

Review

Sponges as Emerging By-Product of Integrated Multitrophic Aquaculture (IMTA)

Joseba Aguilo-Arce ¹, Pere Ferriol ², Roberta Trani ^{1,*}, Patrizia Puthod ¹, Cataldo Pierri ¹
and Caterina Longo ¹

¹ Department of Bioscience, Biotechnology and Environment, University of Bari Aldo Moro, Via Orabona 4, 70125 Bari, Italy

² Interdisciplinary Ecology Group, Department of Biology, University of the Balearic Islands, Carretera de Valldemossa km 7.5, 07122 Palma de Mallorca, Spain

* Correspondence: roberta.trani@uniba.it

Abstract: The use of marine sponges dates back thousands of years, and interest in these animals is increasing as new applications are discovered. Their potential is extensive, both in their ancient and still popular use as bath sponges for cosmetics and regarding the more recent discovery of bioactive secondary metabolites mainly of interest for the pharmaceutical industry and the less developed aquariology. Despite their proven biofiltration and ecosystem restoration ability and the biomass supply problem for the interested industries, few integrated multi-trophic aquaculture (IMTA) systems incorporate these invertebrates in their facilities. Therefore, in this brief review, the benefits that marine sponges could bring to rapidly growing IMTA systems are summarized, highlighting their suitability for a circular blue economy.

Keywords: Porifera; filtration rate; circular economy; restoration; bioremediation; bioactive compounds; aquariology



Citation: Aguilo-Arce, J.; Ferriol, P.; Trani, R.; Puthod, P.; Pierri, C.; Longo, C. Sponges as Emerging By-Product of Integrated Multitrophic Aquaculture (IMTA). *J. Mar. Sci. Eng.* **2023**, *11*, 80. <https://doi.org/10.3390/jmse11010080>

Academic Editor: Ka Hou Chu

Received: 29 November 2022

Revised: 29 December 2022

Accepted: 30 December 2022

Published: 3 January 2023



Copyright: © 2023 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

1. Introduction

Marine sponges have been targeted by fishermen for thousands of years, including in the Egyptian civilization, and their presence in our society has been continuous ever since [1]. However, the increasing interest in these animals during the last century has entailed the impossibility of providing the arising sponge market with an adequate amount of natural biomass. In this sense, when diving and collecting techniques improved in the Mediterranean area, different sponge species were collected without any specific legislation to supply a worldwide trade demanding dozens of tons of marine sponges, causing a dramatic reduction of natural stocks [2]. With the development of the pharmaceutical industry in the last decades of the 1900s, for example, and the strong demand for sponge biomass for the industrial production of avarol, e.g., (a powerful anti-inflammatory, anti-tumor, and anti-psoriatic) [3–5], the systematic collection of *Dysidea avara* caused a dramatic depletion of natural stocks, particularly along the eastern Mediterranean coasts, to the point of it being considered endangered [2]. In response to this intensive withdrawal, many demo-sponge species have been included in the lists of species with high conservation value for which specific protectionist policies are recommended (Annex I of the Berne Convention).

On the other hand, the world's population has tripled in the last seven decades. Contemporaneously, several problems have arisen, one of the most important concerns being food supply [6]. The inability of natural populations to achieve this has accelerated the search for sustainable production alternatives. Fisheries have not been left behind, with aquaculture and its derivative mariculture quadrupling production over the last 3 decades, nearly equalling that of capture fisheries [7]. Still, as in most developing production techniques, there are problems that need to be solved to minimize ecological impact.

Coastal fish farms can have a significant environmental impact due to the release of catabolites by cultured organisms and feed waste, leading to an overall increase in sedimentation, organic matter, and a potentially pathogenic or antibiotic-resistant bacterial load in the water [8]. However, Integrated Multitrophic Aquaculture (IMTA), the practice that combines the cultivation of fed aquaculture species with other organisms able to extract organic and/or inorganic substances from seawater, represents an eco-friendly alternative to monoculture. IMTA allows better water quality and promises high economic return and social suitability, implying an improvement in human welfare and ecosystem services provided by the marine environment.

Among the extractive organisms, economically profitable edible filter-feeders are the most utilized, including the predominant bivalves [9,10]. Nevertheless, Porifera seems to be one of the most promising, although they are still underexploited. Up to now, few sponge species have been tested to assess their rearing suitability and performance, bioactive compound production, or bioremediation capability: on the Mediterranean scale, *Geodia cydonium* [11], *Spongia officinalis* and *Hippospongia communis* [12,13], *Dysidea avara* [14], *Hymeniacidon perlevis* [15], *Chondrosia reniformis* [14,16], *Ircinia variabilis* [17], and *Sarcotragus spinosulus* [18]. In these trials, *G. cydonium* almost doubled its initial weight in six months. *D. avara* and *S. spinosulus* doubled their size in four and twelve months, respectively, and *C. reniformis* achieved a growth rate of 170% in one year, while *S. officinalis* and *H. communis* sponges increased their volume by 100–200% over two years. Additionally, impressive growth exceeding 2000% per year was registered in the Southwestern Pacific Ocean with *Mycale hentscheli* cultured near a mussel farm [19]. Altogether, these impressive results prove the suitability of the rearing system and the species, opening new possibilities in the aquaculture sector.

In this sense, their environmental and economic potential and, thus, the interest in these organisms, is increasing as new sustainable applications arise. This review aims to highlight the suitability and benefits of marine sponges in IMTA systems in a circular blue economy framework by discussing the profitability of these organisms and emphasizing their eco-economic potential. From a literature search conducted in Scopus and Google Scholar databases, the available papers on sponges in IMTA systems were selected to gather current knowledge on this practice, along with relevant literature, providing an informative and comprehensive framework of the status and potential of marine sponges. The results of this bibliographic research are included in the references section of this work.

2. Past and Present Concerns

The trade of sea sponges dates back thousands of years to when they were collected mainly for cosmetic use and known as “bath sponges”. In the last century, sponges could be purchased for USD 30 per individual, and the annual value of imports is estimated to be millions of USD. However, in a span of 50 years, sponge production declined by more than 80% due to unregulated overexploitation, catastrophic diseases, and the introduction of synthetic sponges into the market [20]. Even so, today in the Mediterranean basin, countries such as Italy (e.g., Spugnificio Incorvaia, Gela; Bellini Let's BE natural, Cogozzo di Viadana; Spugnificio Rosenfeld, Muggia), Greece (e.g., Cipreo J.-Kypreos Natural Sea Sponges, Kalymnos; Gerakios traders of natural sponges, Peristeri; Bioesti, Agios Nikolaos), Croatia (e.g., Spuga2, Kapranj), Cyprus (e.g., Old Port Sea Sponges, Limassol), and Tunisia (e.g., Éponge, Kraten) still maintain this economic sector based on traditional harvesting.

Although attempts to culture sponges have been documented since the late 18th century [21], the lack of knowledge and the failure of experiments made harvesting individuals from natural populations the most efficient and profitable methodology [22]. Still, the aforementioned negative events during the 20th century prompted the search for new business strategies. Thus, by the early 1970s, organized and successful mariculture trials with bathing sponges had already been conducted. The number of attempts has only increased over the years, becoming the second market interest for the culture of these animals [23,24]. In the search for sustainable and profitable production, as reviewed in [25], many studies

have tried to define the best rearing system for bath sponges and have concluded it to be strongly dependent upon species and environmental conditions.

In recent years, marine natural products have gained popularity and the demand for sponges, though they are more expensive than those of synthetic origin, is high. However, despite the research effort and promising growth rates of cultured bath sponges (doubling or tripling in size annually) [26–30], few countries currently cultivate them for commercial purposes, where they are mostly sold in the local markets, e.g., Micronesia [31] and Zanzibar [32]. Additionally, few studies have been carried out concerning bath sponges within an IMTA system [12,13], but everything remains in the theoretical framework since, to date, there is no such production method at a commercial level. Incorporating bath sponges in these environments where bacterial load is high involves zero cost of consumables like food, while the material for their cultivation would barely reach a few hundred USD [30]. Since their maintenance is based on monthly growth monitoring, bath sponges rearing seems an ideal candidate for promising high economic profitability when looking for a blue circular economy in IMTA systems.

3. Bioremediation, a Way of Life

One of the main advantages of filter-feeding organisms such as Porifera is that their energy source is obtained by the highly efficient filtration of organic particles between 0.1–50 µm, such as dissolved and particulate organic particles, heterotrophic bacteria and eukaryotes, phytoplankton, and even viruses [33–35], so that their mere growth leads to bioremediation of the surrounding environment. Therefore, they are considered a possible solution to reduce eutrophication and bacterial load.

In this sense, numerous works have tried to calculate this potential by employing experiments on the filtration and retention capacity of sponges. When it comes to those performed *ex situ*, controlled conditions reduce the variability of factors, such as temperature, salinity, nutrients, or microorganisms used, which, together with visualization techniques and cell counting (such as spectrometry or cytometry), have served to prove that this capacity differs significantly depending on the species and size of the sponge explant or the size and even the motility of the microorganism used (Figure 1).

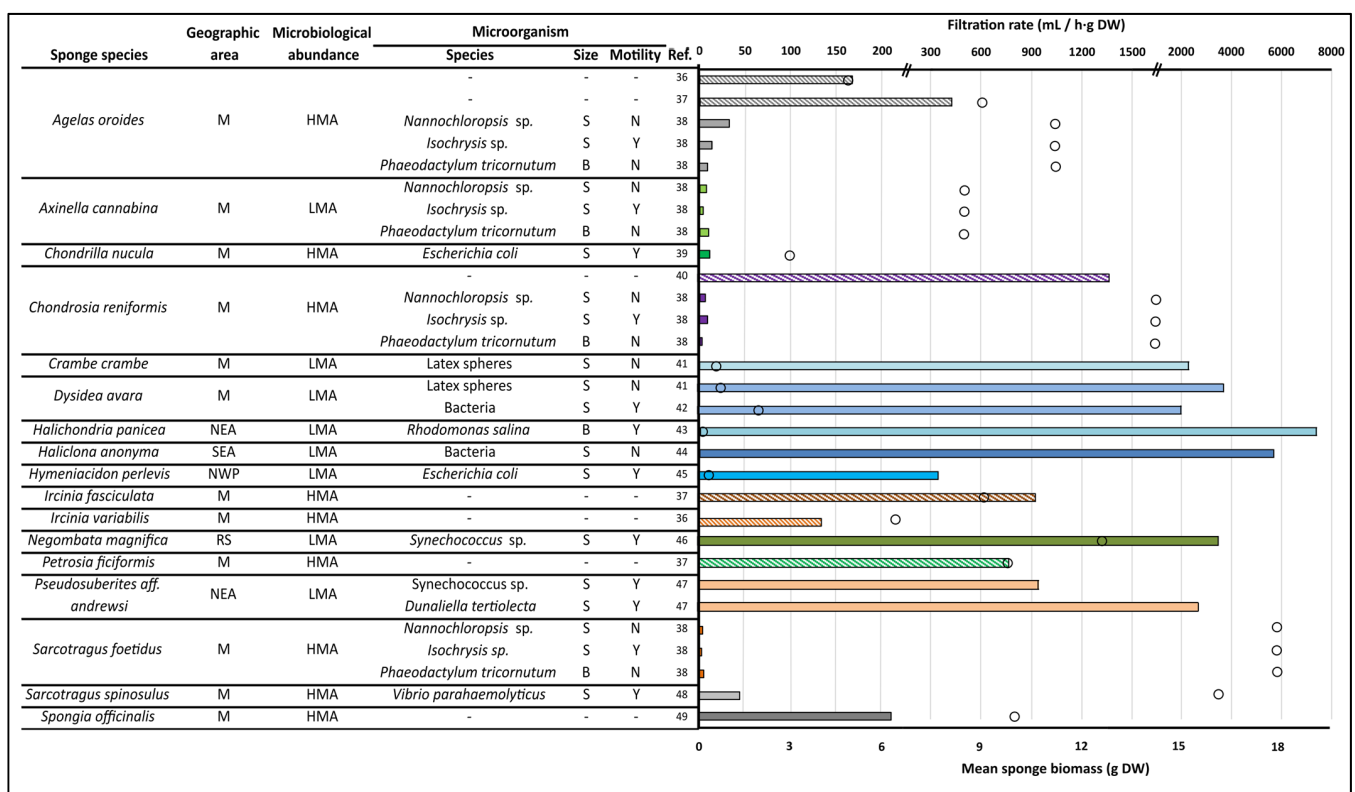


Figure 1. Comparison of sponge filtration rates (bars) according to species, explant biomass (circles), and microorganism characteristics. The cited bibliographic references are shown in the ref column [36–49]. Rayed bars represent in situ studies where no specific microorganism was used. When standardizing explant size and filtration rates, volume-to-weight and weight-to-weight conversions were made based on [50,51], respectively. Microbiological abundance classification was that described in [52]. M (Mediterranean), NEA (North-eastern Atlantic), SEA (South-eastern Atlantic), NWP (North-western Pacific), and RS (Red Sea) for the geographic area; HMA (High Microbiological Abundance) and LMA (Low Microbiological Abundance) for microbiological abundance and S (Small, <15 μ m), B (Big, >15 μ m), Y (motile), and N (non-motile) for microorganism description are the abbreviations used.

