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PORIFERA IN THE REMEDIA LIFE INTEGRATED MULTITROPHIC AQUACULTURE (IMTA) SYSTEM

I PORIFERI NEL SISTEMA DI ACQUACOLTURA MULTI-TROFICA INTEGRATA REMEDIA LIFE

Abstract - *The co-cultivation of sponges near mariculture facilities in floating cages represents a promising practice that can contribute to the development of new Integrated Multi-Trophic Aquaculture systems (IMTA) aimed at building sustainable, resilient and competitive aquaculture.Therefore, in the IMTA system tested within the EU funded REMEDIA Life project, carried out in the Mar Grande of Taranto, different rearing methods and different sponge species were tested in order to detect those with the best performance in such conditions. Three sponge rearing cycles have been followed. Our results showed that explants reared on suspended ropes at least doubled their initial volume within the first 12 rearing months, with annual survival rate exceeding 90%. Results obtained on bioremediation capability also suggested the possibility to design effective multitrophic systems to minimize some microbial impacts of marine aquaculture.*

Key-words*: Porifera, Integrated Multi-trophic Aquaculture, sponge rearing, bioremediation, zooremediation*

Introduction - Porifera, or sponges, are aquatic invertebrates, mainly marine, widely distributed from the surface to the ocean depths. Within benthic habitats they are the most common and abundant filter feeder organisms. Among filter-feeding invertebrates, sponges are among the most effective and efficient being capable to filter actively several thousand liters of water per kg of sponge per day with a high retention efficiency (up to 98%) and capable to retain a wide range of dissolved substances and microparticles between 0.5 and 50 µm in diameter (particulate organic matter, bacteria, phyto- and zooplankton, and even viruses) (e.g. Ribes *et al*., 1999). The high filtration efficiency makes sponges key organisms for the absorption, retention and transfer of energy and substances within marine ecosystems and makes them excellent candidates for bioremediation of organic pollution, especially in confined areas such as bays, gulfs or areas subject to aquaculture activities. The sponge rearing near mariculture plants in floating cages is an extremely innovative methodology that contributes to the development of new IMTA systems aimed at making a sustainable, resilient and competitive aquaculture. In fact, sponge mariculture in IMTA systems can bring several advantages such as the bioremediation of waters subject to organic or bacterial loads, the large-scale production of exploitable biomass and the reduction of the excessive exploitation of natural stocks. In this context, it is required that researches must be focused on identifying suitable species with specific biological and ecological characteristics (easily reared, resistant to handling and new environmental conditions) and the standardization of in situ rearing methods allowing the production of high sponge biomasses. Among marine organisms, Porifera is a taxon of choice in the research of biomolecules, but the use of this resource on a large scale collides with the need to preserve it from indiscriminate and unsustainable exploitation, the main source of biomass to date to support both the advanced research and the final production phases. Therefore, this work summarizes the main results of the EU REMEDIA Life project regarding sponge rearing, bioremediation assays and sponge biomasses potential exploitation in order to take a step forward in the implementation of sustainable production systems like IMTA.

Materials and methods - The IMTA system for sponge rearing developed in the EU REMEDIA Life project (LIFE16 ENV/IT/000343) was stablished in the "Maricoltura Mar Grande" (MMG) mariculture plant on the southwestern side of the Mar Grande of Taranto (Mediterranean Sea). The aquaculture plant consists of six fish cages (Ø 22 m), placed at 7-12 m depth, producing European seabass *Dicentrarchus labrax* (Linnaeus, 1758) and sea bream *Sparus aurata*, Linnaeus, 1758, to which three Long Lines (LLA, LLB, LLC) with bioremediators (sponges, polychaetes, macroalgae and mussels) were associated (Giangrande *et al*., 2020). Long lines for the rearing of bioremediators were supported by buoys (Fig. 1). In the REMEDIA Life IMTA system, 3 rearing cycles of different sponge species were tested. The sponge rearing methods were inspired by previous technical-scientific experiences by UNIBA researchers (Corriero *et al.*, 2004), and allowed the cultivation of a large number of sponge explants. The donor sponge specimens were collected near the mariculture plant. Health status and growth performance of pooled explants has been monthly monitored. In addition, filtering experiments at laboratory scale have been conducted using natural seawater or pathogenic bacterium *Vibrio parahaemolyticus*, in order to assess suitability as microbial bioremediators.

