and R&D project Proinnova Conacyt No. 241777, under the academic responsibility of JMMS. Authors are grateful to Centro de Investigaciones Pesqueras (CIP, Cuba), Centro de Investigaciones Biológicas del Noroeste, S.C. (CIBNOR, México), Antonio Grovas Hernández of Grupo Empresarial de la Industria Alimentaria (GEIA, Cuba) who provided updated sponge extraction data, and Diana Fisher for English edition.

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