However, the logistics and maintenance of conditions involve an expense that does not exist in IMTA systems, being the natural environment of the sponges. In addition, variables such as season, currents, or depth are excluded in ex situ experiments, despite being proven to affect the growth, survival, morphology, composition, and pumping activity of some sponges [39,40,53–56]. Although the remediation and conversion of organic carbon have been studied (references already reviewed in [57]), little work has focused on in situ filtration capacity (e.g., [36,37,40]) and even less on IMTA systems, where knowledge is very limited [58,59]. Despite that, it has been shown that carbon uptake in these animals may exceed that of commercial species, such as bivalves, whose market is well established and generates large economic benefits while that of sponges is still under development [60].

Similarly, being filter-feeding organisms, they are constantly exposed to contamination of the water column. More specifically, since the last century, numerous experiments have been carried out to test the accumulation capacity and levels of pollutants, such as heavy metals (HM, related to diseases such as autism, Alzheimer, or diabetes mellitus) [61] from mercury or copper to heavier metals such as uranium, americium, or rare earth elements, which in some cases have been seen to be higher than in mussels [62–83]. As with filtration, it has been shown that this ability depends on the sponge species and the contaminant tested, including the morphology of the individual, and that, although spicules represent the main component of the biomass, they accumulate mainly in the organic tissue [84,85].

Additionally, they could potentially consume contaminated bacteria and incorporate their HMs [86] and are being proposed as a source of biomagnification of these compounds in higher trophic levels [87]. However, subjecting sponges to elevated HM concentrations has been found to negatively affect growth, survival, fecundity, and filtering ability and to cause DNA damage, ROS production increase, alterations in macromolecule composition, or even apoptosis, suggesting them as bioremediators of environments partially exposed to these contaminants [64,67–69,88–92].

The same is true for organic pollutants (OP), whose accumulation in sponges and biomagnification has also been demonstrated, including natural compounds that have been classified as such due to their possible toxic effects [93–98]. In this regard, there is a diversity of results according to contaminants and sponge species. While some results state that the accumulation of some polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs) is higher than in some commercial oysters and mussels, others have found similar levels [72,76,94,99]. However, as expected with pollutant compounds, also OPs induce stress, DNA damage, and cell apoptosis in sponges [93,100,101].

On the other hand, microplastics (MP) represent a threat that has been gaining importance for the past decade, despite having been found in sponge samples dated more than 20 years ago [102,103]. Therefore, work and knowledge on the accumulation of these contaminants and their derivatives in these animals are scarce [104–108]. As might be expected, a higher concentration of MPs has been seen in filter feeders (similar between sponges and mussels) than in other feeding strategies, and in the case of sponges, a possible preference for very small fibers and particles as well [102,104]. While no negative effect has also been reported [106,109], a more recent study demonstrates that the uptake of some of these contaminants reduces filtration and respiration rates [110]. However, being that the levels of MPs in the surrounding water are higher than in their tissues, these studies agree and suggest a possible resistance or ejection mechanism that allows them to thrive in contaminated waters [106,110].

When talking about remediation, and considering the concept of the sponge as a holobiont, the capacity of the associated microbiota to resist, accumulate, and degrade contaminants cannot be disregarded. In this sense, recent works have demonstrated the HM accumulation capacity of some symbionts and identified genes that grant resistance to them, which could have been transmitted via plasmids [111–117]. However, not all these microorganisms appear to possess them, and, although no differences have also been reported [118,119], the accumulation of HMs in the host has been shown to negatively affect symbiont communities [79,120]. The usefulness of these microorganisms does not stop there. They have also been proposed to biotransform and can produce biosurfactants for the bioremediation of these metals [121–126], for the degradation of MPs [127], and of many OPs, such as pyrenes, brominated phenols, steroids, crude oil, dyes used in the textile industry, or even alkylbenzene sulfonates present in detergents [96,128–136], which increases the interest in and confirms sponges as a hot-spot for the search of new green alternatives in this field.

All in all, the works cited above define marine sponges as good biofilters and bioindicators of pollution caused by increased bacterial load and organic and inorganic contaminants due to their ability to filter and accumulate them. In search of new remediation technologies, these animals have even inspired the creation of synthetic sponges to treat water [137–139]. Therefore, incorporating them into the production systems of species for human consumption, such as IMTAs, implies the possibility of monitoring and improving water quality and, thanks to the demonstrated ability to reduce the pathogen bacterial load, a possible reduction in antibiotic costs.

4. A Marine Bioactive Compound Factory

The first drugs of marine origin reaching clinical trials were extracted from a Caribbean sponge around seven decades ago [140]; since then, the number of these compounds has only increased, and, together with cnidarians, they are the most prominent organisms

discovered [141]. By November 2022, nearly 12,000 compounds were reported from the phylum Porifera (exceeding a quarter of the total of marine origin), more than 200 of which were described this year (Figure 2). These are synthesized not only by sponges but also by their symbiont microorganisms. The value of the approved and artificially synthesized ones can reach from hundreds to thousands of USD [142,143], demonstrating the potential of profitable natural production carried out by these organisms.

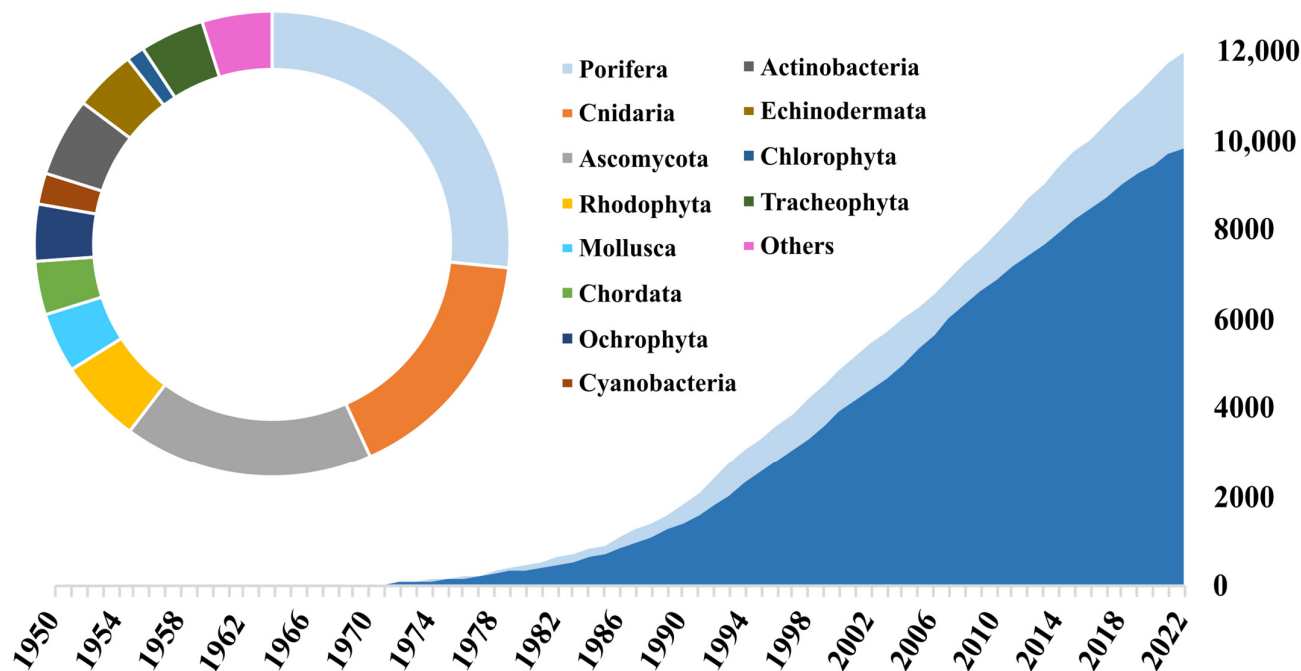


Figure 2. Cumulative number of compound discoveries (light) and publications (dark) on marine sponges over the last seven decades. The proportion of marine natural products of poriferan origin regarding the total number of described molecules is shown in the pie chart. Row data from <https://marinlit.rsc.org> (accessed on 14 November 2022).

The different sponge species and their micro inhabitants open the possibility to search for and characterize a great number of biomolecules, with different structures and activities that review works have already tried to collect and synthesize, e.g., [141,143–146]. In a very generalized way and without detailing, they have a wide range of applications: from anti-tumour, antiviral, and antimicrobials in human medicine to antimicrobial and antifouling activities in the aquaculture industry or biomaterial production in different sectors. However, obtaining the needed biomass involves a considerable challenge, as natural populations cannot supply this market sustainably.

Therefore, as with bath sponges, attempts to culture them for this purpose have increased in recent years to become the main commercial target of these activities [24]. However, few attempts have been carried out in IMTA systems, and some of these are cultures close to other fisheries facilities [11,14,16,18,19,147–149]. Considering the importance of symbionts in the synthesis of bioactive compounds, the conditions to ensure their production should be optimal not only for the sponge but also for their inhabitants, which ex situ can be costly and difficult to maintain. Therefore, co-culture strategies such as IMTA appear to be possible and economically profitable solutions, as from reared sponge biomass, as well as others for the pharmaceutical industry, antifouling and antibiotic compounds could be obtained that would reduce the annual losses of billions for fisheries [150], fostering a circular economy of the sector.

5. From the Sea to the Tank

With hundreds of aquariums worldwide and millions of recreational ones, another economic potential of marine sponges is their sale for this activity, as due to their diverse colors and shapes they are particularly attractive (Figure 3). There are companies dedicated to their trade (mainly in the US), and their prices vary from tens to hundreds of USD per individual, depending on species and size (e.g., Marine World Aquatics Ltd., Bradford, UK; RUSALTY, St Okeechobee, FL, USA; Aquarium Creations Online, Lauderdale Lakes, FL, USA).



Figure 3. The bright orange and stylized sponge *Axinella cannabina* as an ornamental aquarium species.

In addition, there are fish families such as angelfish (*Pomacanthidae*), filefish (*Monacanthidae*), boxfish (*Ostraciidae*), or pufferfish (*Tetraodontidae*) that graze on different sponge species and can contribute to over 70% of their diet [151–153]. As it is used as an aquarium species, sponge-based food supplies have already been developed (e.g., Mega-Marine Angel, Hikari; Sponge Professional Softgran, EBO; Angel Formula, Ocean Nutrition).

Considering that some of the sponges consumed by these fish have already been the target of in situ culture attempts (albeit if for a different purpose, such as *Agelas* sp., *Callyspongia* spp., *Chondrilla* sp., *Chondrosia* sp., *Geodia* sp., *Haliclona* sp., *Ircinia* spp., *Mycale* spp., *Spongia* spp., or *Xestospongia* sp.) [11,13,14,16,26,27,30,36,53,147–149,154–160], incorporating them into IMTA systems would be a viable option for the production of aquarium feed supplements. On the other hand, physical traits such as color, shape, or size are vital when selecting ornamental aquarium sponges. Depending on the geographic position, these facilities could provide a suitable environment for the correct growth and sustainable production of local ornamental aquarium species.

6. The Challenge in Marine Sponges' Restoration

As many sponge species are considered endangered, efforts to recover natural populations are increasing (Annex I of the Berne Convention). From artificial reefs to vertical collectors, ideas are emerging for different restoration structures to increase biodiversity and create a biotope for these species [161]. Transplanting sponges to areas where they had been almost eradicated has been seen as a viable option to recover the populations of these

animals, with 100% survival rates and maintaining fertile individuals to favor the natural recruitment of juveniles and other organisms, such as corals, would improve ecological succession [162,163].

In this sense, wisely planned IMTA systems could be reasonably proposed for environmental restoration and conservation purposes. Such facilities combine bioremediation with biodiversity increase thanks to the fouling attached to artificial substrates and reared specimens (Figure 4). In the case of sponges, the biomass obtained can be valorized for transplantation or restocking of threatened or vulnerable species up to benthic habitat restoration. In addition to the environmental value, the creation of these ecosystems and the indirect recruitment of other species could represent a benchmark of underwater tourism that, at zero cost, would bring income to the local community [161].

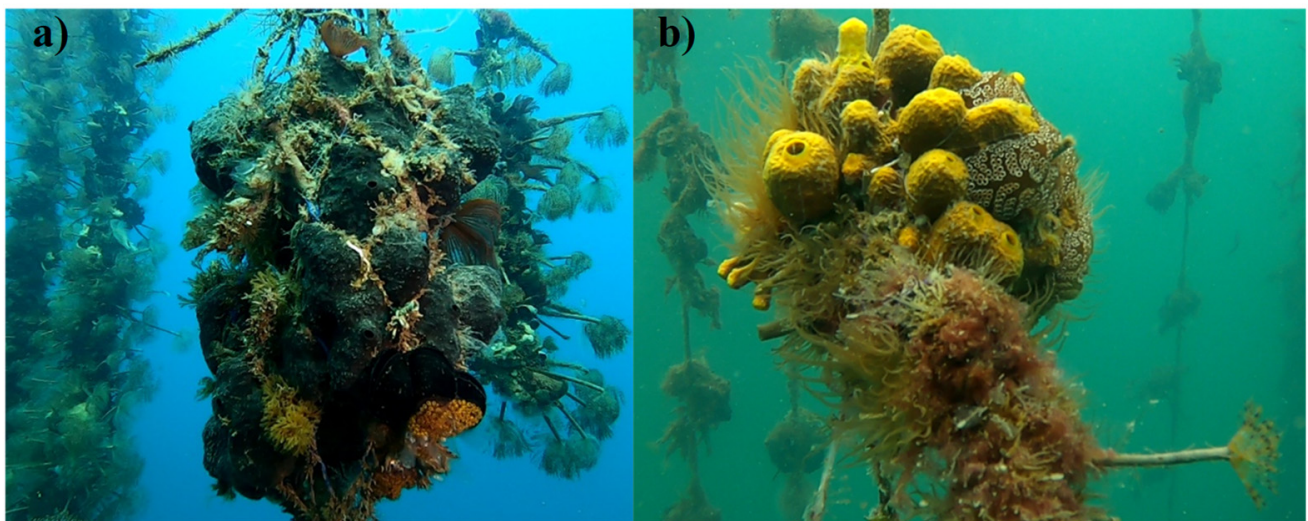


Figure 4. Algae, ascidians, polychaetes, and sea anemones growing on *Sarcotragus spinosulus* (a) and *Aplysina aerophoba* (b) reared in the Remedía Life IMTA system.

7. Deciding the Methodological Approach

Planning any sponge farm (including those in an IMTA system) requires in-depth preliminary studies to first evaluate the consistency of the natural stocks which will act as “donors”. Once the distribution and abundance of the sponge donor beds have been characterized, it is necessary to study thoroughly the biological and ecological characteristics of the potentially selected species. Among the features that must be considered in the species selection, expertise in reproduction, growth performance, resistance to survival in critical conditions, and resistance to manipulation are fundamental.

Going into more detail on the methodology and practical aspects of sponge culture, the design of the systems and the survival and growth rates of the explants used vary according to the sponge species, their skeletal consistency, and the aim of production. Thus, for secondary metabolite production, the shape and appearance of the individual are taken less into consideration, whereas maturity or symbiotic composition are. At the same time, the opposite would be true if the cultured individuals were to be destined for an aquarium.

In this sense, sponge farming systems could be performed vertically in the water column or horizontally on the seabed using different materials and tools. Mobile structures suspended in the water column allow the rearing of many sponge explants around the fish farming cages. In such systems, different tools have been tested, such as ropes, tubular nets, mesh panels, lantern nets, and SEAPA cages where the sponge explants have been inserted (Figure 5). [24] reviews the methodology of studies that have cultured sponges in situ and concludes that artificial substrates are the predominant choice, followed by rope and mesh systems, all with similar percentages (between 25% and 30% of the studies reviewed for each). However, when the search is narrowed down to IMTA systems (present

study), those with thread lines running through explants and mesh systems become the most studied (encompassing almost all the studies), while artificial substrates are hardly used [16]. For *Dysidea avara*, for example, Ref. [164] concludes that in pristine natural waters a cage system promotes a higher growth rate when compared with rope and mesh systems, while [14] and the Porifarma company described in [25], being fish-farming associated sponge rearing systems, utilize nylon rope systems with promising results. This change in the choice of methodology could be mainly because, in IMTA systems, the organic load in the water column coming from fish production is high and increases sedimentation [8], which has been shown to negatively affect sponge culture structures with large exposed or semi-enclosed surfaces, such as artificial substrates or cages [14]. Therefore, designs in which more of the sponge surface area is in contact with the water column and less is available for sedimentation and fouling colonization seem to be the most suitable for explant rearing, such as the rope and mesh system variants.

However, when choosing the type of culture system, other factors must also be considered, which in some cases determine the biomass production yield or its usefulness for the established objective. Depth, for example, is a determining factor for collagen production in *Chondrosia reniformis* (higher content in shallow waters) [40]. Consequently, culture structures should be located a few meters from the surface. Heat stress, on the other hand, induces the loss of symbionts [165], which can be crucial to produce secondary metabolites; thus, in areas where the water surface temperature rises above 30 °C, the culture should be placed at greater depths. All in all, the selection of the cultivation method for marine sponge explants is the result of different factors, such as environmental factors, species, or production objectives, that will determine the type of system, material, and placement of the structures.

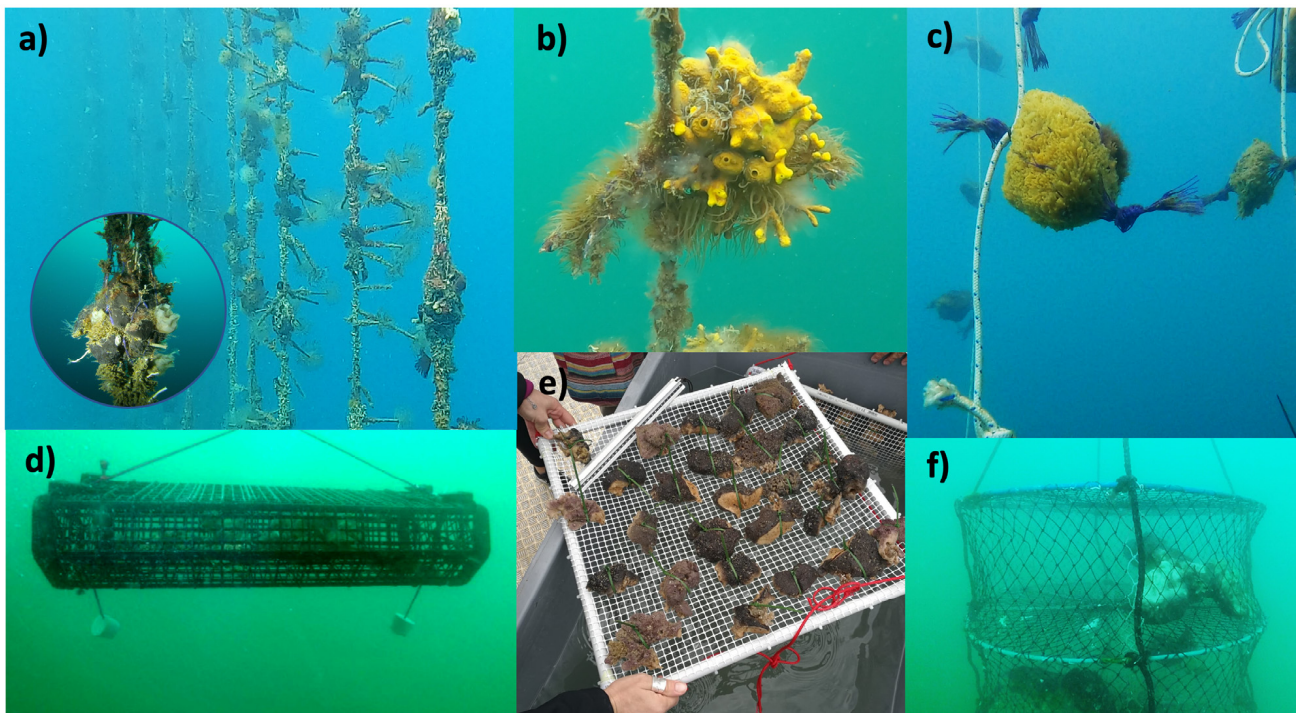


Figure 5. Main rearing methods in Remedia Life (upper) and ASMAR (lower) IMTA systems. *Sarcotragus spinosulus* reared in tubular nets (a), *Aplysina aerophoba* (b), and *Hymeniacidon perlevis* (c) reared in rope systems with net bags in the Maricoltura del Mar Grande fish farm (Mar Grande of Taranto, northern Ionian Sea); *S. spinosulus* in SEAPA nets (d), mesh panels (e) and lantern nets (f) close to Gargano fish farm (Gulf of Manfredonia, south-eastern Adriatic Sea). ASMAR project: Assessment of Sponge Mariculture Potential in Polyculture System in the Manfredonia Gulf–Interreg Adrion Blue Boost 2019–2020.

8. Fitting Strategic and Sustainable Development Goals

The European Union, in the amended 2022 “New strategic guidelines for aquaculture”, improved the “Strategic Guidelines for a more sustainable and competitive European aquaculture for the period from 2021 to 2030” with a shared vision for further development of aquaculture in the EU. The goal is to build a sustainable, resilient, and competitive aquaculture (marine and freshwater). Particular attention is paid to the need to put science into practice through applied research and innovation, nationally and internationally. Among the strategic points that member states must consider to achieve the proposed goal by 2030 are supporting the development of new aquaculture methods, in particular those with low environmental impact (e.g., IMTA), and promoting diversified production to expand the supply of aquaculture products, using promising new species in the EU, including marine invertebrates.

From a global point of view and with a focus on future feasible socio-economic development, the use of marine sponges in IMTA systems fits perfectly with the Sustainable Development Goals for 2030 described by the United Nations [166], which detail objectives, such as reducing biodiversity loss and poverty, making sustainable use of marine resources, and promoting environmentally sustainable economic development, among others. Although the inclusion of sponges in IMTA is still underutilized, keeping avoiding the over-exploitation of natural sponge populations in mind, the spreading of such practices can combine environmental needs and sustainable development [24,25,57].

As mentioned above, sponge mariculture has been known for a long time but with only a few large-scale applications, mainly related to “bath sponges” [24,25,57]. Currently, a positive impact has been reported in regions such as Zanzibar and Micronesia, where in situ marine sponge culture systems enhance the recruitment of other species and provide a source of income for the local population [31,32]. Thus, despite being underexploited species in IMTA systems, the environmental and economic potentials of marine sponges are important in the pursuit of the fixed goals of the aquaculture sector and sustainable societal development.

9. Conclusions

The production of biomass from non-edible species in properly designed IMTAs, such as marine sponges with important profitable applications, implies using new resources that promote a blue circular economy (Figure 6). In this sense, these systems represent an eco-friendly sponge biomass supply not only for economic interests, such as the bath sponge market, green extraction of bioactive molecules, and aquariology (ornamental species or food for fishes) but also for environmental welfare as bioremediation or restoration purposes that increase ecosystem biodiversity. The IMTA systems not only fit perfectly with the general Sustainable Development Goals proposed by the United Nations but, at the same time, lowering the use of antibiotics would reduce costs and economic losses in the pursuit of the aquaculture sector’s environmentally friendly progress.

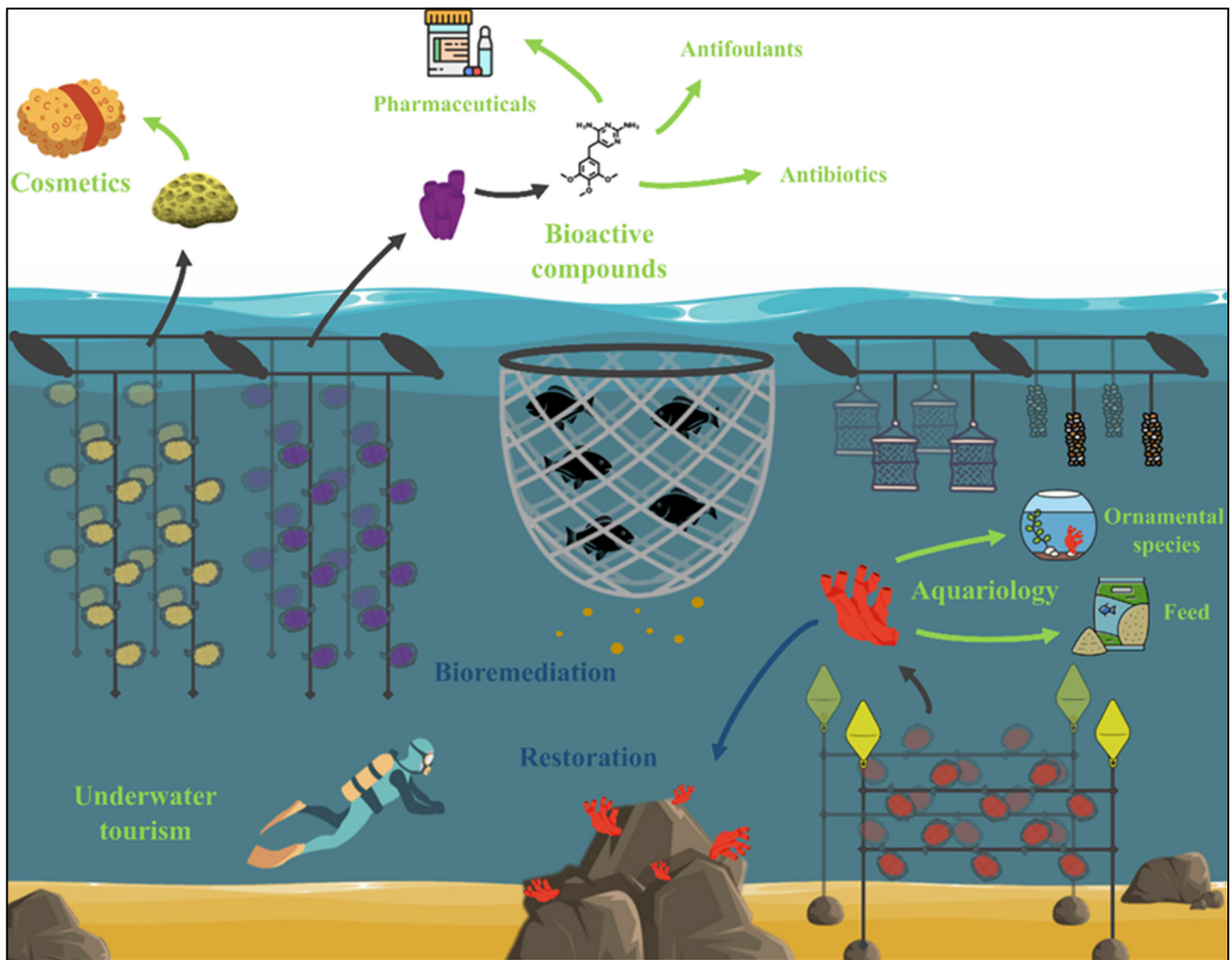


Figure 6. Sponges as a by-product of an IMTA system. Environmental and economic benefits are represented in blue and green, respectively.

Author Contributions: Conceptualization, C.L. and J.A.-A.; formal analysis, J.A.-A.; data curation, J.A.-A., R.T., P.P., C.P. and P.F.; writing—original draft preparation, C.L. and J.A.-A.; writing—review and editing, J.A.-A., R.T., P.P., C.P. and P.F.; supervision, C.L.; project administration, C.L.; funding acquisition, C.L. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the European Community, Life Environment funding program: Remedia-Life project (LIFE16 ENV/IT/000343): Remediation of Marine Environment and Development of Innovative Aquaculture: exploitation of Edible/not Edible biomass.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: Authors would like to acknowledge the time and effort devoted by reviewers to improve the quality of the manuscript. We sincerely appreciate all valuable comments and suggestions, which helped us to improve the quality of the published manuscript.

Conflicts of Interest: The authors declare no conflict of interest.

References

- Chaviarà, D. Le spugne e i loro pescatori dai tempi antichi ad ora. *Mem. Reg. Com. Talassogr. Ital.* **1920**, *74*, 1–49.
- Pronzato, R.; Manconi, R. Mediterranean commercial sponges: Over 5000 years of natural history and cultural heritage. *Mar. Ecol.* **2008**, *29*, 146–166. [\[CrossRef\]](#)
- Müller, W.E.G.; Zahn, R.K.; Gasić, M.J.; Dogović, N.; Maidhof, A.; Becker, C.; Diehl-Seifert, B.; Eich, E. Avarol, a cytostatically active compound from the marine sponge *Dysidea avara*. *Comp. Biochem. Physiol. Part C Comp. Pharmacol.* **1985**, *80*, 47–52. [\[CrossRef\]](#) [\[PubMed\]](#)
- Ferrándiz, M.L.; Sanz, M.J.; Bustos, G.; Payá, M.; Alcaraz, M.J.; De Rosa, S. Avarol and avarone, two new anti-inflammatory agents of marine origin. *Eur. J. Pharmacol.* **1994**, *253*, 75–82. [\[CrossRef\]](#) [\[PubMed\]](#)
- Amigó, M.; Payá, M.; Braza-Boils, A.; De Rosa, S.; Terencio, M.C. Avarol inhibits TNF- α generation and NF- κ B activation in human cells and in animal models. *Life Sci.* **2008**, *82*, 256–264. [\[CrossRef\]](#)
- United Nations Department of Economic and Social Affairs, Population Division. *World Population Prospects 2022: Summary of Results*; UN DESA/POP/2022/TR/NO. 3; United Nations Publications: New York, NY, USA, 2022.
- FAO. The State of World Fisheries and Aquaculture 2022. In *Towards Blue Transformation*; FAO: Rome, Italy, 2022.
- Gowen, R.J.; Bradbury, N.B. The ecological impact of salmonid farming in coastal waters: A review. *Oceanogr. Mar. Biol.* **1987**, *25*, 563–575. [\[CrossRef\]](#)
- Holdt, S.L.; Edwards, M.D. Cost-effective IMTA: A comparison of the production efficiencies of mussels and seaweed. *J. Appl. Phycol.* **2014**, *26*, 933–945. [\[CrossRef\]](#)
- Irisarri, J.; Fernández-Reiriz, M.J.; Labarta, U.; Cranford, P.J.; Robinson, S.M. Availability and utilization of waste fish feed by mussels *Mytilus edulis* in a commercial integrated multi-trophic aquaculture (IMTA) system: A multi-indicator assessment approach. *Ecol. Indic.* **2015**, *48*, 673–686. [\[CrossRef\]](#)
- Müller, W.E.; Wimmer, W.; Schatton, W.; Böhm, M.; Batel, R.; Filic, Z. Initiation of an aquaculture of sponges for the sustainable production of bioactive metabolites in open systems: Example, *Geodia cydonium*. *Mar. Biotechnol.* **1999**, *1*, 569–579. [\[CrossRef\]](#)
- Pronzato, R.; Cerrano, C.; Cubeddu, T.; Lanza, S.; Magnino, G.; Manconi, R.; Pantelis, J.; Sarà, A.; Sidri, M. Sustainable development in coastal areas: Role of sponge farming in integrated aquaculture. In *Proceedings of the Aquaculture Europe*, Bordeaux, France, 7–10 October 1998. [\[CrossRef\]](#)
- Pronzato, R. Sponge Farming in the Mediterranean Sea: New Perspectives. *Mem. Qld. Mus.* **1999**, *44*, 485–491.
- Osinga, R.; Sidri, M.; Cerig, E.; Gokalp, S.Z.; Gokalp, M. Sponge Aquaculture Trials in the East-Mediterranean Sea: New Approaches to Earlier Ideas. *Open. Mar. Biol. J.* **2010**, *4*, 74–81. [\[CrossRef\]](#)
- Longo, C.; Cardone, F.; Corriero, G.; Licciano, M.; Pierri, C.; Stabili, L. The co-occurrence of the demosponge *Hymeniacidon perlevis* and the edible mussel *Mytilus galloprovincialis* as a new tool for bacterial load mitigation in aquaculture. *Environ. Sci. Pollut. Res.* **2016**, *23*, 3736–3746. [\[CrossRef\]](#) [\[PubMed\]](#)
- Gokalp, M.; Wijgerde, T.; Sarà, A.; De Goeij, J.M.; Osinga, R. Development of an integrated mariculture for the collagen-rich sponge *Chondrosia reniformis*. *Mar. Drugs* **2019**, *17*, 29. [\[CrossRef\]](#)
- Longo, C.; Scrascia, M.; Trani, R.; Pierri, C.; Cariglia, A.; Cariglia, F.; Cariglia, M. Assessment of sponge mariculture potential in polyculture system in Manfredonia Gulf toward the IMTA implementation. In *Proceedings of the Aquafarm Novelfarm*, Pordenone, Italy, 19–20 February 2020.
- Giangrande, A.; Pierri, C.; Arduini, D.; Borghese, J.; Licciano, M.; Trani, R.; Corriero, G.; Basile, G.; Cecere, E.; Petrocelli, A. An Innovative IMTA System: Polychaetes, Sponges and Macroalgae Co-Cultured in a Southern Italian in-Shore Mariculture Plant (Ionian Sea). *J. Mar. Sci. Eng.* **2020**, *8*, 733. [\[CrossRef\]](#)
- Page, M.J.; Northcote, P.T.; Webb, V.L.; Mackey, S.; Handley, S.J. Aquaculture trials for the production of biologically active metabolites in the New Zealand sponge *Mycale hentscheli* (Demospongiae: Poecilosclerida). *Aquaculture* **2005**, *250*, 256–269. [\[CrossRef\]](#)
- FAO. Available online: <https://www.fao.org/3/ac286e/AC286E00.htm> (accessed on 26 November 2022).
- Cavolini, F. *Memorie Per Servire Alla Storia de' Polipi Marini*; Wentworth Press: Napoli, Italy, 1785; pp. 262–265.
- Crawshaw, L.R. Studies in the market sponges I. Growth from the planted cutting. *J. Mar. Biol. Assoc. UK* **1939**, *23*, 553–574. [\[CrossRef\]](#)
- Gokalp, N. Türkiye’de İlk Sünger Yetistirme Tecrübeleri. *Balık ve Balıkçılık* **1974**, *12*, 1–10.
- Bierwirth, J.; Mantas, T.P.; Villechanoux, J.; Cerrano, C. Restoration of marine sponges—What can we learn from over a century of experimental cultivation? *Water* **2022**, *14*, 1055. [\[CrossRef\]](#)
- Duckworth, A. Farming Sponges to Supply Bioactive Metabolites and Bath Sponges: A Review. *Mar. Biotechnol.* **2009**, *11*, 669–679. [\[CrossRef\]](#)
- Verdenal, B.; Vacelet, J. Sponge culture on vertical ropes in the Northwestern Mediterranean Sea. In *New Perspectives in Sponge Biology*; Rützler, K., Ed.; Smithsonian Institution Press: Washington, DC, USA, 1990; pp. 416–424.
- Corriero, G.; Longo, C.; Mercurio, M.; Marzano, C.N.; Lembo, G.; Spedicato, M.T. Rearing performance of *Spongia officinalis* on suspended ropes off the Southern Italian coast (Central Mediterranean Sea). *Aquaculture* **2004**, *238*, 195–205. [\[CrossRef\]](#)
- Duckworth, A.R.; Wolff, C. Sath sponge aquaculture in Torres Strait, Australia: Effect of explant size, farming method and the environment on culture success. *Aquaculture* **2007**, *271*, 188–195. [\[CrossRef\]](#)

29. Duckworth, A.R.; Wolff, C.; Evans-Illidge, E. Developing methods for commercially farming bath sponges in tropical Australia. *Porifera Res.-Biodivers. Innov. Sustain. Rio de Jan. Mus. Nac. Ser. Livros* **2007**, *28*, 297–302.
30. Oronti, A.; Danylchuk, A.J.; Elmore, C.E.; Auriemma, R.; Pesle, G. Assessing the Feasibility of Sponge Aquaculture as a Sustainable Industry in The Bahamas. *Aquac. Int.* **2012**, *20*, 295–303. [\[CrossRef\]](#)
31. Tobey, J.A.; Haws, M.C.; Ellis, S.S. Aquaculture Profile for Pohnpei Federated States of Micronesia; Technical Report; Pohnpei State Division of Marine Development, Office of Economic Affairs and the Conservation Society of Pohnpei. 2004. Available online: <https://repository.library.noaa.gov/view/noaa/39936> (accessed on 26 November 2022).
32. Marinecultures. Available online: <https://www.marinecultures.org/en/projects/spongefarming/spongefarming/> (accessed on 26 November 2022).
33. Simpson, T.L. *The Cell Biology of Sponges*, 1st ed.; Springer: New York, NY, USA, 1984.
34. Riisgård, H.U.; Larsen, P.S. Filter-feeding in marine macro-invertebrates: Pump characteristics, modelling and energy cost. *Biol. Rev.* **1995**, *70*, 67–106. [\[CrossRef\]](#)
35. Hadas, E.; Marie, D.; Shpigel, M.; Ilan, M. Virus predation by sponges is a new nutrient-flow pathway in coral reef food webs. *Limnol. Oceanogr.* **2006**, *51*, 1548–1550. [\[CrossRef\]](#)
36. Ledda, F.D.; Pronzato, R.; Manconi, R. Mariculture for bacterial and organic waste removal: A field study of sponge filtering activity in experimental farming. *Aquac. Res.* **2014**, *45*, 1389–1401. [\[CrossRef\]](#)
37. Gili, J.M.; Bibiloni, M.A.; Montserrat, A. Tasas de filtración y retención de bacterias “in situ” de tres especies de esponjas litorales. Estudio preliminar. *Misc. Zool.* **1984**, *8*, 13–21.
38. Varamogianni-Mamatsi, D.; Anastasiou, T.I.; Vernadou, E.; Papandroulakis, N.; Kalogerakis, N.; Dailianis, T.; Mandalakis, M.A. Multi-species investigation of sponges’ filtering activity towards marine microalgae. *Mar. Drugs* **2021**, *20*, 24. [\[CrossRef\]](#)
39. Milanese, M.; Chelossi, E.; Manconi, R.; Sarà, A.; Sidri, M.; Pronzato, R. The marine sponge *Chondrilla nucula* Schmidt, 1862 as an elective candidate for bioremediation in integrated aquaculture. *Biomol. Eng.* **2003**, *20*, 363–368. [\[CrossRef\]](#)
40. Gökalp, M.; Kooistra, T.; Rocha, M.S.; Silva, T.H.; Osinga, R.; Murk, A.J.; Wijgerde, T. The effect of depth on the morphology, bacterial clearance, and respiration of the mediterranean sponge *Chondrosia reniformis* (Nardo, 1847). *Mar. Drugs* **2020**, *18*, 358. [\[CrossRef\]](#)
41. Turon, X.; Galera, J.; Uriz, M.J. Clearance rates and aquiferous systems in two sponges with contrasting life-history strategies. *J. Exp. Zool.* **1997**, *278*, 22–36. [\[CrossRef\]](#)
42. Ribes, M.; Coma, R.; Gili, J.-M. Natural diet and grazing rate of the temperate sponge *Dysidea avara* (Demospongiae, Dendroceratida) throughout an annual cycle. *Mar. Ecol. Prog. Ser.* **1999**, *176*, 179–190. [\[CrossRef\]](#)
43. Kumala, L.; Riisgård, H.; Canfield, D. Osculum dynamics and filtration activity in small single-osculum explants of the Demosponge *Halichondria panicea*. *Mar. Ecol. Prog. Ser.* **2017**, *572*, 117–128. [\[CrossRef\]](#)
44. Stuart, V.; Klumpp, D. Evidence for food-resource partitioning by kelp-bed filter feeders. *Mar. Ecol. Prog. Ser.* **1984**, *16*, 27–37. [\[CrossRef\]](#)
45. Fu, W.; Sun, L.; Zhang, X.; Zhang, W. Potential of the marine sponge *Hymeniacidon perleue* as a bioremediator of pathogenic bacteria in integrated aquaculture ecosystems. *Biotechnol. Bioeng.* **2006**, *93*, 1112–1122. [\[CrossRef\]](#)
46. Hadas, E.; Shpigel, M.; Ilan, M. Particulate organic matter as a food source for a coral reef sponge. *J. Exp. Biol.* **2009**, *212*, 3643–3650. [\[CrossRef\]](#)
47. Osinga, R.; Kleijn, R.; Groenendijk, E.; Niesink, P.; Tramper, J.; Wijffels, R.H. Development of in vivo sponge cultures: Particle feeding by the tropical sponge *Pseudosuberites* aff. *andrewsi*. *Mar. Biotechnol.* **2001**, *3*, 544–554. [\[CrossRef\]](#)
48. Trani, R.; Corriero, G.; de Pinto, M.C.; Mercurio, M.; Pazzani, C.; Pierri, C.; Scarscia, M.; Longo, C. Filtering activity and nutrient release by the keratose sponge *Sarcotragus spinosulus* Schmidt, 1862 (Porifera, Demospongiae) at the laboratory scale. *J. Mar. Sci. Eng.* **2021**, *9*, 178. [\[CrossRef\]](#)
49. Stabili, L.; Licciano, M.; Giangrande, A.; Longo, C.; Mercurio, M.; Marzano, C.N.; Corriero, G. Filtering activity of *Spongia officinalis* var. *adriatica* (Schmidt) (Porifera, Demospongiae) on bacterioplankton: Implications for bioremediation of polluted seawater. *Water Res.* **2006**, *40*, 3083–3090. [\[CrossRef\]](#)
50. Riisgård, H.; Thomassen, S.; Jakobsen, H.; Weeks, J.; Larsen, P. Suspension feeding in marine sponges *Halichondria panicea* and *Haliclona urceolus*: Effects of temperature on filtration rate and energy cost of pumping. *Mar. Ecol. Prog. Ser.* **1993**, *96*, 177–188. [\[CrossRef\]](#)
51. Ricciardi, A.; Bourget, E. Weight-to-Weight conversion factors for marine benthic macroinvertebrates. *Mar. Ecol. Prog. Ser.* **1998**, *163*, 245–251. [\[CrossRef\]](#)
52. Moitinho-Silva, L.; Steinert, G.; Nielsen, S.; Hardoim, C.C.; Wu, Y.-C.; McCormack, G.P.; López-Legentil, S.; Marchant, R.; Webster, N.; Thomas, T. Predicting the HMA-LMA status in marine sponges by machine learning. *Front. Microbiol.* **2017**, *8*, 752. [\[CrossRef\]](#) [\[PubMed\]](#)
53. Wilkinson, C.R.; Vacelet, J. Transplantation of marine sponges to different conditions of light and current. *J. Exp. Mar. Biol. Ecol.* **1979**, *37*, 91–104. [\[CrossRef\]](#)
54. Duckworth, A.R.; Battershill, C.N.; Bergquist, P.R. Influence of explant procedures and environmental factors on culture success of three sponges. *Aquaculture* **1997**, *156*, 251–267. [\[CrossRef\]](#)
55. Duckworth, A.R.; Battershill, C.N.; Schiel, D.R. Effects of depth and water flow on growth, survival and bioactivity of two temperate sponges cultured in different seasons. *Aquaculture* **2004**, *242*, 237–250. [\[CrossRef\]](#)

56. Mendola, D.; De Caralt, S.; Uriz, M.; Van den End, F.; Van Leeuwen, J.L.; Wijffels, R.H. Environmental Flow Regimes for *Dysidea avara* Sponges. *Mar. Biotechnol.* **2008**, *10*, 622–630. [\[CrossRef\]](#)
57. Gökalp, M.; Mes, D.; Nederlof, M.; Zhao, H.; Merijn de Goeij, J.; Osinga, R. The potential roles of sponges in integrated mariculture. *Rev. Aquac.* **2021**, *13*, 1159–1171. [\[CrossRef\]](#)
58. Fu, W.; Wu, Y.; Sun, L.; Zhang, W. Efficient bioremediation of total organic carbon (TOC) in integrated aquaculture system by marine sponge *Hymeniacidon perleue*. *Biotechnol. Bioeng.* **2007**, *97*, 1387–1397. [\[CrossRef\]](#)
59. Longo, C.; Corriero, G.; Licciano, M.; Stabili, L. Bacterial accumulation by the Demospongiae *Hymeniacidon perlevis*: A tool for the bioremediation of polluted seawater. *Mar. Pollut. Bull.* **2010**, *60*, 1182–1187. [\[CrossRef\]](#)
60. Riisgård, H.U.; Larsen, P.S. Comparative ecophysiology of active zoobenthic filter feeding, essence of current knowledge. *J. Sea Res.* **2000**, *44*, 169–193. [\[CrossRef\]](#)
61. Jaishankar, M.; Tseten, T.; Anbalagan, N.; Mathew, B.B.; Beeregowda, K.N. Toxicity, mechanism and health effects of some heavy metals. *Interdiscip. Toxicol.* **2014**, *7*, 60. [\[CrossRef\]](#) [\[PubMed\]](#)
62. Leatherland, T.M.; Burton, J.D. The occurrence of some trace metals in coastal organisms with particular reference to the Solent Region. *J. Mar. Biol. Assoc. UK* **1974**, *54*, 457–468. [\[CrossRef\]](#)
63. Patel, B.; Balani, M.C.; Patel, S. Sponge ‘sentinel’ of heavy metals. *Sci. Total Environ.* **1985**, *41*, 143–152. [\[CrossRef\]](#) [\[PubMed\]](#)
64. Olesen, T.M.E.; Weeks, J.M. Accumulation of Cd by the marine sponge *Halichondria panicea* Pallas: Effects upon filtration rate and its relevance for biomonitoring. *Bull. Environ. Contam. Toxicol.* **1994**, *52*, 722–728. [\[CrossRef\]](#)
65. Hansen, I.V.; Weeks, J.M.; Depledge, M.H. Accumulation of Copper, Zinc, Cadmium and Chromium by the marine sponge *Halichondria panicea* Pallas and the implications for biomonitoring. *Mar. Pollut. Bull.* **1995**, *31*, 133–138. [\[CrossRef\]](#)
66. Philp, R.B. Cadmium content of the marine sponge *Microciona prolifera*, other sponges, water and sediment from the eastern Florida panhandle: Possible effects on *Microciona* cell aggregation and potential roles of low pH and low salinity. *Comp. Biochem. Physiol. Part C Pharmacol. Toxicol. Endocrinol.* **1999**, *124*, 41–49. [\[CrossRef\]](#)
67. Cebrian, E.; Marti, R.; Uriz, J.M.; Turon, X. Sublethal effects of contamination on the mediterranean sponge *Crambe crambe*: Metal accumulation and biological responses. *Mar. Pollut. Bull.* **2003**, *46*, 1273–1284. [\[CrossRef\]](#)
68. Rao, J.V.; Kavitha, P.; Reddy, N.C.; Rao, T.G. *Petrosia testudinaria* as a biomarker for metal contamination at Gulf of Mannar, Southeast Coast of India. *Chemosphere* **2006**, *65*, 634–638. [\[CrossRef\]](#)
69. Rao, J.V.; Kavitha, P.; Srikanth, K.; Usman, P.K.; Rao, T.G. Environmental contamination using accumulation of metals in marine sponge, *Sigmadocia fibulata* inhabiting the coastal waters of Gulf of Mannar, India. *Toxicol. Environ. Chem.* **2007**, *89*, 487–498. [\[CrossRef\]](#)
70. Venkateswara Rao, J.; Srikanth, K.; Pallela, R.; Gnaneshwar Rao, T. The use of marine sponge, *Haliclona tenuiramosa* as bioindicator to monitor heavy metal pollution in the coasts of Gulf of Mannar, India. *Environ. Monit. Assess.* **2009**, *156*, 451. [\[CrossRef\]](#)
71. Annibaldi, A.; Truzzi, C.; Illuminati, S.; Bassotti, E.; Finale, C.; Scarponi, G. First systematic voltammetric measurements of Cd, Pb, and Cu in hydrofluoric acid-dissolved siliceous spicules of marine sponges: Application to Antarctic specimens. *Anal. Lett.* **2011**, *44*, 2792–2807. [\[CrossRef\]](#)
72. Mahaut, M.-L.; Basuyaux, O.; Baudinière, E.; Chataignier, C.; Pain, J.; Caplat, C. The Porifera *Hymeniacidon perlevis* (Montagu, 1818) as a bioindicator for water quality monitoring. *Environ. Sci. Pollut. Res.* **2013**, *20*, 2984–2992. [\[CrossRef\]](#) [\[PubMed\]](#)
73. Batista, D.; Muricy, G.; Rocha, R.C.; Miekeley, N.F. Marine sponges with contrasting life histories can be complementary biomonitoring of heavy metal pollution in coastal ecosystems. *Environ. Sci. Pollut. Res.* **2014**, *21*, 5785–5794. [\[CrossRef\]](#) [\[PubMed\]](#)
74. Maloubier, M.; Michel, H.; Solari, P.L.; Moisy, P.; Tribalat, M.-A.; Oberhaensli, F.R.; Bottein, M.Y.D.; Thomas, O.P.; Monfort, M.; Moulin, C. Speciation of Americium in seawater and accumulation in the marine sponge *Aplysina cavernicola*. *Dalton Trans.* **2015**, *44*, 20584–20596. [\[CrossRef\]](#) [\[PubMed\]](#)
75. Celik, F.; Camas, M.; Camas, A.S.; Ozalp, H.B. Uranium (VI) biosorption on marine sponge, *Sarcotragus foetidus* (Schmidt, 1862) and its statistical investigation using central composite design. *Turkish J. Fish. Aquat. Sci.* **2016**, *16*, 899–911. [\[CrossRef\]](#)
76. Gentric, C.; Rehel, K.; Dufour, A.; Sauleau, P. Bioaccumulation of metallic trace elements and organic pollutants in marine sponges from the South Brittany Coast, France. *J. Environ. Sci. Health A* **2016**, *51*, 213–219. [\[CrossRef\]](#)
77. Ferrante, M.; Vassallo, M.; Mazzola, A.; Brundo, M.V.; Pecoraro, R.; Grasso, A.; Copat, C. In Vivo Exposure of the marine sponge *Chondrilla nucula* Schmidt, 1862 to Cadmium (Cd), Copper (Cu) and Lead (Pb) and its potential use for bioremediation purposes. *Chemosphere* **2018**, *193*, 1049–1057. [\[CrossRef\]](#)
78. Orani, A.M.; Barats, A.; Vassileva, E.; Thomas, O.P. Marine sponges as a powerful tool for trace elements biomonitoring studies in coastal environment. *Mar. Pollut. Bull.* **2018**, *131*, 633–645. [\[CrossRef\]](#)
79. Rodríguez, G.R.; Morales, E.O. Assessment of heavy metal contamination at Tallaboa Bay (Puerto Rico) by marine sponges’ bioaccumulation and fungal community composition. *Mar. Pollut. Bull.* **2020**, *161*, 111803. [\[CrossRef\]](#)
80. Srikanth, K.; Rao, J.V.; Rao, A.R. Trace elements in *Endectyon fruticosa* collected from a sewage outfall site, Therespuram, Tuticorin coast, India. *Int. J. Environ. Sci. Technol.* **2020**, *17*, 267–272. [\[CrossRef\]](#)
81. Gravina, M.F.; Longo, C.; Puthod, P.; Rosati, M.; Colozza, N.; Scarselli, M. Heavy metal accumulation capacity of *Axinella damicornis* (Esper, 1794) (Porifera, Demospongiae): A tool for bioremediation of polluted seawaters. *Mediterr. Mar. Sci.* **2022**, *23*, 125–133. [\[CrossRef\]](#)

82. Krikech, I.; Jafarabadi, A.R.; Leermakers, M.; Le Pennec, G.; Cappello, T.; Ezziyyani, M. Insights into bioaccumulation and bioconcentration of potentially toxic elements in marine sponges from the Northwestern Mediterranean coast of Morocco. *Mar. Pollut. Bull.* **2022**, *180*, 113770. [[CrossRef](#)] [[PubMed](#)]
83. Orani, A.M.; Vassileva, E.; Thomas, O.P. Marine sponges as coastal bioindicators of rare earth elements bioaccumulation in the French Mediterranean Sea. *Environ. Pollut.* **2022**, *304*, 119172. [[CrossRef](#)] [[PubMed](#)]
84. Genta-Jouve, G.; Cachet, N.; Oberhänsli, F.; Noyer, C.; Teyssié, J.-L.; Thomas, O.P.; Lacoue-Labarthe, T. Comparative bioaccumulation kinetics of trace elements in Mediterranean marine sponges. *Chemosphere* **2012**, *89*, 340–349. [[CrossRef](#)]
85. Illuminati, S.; Annibaldi, A.; Truzzi, C.; Scarponi, G. Heavy metal distribution in organic and siliceous marine sponge tissues measured by square wave anodic stripping voltammetry. *Mar. Pollut. Bull.* **2016**, *111*, 476–482. [[CrossRef](#)] [[PubMed](#)]
86. Lacoue-Labarthe, T.; Warnau, M.; Beaugéard, L.; Pascal, P.-Y. Trophic transfer of radioisotopes in Mediterranean sponges through bacteria consumption. *Chemosphere* **2016**, *144*, 1885–1892. [[CrossRef](#)]
87. Agusa, T.; Takagi, K.; Kubota, R.; Anan, Y.; Iwata, H.; Tanabe, S. Specific accumulation of arsenic compounds in green turtles (*Chelonia mydas*) and hawksbill turtles (*Eretmochelys imbricata*) from Ishigaki Island, Japan. *Environ. Pollut.* **2008**, *153*, 127–136. [[CrossRef](#)]
88. Batel, R.; Bihari, N.; Rinkevich, B.; Dapper, J.; Schäcke, H.; Schröder, H.C.; Müller, W.E. Modulation of organotin-induced apoptosis by the water pollutant methyl mercury in a human lymphoblastoid tumour cell line and a marine sponge. *Mar. Ecol. Prog. Ser.* **1993**, *93*, 245–251. [[CrossRef](#)]
89. Wagner, C.; Steffen, R.; Koziol, C.; Batel, R.; Lacorn, M.; Steinhart, H.; Simat, T.; Müller, W.E.G. Apoptosis in marine sponges: A biomarker for environmental stress (cadmium and bacteria). *Mar. Biol.* **1998**, *131*, 411–421. [[CrossRef](#)]
90. Schröder, H.C.; Hassanein, H.M.A.; Lauenroth, S.; Koziol, C.; Mohamed, T.-A.; Lacorn, M.; Steinhart, H.; Batel, R.; Müller, W.E.G. Induction of DNA strand breaks and expression of HSP70 and GRP78 homolog by cadmium in the marine sponge *Suberites domuncula*. *Arch. Environ. Contam. Toxicol.* **1999**, *36*, 47–55. [[CrossRef](#)]
91. Wanick, R.C.; de Sousa Barbosa, H.; Frazão, L.R.; Santelli, R.E.; Arruda, M.A.Z.; Coutinho, C.C. Evaluation of differential protein expression in *Haliclona aquarius* and sponge-associated microorganisms under cadmium stress. *Anal. Bioanal. Chem.* **2013**, *405*, 7661–7670. [[CrossRef](#)]
92. Akpiri, R.U.; Konya, R.S.; Hodges, N.J. Development of cultures of the marine sponge *Hymeniacidon perlevis* for genotoxicity assessment using the alkaline comet assay. *Environ. Toxicol. Chem.* **2017**, *36*, 3314–3323. [[CrossRef](#)] [[PubMed](#)]
93. Zahn, R.K.; Kurelec, B.; Zahn-Daimler, G.; Müller, W.E.G.; Rijavec, M.; Batel, R.; Given, R.; Pondeljak, V.; Beyer, R. The effect of benzo[a]pyrene on sponges as model organisms in marine pollution. *Chem. Biol. Interact.* **1982**, *39*, 205–220. [[CrossRef](#)] [[PubMed](#)]
94. Perez, T.; Wafo, E.; Fourt, M.; Vacelet, J. Marine sponges as biomonitor of polychlorobiphenyl contamination: Concentration and fate of 24 congeners. *Environ. Sci. Technol.* **2003**, *37*, 2152–2158. [[CrossRef](#)] [[PubMed](#)]
95. Haraguchi, K.; Kato, Y.; Ohta, C.; Koga, N.; Endo, T. Marine sponge: A potential source for methoxylated polybrominated diphenyl ethers in the Asia-Pacific food web. *J. Agric. Food Chem.* **2011**, *59*, 13102–13109. [[CrossRef](#)]
96. Aresta, A.; Marzano, C.N.; Lopane, C.; Corriero, G.; Longo, C.; Zambonin, C.; Stabili, L. Analytical investigations on the lindane bioremediation capability of the Demosponge *Hymeniacidon perlevis*. *Mar. Pollut. Bull.* **2015**, *90*, 143–149. [[CrossRef](#)]
97. Webster, L.; Russell, M.; Shepherd, N.; Packer, G.; Dalgarno, E.J.; Neat, F. Monitoring of Polycyclic Aromatic Hydrocarbons (PAHs) in Scottish Deepwater environments. *Mar. Pollut. Bull.* **2018**, *128*, 456–459. [[CrossRef](#)]
98. Wu, Q.; Eisenhardt, N.; Holbert, S.S.; Pawlik, J.R.; Kucklick, J.R.; Vetter, W. Naturally occurring organobromine compounds (OBCs) including polybrominated dibenzo-p-dioxins in the marine sponge *Hyrtios proteus* from The Bahamas. *Mar. Pollut. Bull.* **2021**, *172*, 112872. [[CrossRef](#)]
99. Batista, D.; Tellini, K.; Nudi, A.H.; Massone, T.P.; Scofield, A.D.L.; de LR Wagener, A. Marine sponges as bioindicators of oil and combustion derived PAH in coastal waters. *Mar. Environ. Res.* **2013**, *92*, 234–243. [[CrossRef](#)]
100. Schröder, H.C.; Badria, F.A.; Ayyad, S.N.; Batel, R.; Wiens, M.; Hassanein, H.M.; Kurelec, B.; Müller, W.E. Inhibitory effects of extracts from the marine alga *Caulerpa taxifolia* and of toxin from *Caulerpa racemosa* on multixenobiotic resistance in the marine sponge *Geodia cydonium*. *Environ. Toxicol. Pharmacol.* **1998**, *5*, 119–126. [[CrossRef](#)]
101. Châtel, A.; Talarmin, H.; Hamer, B.; Schröder, H.C.; Müller, W.E.G.; Dorange, G. MAP Kinase cell signaling pathway as biomarker of environmental pollution in the sponge *Suberites domuncula*. *Ecotoxicology* **2011**, *20*, 1727–1740. [[CrossRef](#)] [[PubMed](#)]
102. Modica, L.; Lanuza, P.; García-Castrillo, G. Surrounded by microplastic, since when? Testing the feasibility of exploring past levels of plastic microfibre pollution using natural history museum collections. *Mar. Pollut. Bull.* **2020**, *151*, 110846. [[CrossRef](#)] [[PubMed](#)]
103. Soares, G.M.; Barros, F.; Lanna, E.; da Silva, M.V.S.; Cavalcanti, F.F. Sponges as libraries: Increase in microplastics in *Cinachyrella alloclada* after 36 years. *Mar. Pollut. Bull.* **2022**, *185*, 114339. [[CrossRef](#)] [[PubMed](#)]
104. Karlsson, T.M.; Vethaak, A.D.; Almroth, B.C.; Ariese, F.; van Velzen, M.; Hassellöv, M.; Leslie, H.A. Screening for microplastics in sediment, water, marine invertebrates and fish: Method development and microplastic accumulation. *Mar. Pollut. Bull.* **2017**, *122*, 403–408. [[CrossRef](#)]
105. Celis-Hernández, O.; Ávila, E.; Ward, R.D.; Rodríguez-Santiago, M.A.; Aguirre-Téllez, J.A. Microplastic distribution in urban vs pristine mangroves: Using marine sponges as bioindicators of environmental pollution. *Environ. Pollut.* **2021**, *284*, 117391. [[CrossRef](#)] [[PubMed](#)]

106. Fallon, B.R.; Freeman, C.J. Plastics in Porifera: The occurrence of potential microplastics in marine sponges and seawater from Bocas Del Toro, Panamá. *PeerJ* **2021**, *9*, e11638. [[CrossRef](#)] [[PubMed](#)]
107. Giametti, S.D.; Finelli, C.M. Detection of plastic-associated compounds in marine sponges. *Mar. Pollut. Bull.* **2022**, *175*, 113141. [[CrossRef](#)]
108. Saliu, F.; Biale, G.; Raguso, C.; La Nasa, J.; Degano, I.; Seveso, D.; Galli, P.; Lasagni, M.; Modugno, F. Detection of plastic particles in marine sponges by a combined infrared micro-spectroscopy and pyrolysis-gas chromatography-mass spectrometry approach. *Sci. Total Environ.* **2022**, *819*, 152965. [[CrossRef](#)]
109. Baird, C.A. Measuring the Effects of Microplastics on Sponges. Ph.D. Thesis, Te Herenga Waka-Victoria University of Wellington, Wellington, New Zealand, 2016.
110. De Marchi, L.; Renzi, M.; Anselmi, S.; Pretti, C.; Guazzelli, E.; Martinelli, E.; Cuccaro, A.; Oliva, M.; Magri, M.; Bulleri, F. Polyethylene microplastics reduce filtration and respiration rates in the Mediterranean sponge *Petrosia ficiformis*. *Environ. Res.* **2022**, *211*, 113094. [[CrossRef](#)]
111. Selvin, J.; Priya, S.S.; Kiran, G.S.; Thangavelu, T.; Bai, N.S. Sponge-associated marine bacteria as indicators of heavy metal pollution. *Microbiol. Res.* **2009**, *164*, 352–363. [[CrossRef](#)]
112. Mori, T.; Iwamoto, K.; Wakaoji, S.; Araie, H.; Kohara, Y.; Okamura, Y.; Shiraiwa, Y.; Takeyama, H. Characterization of a novel gene involved in cadmium accumulation screened from sponge-associated bacterial metagenome. *Gene* **2016**, *576*, 618–625. [[CrossRef](#)] [[PubMed](#)]
113. Karimi, E.; Gonçalves, J.M.; Reis, M.; Costa, R. Draft genome Sequence of *Microbacterium* Sp. strain Alg239_V18, an Actinobacterium retrieved from the marine sponge *Spongia* Sp. *Genome Announc.* **2017**, *5*, e01457-16. [[CrossRef](#)] [[PubMed](#)]
114. Sun, W.; Liu, C.; Zhang, F.; Zhao, M.; Li, Z. Comparative genomics provides insights into the marine adaptation in sponge-derived *Kocuria flava* S43. *Front. Microbiol.* **2018**, *9*, 1257. [[CrossRef](#)]
115. Freitas-Silva, J.; de Oliveira, B.F.R.; Vigoder, F.D.M.; Muricy, G.; Dobson, A.D.; Laport, M.S. Peeling the layers away: The genomic characterization of *Bacillus pumilus* 64-1, an isolate with antimicrobial activity from the marine sponge *Plakina cyanorosea* (Porifera, Homoscleromorpha). *Front. Microbiol.* **2021**, *11*, 592735. [[CrossRef](#)]
116. Marzuki, I.; Kamaruddin, M.; Ahmad, R.; Asaf, R.; Armus, R.; Siswanti, I. Performance of cultured marine sponges-symbiotic bacteria as a heavy metal bio-adsorption. *Biodiversitas* **2021**, *22*, 5536–5543. [[CrossRef](#)]
117. Chen, Y.; Pan, T.; Chai, G.; Li, Z. Complete Genome of *Mycetocola spongiae* MSC19T isolated from deep-sea sponge *Cacospongia mycofijiensis* indicates the adaptation to deep-sea environment and sponge-microbe symbioses. *Mar. Genom.* **2022**, *63*, 100955. [[CrossRef](#)] [[PubMed](#)]
118. Bauvais, C.; Zirah, S.; Piette, L.; Chaspoul, F.; Domart-Coulon, I.; Chapon, V.; Gallice, P.; Rebuffat, S.; Pérez, T.; Bourguet-Kondracki, M.-L. Sponging up metals: Bacteria associated with the marine sponge *Spongia officinalis*. *Mar. Environ. Res.* **2015**, *104*, 20–30. [[CrossRef](#)] [[PubMed](#)]
119. Gantt, S.E.; Lopez-Legentil, S.; Erwin, P.M. Stable microbial communities in the sponge *Crambe crambe* from inside and outside a polluted Mediterranean harbor. *FEMS Microbiol. Lett.* **2017**, *364*, 11. [[CrossRef](#)] [[PubMed](#)]
120. Webster, N.S.; Webb, R.I.; Ridd, M.J.; Hill, R.T.; Negri, A.P. The effects of copper on the microbial community of a coral reef sponge. *Environ. Microbiol.* **2001**, *3*, 19–31. [[CrossRef](#)]
121. Santos-Gandelman, J.F.; Cruz, K.; Crane, S.; Muricy, G.; Giambiagi-deMarval, M.; Barkay, T.; Laport, M.S. Potential application in mercury bioremediation of a marine sponge-isolated *Bacillus cereus* strain Pj1. *Curr. Microbiol.* **2014**, *69*, 374–380. [[CrossRef](#)]
122. Sajayan, A.; Kiran, G.S.; Priyadharshini, S.; Poullose, N.; Selvin, J. Revealing the ability of a novel polysaccharide bioflocculant in bioremediation of heavy metals sensed in a *Vibrio* bioluminescence reporter assay. *Environ. Pollut.* **2017**, *228*, 118–127. [[CrossRef](#)] [[PubMed](#)]
123. Orani, A.M.; Barats, A.; Zitte, W.; Morrow, C.; Thomas, O.P. Comparative study on the bioaccumulation and biotransformation of arsenic by some northeastern Atlantic and northwestern Mediterranean sponges. *Chemosphere* **2018**, *201*, 826–839. [[CrossRef](#)] [[PubMed](#)]
124. Orani, A.M.; Vassileva, E.; Azemard, S.; Thomas, O.P. Comparative study on Hg bioaccumulation and biotransformation in Mediterranean and Atlantic sponge species. *Chemosphere* **2020**, *260*, 127515. [[CrossRef](#)]
125. Ravindran, A.; Sajayan, A.; Priyadharshini, G.B.; Selvin, J.; Kiran, G.S. Revealing the efficacy of thermostable biosurfactant in heavy metal bioremediation and surface treatment in vegetables. *Front. Microbiol.* **2020**, *11*, 222. [[CrossRef](#)]
126. Freitas-Silva, J.; de Oliveira, B.F.R.; Dias, G.R.; de Carvalho, M.M.; Laport, M.S. Unravelling the sponge microbiome as a promising source of biosurfactants. *Crit. Rev. Microbiol.* **2022**, 1–16. [[CrossRef](#)] [[PubMed](#)]
127. Almeida, E.L.; Rincón, A.F.C.; Jackson, S.A.; Dobson, A.D. In silico screening and heterologous expression of a polyethylene terephthalate hydrolase (PETase)-like enzyme (SM14est) with polycaprolactone (PCL)-degrading activity, from the marine sponge-derived strain *Streptomyces* sp. SM14. *Front. Microbiol.* **2019**, *10*, 2187. [[CrossRef](#)] [[PubMed](#)]
128. Perez, T.; Sarrazin, L.; Rebouillon, P.; Vacelet, J. First evidences of surfactant biodegradation by marine sponges (porifera): An experimental study with a linear alkylbenzenesulfonate. *Hydrobiologia* **2002**, *489*, 225–233. [[CrossRef](#)]
129. Bonugli-Santos, R.C.; Durrant, L.R.; Sette, L.D. The production of ligninolytic enzymes by marine-derived Basidiomycetes and their biotechnological potential in the biodegradation of recalcitrant pollutants and the treatment of textile effluents. *Water Air Soil Pollut.* **2012**, *223*, 2333–2345. [[CrossRef](#)]

130. Dhasayan, A.; Kiran, G.S.; Selvin, J. Production and characterisation of glycolipid biosurfactant by *Halomonas* Sp. MB-30 for potential application in enhanced oil recovery. *Appl. Biochem. Biotechnol.* **2014**, *174*, 2571–2584. [\[CrossRef\]](#)
131. Loredana, S.; Graziano, P.; Antonio, M.; Carlotta, N.M.; Caterina, L.; Maria, A.A.; Carlo, Z.; Giuseppe, C.; Pietro, A. Lindane bioremediation capability of bacteria associated with the Demosponge *Hymeniacidon perlevis*. *Mar. Drugs* **2017**, *15*, 108. [\[CrossRef\]](#)
132. Holert, J.; Cardenas, E.; Bergstrand, L.H.; Zaikova, E.; Hahn, A.S.; Hallam, S.J.; Mohn, W.W. Metagenomes reveal global distribution of bacterial steroid catabolism in natural, engineered, and host environments. *mBio* **2018**, *9*, e02345-17. [\[CrossRef\]](#) [\[PubMed\]](#)
133. Bojko, B.; Onat, B.; Boyaci, E.; Psillakis, E.; Dailianis, T.; Pawliszyn, J. Application of in situ solid-phase microextraction on Mediterranean sponges for untargeted exometabolome screening and environmental monitoring. *Front. Mar. Sci.* **2019**, *6*, 632. [\[CrossRef\]](#)
134. Vasconcelos, M.R.; Vieira, G.A.; Otero, I.V.; Bonugli-Santos, R.C.; Rodrigues, M.V.; Rehder, V.L.; Ferro, M.; Boaventura, S.; Bacci, M.; Sette, L.D. Pyrene degradation by marine-derived ascomycete: Process optimization, toxicity, and metabolic analyses. *Environ. Sci. Pollut. Res.* **2019**, *26*, 12412–12424. [\[CrossRef\]](#) [\[PubMed\]](#)
135. Horna-Gray, I.; Lopez, N.A.; Nijenhuis, I.; Ahn, Y.; Richnow, H.H.; Häggblom, M.M. Reductive debromination by sponge-associated anaerobic bacteria coupled to carbon isotope fractionation. *Int. Biodeterior. Biodegrad.* **2020**, *155*, 105093. [\[CrossRef\]](#)
136. Marzuki, I.; Nisaa, K.; Asaf, R.; Athirah, A.; Paena, M.; Susianingsih, E.; Nurhidayah, N.; Kadriah, I.A.K.; Kamaruddin, K.; Sahabuddin, S. Comparison of pyrene biodegradation using two types of marine bacterial isolates. *Sustainability* **2022**, *14*, 9890. [\[CrossRef\]](#)
137. Schleuter, D.; Günther, A.; Paasch, S.; Ehrlich, H.; Kljajić, Z.; Hanke, T.; Bernhard, G.; Brunner, E. Chitin-based renewable materials from marine sponges for uranium adsorption. *Carbohydr. Polym.* **2013**, *92*, 712–718. [\[CrossRef\]](#)
138. Wang, D.; Song, J.; Lin, S.; Wen, J.; Ma, C.; Yuan, Y.; Lei, M.; Wang, X.; Wang, N.; Wu, H. A marine-inspired hybrid sponge for highly efficient uranium extraction from seawater. *Adv. Funct. Mater.* **2019**, *29*, 1901009. [\[CrossRef\]](#)
139. Machałowski, T.; Jankowska, K.; Bachosz, K.; Smulek, W.; Ehrlich, H.; Kaczorek, E.; Zdzarta, J.; Jesionowski, T. Biocatalytic system made of 3D chitin, silica nanopowder and horseradish peroxidase for the removal of 17 α -ethinylestradiol: Determination of process efficiency and degradation mechanism. *Molecules* **2022**, *27*, 1354. [\[CrossRef\]](#)
140. Bergmann, W.; Feeney, R.J. Contributions to the Study of Marine Products. XXXII. The Nucleosides of Sponges. I. *J. Org. Chem.* **1951**, *16*, 981–987. [\[CrossRef\]](#)
141. Carroll, A.R.; Copp, B.R.; Davis, R.A.; Keyzers, R.A.; Prinsep, M.R. Marine natural products. *Nat. Prod. Rep.* **2019**, *36*, 122–173. [\[CrossRef\]](#)
142. Proksch, P.; Edrada, R.; Ebel, R. Drugs from the seas—current status and microbiological implications. *Appl. Microbiol. Biotechnol.* **2002**, *59*, 125–134. [\[CrossRef\]](#) [\[PubMed\]](#)
143. Maslin, M.; Gaertner-Mazouni, N.; Debitus, C.; Joy, N.; Ho, R. Marine sponge aquaculture towards drug development: An ongoing history of technical, ecological, chemical considerations and challenges. *Aquac. Rep.* **2021**, *21*, 100813. [\[CrossRef\]](#)
144. Sipkema, D.; Franssen, M.C.; Osinga, R.; Tramper, J.; Wijffels, R.H. Marine sponges as pharmacy. *Mar. Biotechnol.* **2005**, *7*, 142–162. [\[CrossRef\]](#) [\[PubMed\]](#)
145. Rotter, A.; Barbier, M.; Bertoni, F.; Bones, A.M.; Cancela, M.L.; Carlsson, J.; Carvalho, M.F.; Ceglowska, M.; Chirivella-Martorell, J.; Conk Dalay, M.; et al. The essentials of marine biotechnology. *Front. Mar. Sci.* **2021**, *8*, 629629. [\[CrossRef\]](#)
146. Varijakzhan, D.; Loh, J.-Y.; Yap, W.-S.; Yusoff, K.; Seboussi, R.; Lim, S.-H.E.; Lai, K.-S.; Chong, C.M. Bioactive compounds from marine sponges: Fundamentals and applications. *Mar. Drugs* **2021**, *19*, 246. [\[CrossRef\]](#)
147. Lipton, A.P.; Sunith, S. Mariculture of marine sponges for drug development: Bioactivity potentials of cultured sponges, *Callispongia subarmigera* (Ridley) and *Echinodictyum gorgonoides* (Dendy). *Mar. Fish. Infor. Serv. T&E Ser.* **2009**, *202*, 7–10. Available online: <http://eprints.cmfri.org.in/id/eprint/6469> (accessed on 26 November 2022).
148. Page, M.J.; Handley, S.J.; Northcote, P.T.; Cairney, D.; Willan, R.C. Successes and pitfalls of the aquaculture of the sponge *Mycale hentscheli*. *Aquaculture* **2011**, *312*, 52–61. [\[CrossRef\]](#)
149. Santiago, V.S.; Manzano, G.G.; Clairecynth, C.Y.; Aliño, P.M.; Salvador-Reyes, L.A. Mariculture potential of renieramycin-producing philippine blue sponge *Xestospongia* sp. (Porifera: Haplosclerida). *Aquaculture* **2019**, *502*, 356–364. [\[CrossRef\]](#)
150. Mishra, S.; Das, R.; Swain, P. Status of fish diseases in aquaculture and assessment of economic loss due to disease. In *Contemporary Trends in Fisheries and Aquaculture*; Rao, P., Pandey, B., Pandey, P., Joshi, B.D., Eds.; Today & Tomorrow's Printers and Publishers: New Delhi, India, 2018.
151. Randall, J.E.; Hartman, W.D. Sponge-feeding fishes of the West Indies. *Mar. Biol.* **1968**, *1*, 216–225. [\[CrossRef\]](#)
152. Wulff, J.L. Sponge Feeding by Caribbean Angelfishes, Trunkfishes, and Filefishes. In *Sponges in Time and Space*; van Soests, R.W.M., van Kempen, T.M.G., Braekman, J.C., Eds.; Balkema: Rotterdam, The Netherlands, 1994; pp. 265–271.
153. Ruzicka, R.; Gleason, D.F. Latitudinal variation in spongivorous fishes and the effectiveness of sponge chemical defenses. *Oecologia* **2008**, *154*, 785–794. [\[CrossRef\]](#)
154. Kaandorp, J.A.; De Kluijver, M.J. Verification of fractal growth models of the sponge *Haliclona oculata* (Porifera) with transplantation experiments. *Mar. Biol.* **1992**, *113*, 133–143. [\[CrossRef\]](#)
155. van Treeck, P.; Eisinger, M.; Müller, J.; Paster, M.; Schuhmacher, H. Mariculture trials with Mediterranean sponge species: The exploitation of an old natural resource with sustainable and novel methods. *Aquaculture* **2003**, *218*, 439–455. [\[CrossRef\]](#)

156. Kelly, M.; Handley, S.; Page, M.; Butterfield, P.; Hartill, B.; Kelly, S. Aquaculture trials of the New Zealand bath-sponge *Spongia* (Heterofibria) *manipulatus* using lanterns. *N. Z. J. Mar. Freshw. Res.* **2004**, *38*, 231–241. [\[CrossRef\]](#)
157. De Voogd, N.J. An assessment of sponge mariculture potential in the Spermonde Archipelago, Indonesia. *J. Mar. Biolog. Assoc. UK* **2007**, *87*, 1777–1784. [\[CrossRef\]](#)
158. de Voogd, N.J. The mariculture potential of the Indonesian reef-dwelling sponge *Callyspongia* (*Euplacella*) *biru*: Growth, survival and bioactive compounds. *Aquaculture* **2007**, *262*, 54–64. [\[CrossRef\]](#)
159. Carballo, J.L.; Yañez, B.; Zubía, E.; Ortega, M.J.; Vega, C. Culture of explants from the sponge *Mycale cecilia* to obtain bioactive mycalazal-type metabolites. *Mar. Biotechnol.* **2010**, *12*, 516–525. [\[CrossRef\]](#) [\[PubMed\]](#)
160. Gökalp, M.; Wijgerde, T.; Murk, A.; Osinga, R. Design for large-scale maricultures of the mediterranean demosponge *Chondrosia reniformis* Nardo, 1847 for collagen production. *Aquaculture* **2022**, *548*, 737702. [\[CrossRef\]](#)
161. Giangrande, A.; Gravina, M.F.; Rossi, S.; Longo, C.; Pierri, C. Aquaculture and restoration: Perspectives from mediterranean sea experiences. *Water* **2021**, *13*, 991. [\[CrossRef\]](#)
162. Baldacconi, R.; Cardone, F.; Longo, C.; Mercurio, M.; Marzano, C.N.; Gaino, E.; Corriero, G. Transplantation of *Spongia officinalis* L. (Porifera, Demospongiae): A technical approach for restocking this endangered species. *Mar. Ecol.* **2010**, *31*, 309–317. [\[CrossRef\]](#)
163. Biggs, B.C. Harnessing natural recovery processes to improve restoration outcomes: An experimental assessment of sponge-mediated coral reef restoration. *PLoS ONE* **2013**, *8*, e64945. [\[CrossRef\]](#)
164. De Caralt, S.; Sánchez-Fontenla, J.; Uriz, M.J.; Wijffels, R.H. In situ aquaculture methods for *Dysidea avara* (Demospongiae, Porifera) in the Northwestern Mediterranean. *Mar. Drugs* **2010**, *8*, 1731–1742. [\[CrossRef\]](#) [\[PubMed\]](#)
165. Webster, N.S.; Cobb, R.E.; Negri, A.P. Temperature thresholds for bacterial symbiosis with a sponge. *ISME J.* **2008**, *2*, 830–842. [\[CrossRef\]](#) [\[PubMed\]](#)
166. United Nations Department of Economic and Social Affairs. *The Sustainable Development Goals Report*; United Nations: New York, NY, USA, 2022; p. 68. [\[CrossRef\]](#)

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.