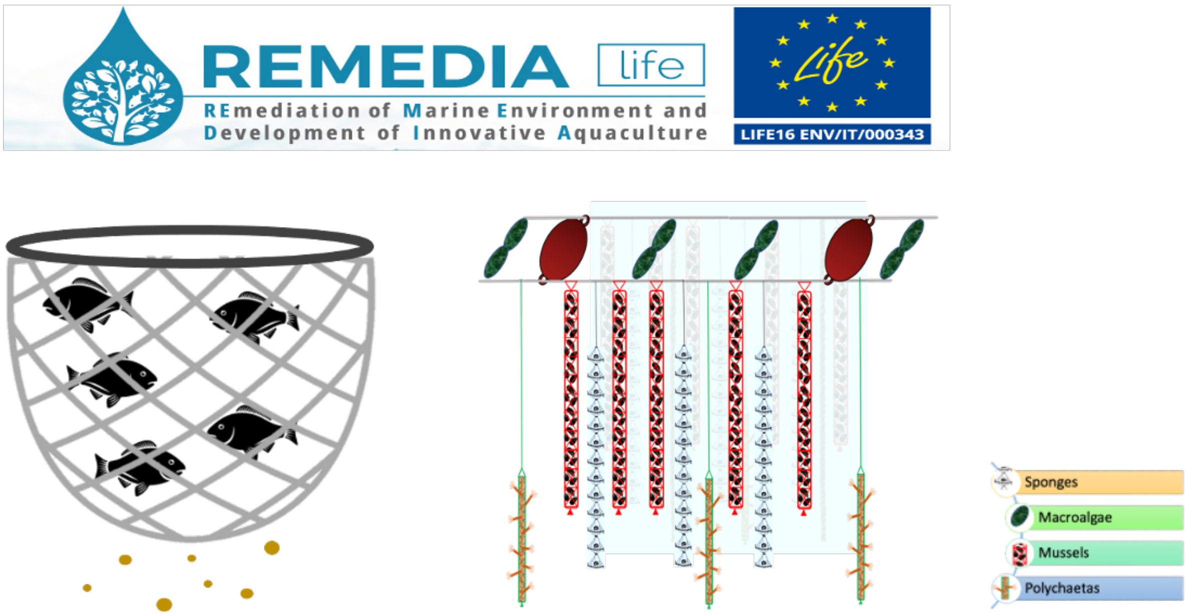

Fig. 1 - Schematic representation of the REMEDIA Life Integrated Multitrophic Aquaculture system developed in the Maricoltura Mar Grande (Taranto) plant.
Rappresentazione schematica del sistema di Acquacoltura Multitrofica Integrata REMEDIA Life sviluppato nell'impianto Maricoltura Mar Grande (Taranto).

Results - Our results showed that explants reared on suspended ropes at least doubled their initial volume within the first 12 rearing months, with annual survival rate exceeding 90% (Fig. 2). In the case of rearing experiences of the keratose *Sarcotragus spinosulus* Schmidt, 1862, explants monitoring demonstrated high performance, with increased survival rate and notable biomass growth within relatively short timeframes (Giangrande *et al.,* 2020). Infact, during the first rearing year the mean percentage of living *S. spinosulus* explants ranged from 93% in first month and to 80.84% in last month. The highest percentage of damaged explants occurred only after the initial three rearing months, reasonably due to manipulation, but significantly decreased onwards. The specific growth rate of *S. spinosulus* explants showed an initial volume loss due to the stress of collection and cutting of donor sponges. However, a continuous positive trend in all LLs was observed from the second rearing month up to the entire year when the explants in the rearing modules had more than doubled in volume, from about 100 ± 10 mL to approximately 240 ± 20 mL (mean ± SD) (Giangrande *et al.,* 2020). Results obtained on ex-situ microbial bioremediation capability suggested the possibility to design effective multitrophic systems to minimize some microbial impacts of marine aquaculture. Different species exhibited specific performances: *Spongia officinalis* Linnaeus, 1759, *Tethya meloni* Corriero, Gadaleta & Bavestrello, 2015 and *S. spinosulus* showed maximum CR values of 210, 66 and 45 ml h^{-1} g^{-1} DW, respectively (Stabili *et al.*, 2006; Trani *et al.,* 2021; 2022). However, the ability of the species to survive in critical conditions such as those found near an aquaculture plant should not be overlooked. Indeed, *S. officinalis* is less suitable in certain rearing conditions (Caterina Longo, personal observations), while for *S. spinosulus* we have demonstrated that it is well suited in the REMEDIA Life IMTA system.

Fig. 2 – *Aplysina aerophoba* (Nardo, 1833) (a) and *Hymeniacidon perlevis* (Montagu, 1814) (b) reared in the REMEDIA Life Integrated Multitrophic Aquaculture system in the Mar Grande of Taranto.
Aplysina aerophoba *(Nardo, 1833) (a) e* Hymeniacidon perlevis *(Montagu, 1814) (b) allevate nell'impianto di acquacoltura multitrofica integragrata REMEDIA Life nel Mar Grande di Taranto.*

Conclusions - Although sponge mariculture has been known for a long time, its promising use in IMTA systems is still underexploited, as knowledge in reproduction, growth performance, resistance to survival in critical conditions and resistance to manipulation are fundamental when selecting species. So far, only a few sponges species have been tested in the Mediterranean under such conditions in order to evaluate their suitability or rearing performance, production of bioactive compounds or bioremediation capability, which, however, showed promising results doubling their initial biomass during a period from 6 to 24 months (Aguilo-Arce *et al*., 2023 and references therein). When it comes to valorization, the sponge biomass obtained in IMTA systems has considerable potential from a commercial point of view, having high appeal both for cosmetic, hobbyist and pharmaceutical applications (Aguilo-Arce *et al.,* 2023). Among marine invertebrates Porifera is the main prolific taxon of natural bioactive compounds. Some of these compounds of considerable interest in different fields are, however, challenging to find on the market due to the unavailability of adequate sponge biomasses. To date, the only viable way to obtain large sponge biomass is the *in situ* rearing. In addition, despite the striking application potential, bioremediation using sponges is currently confined to limited practices, mainly experimental, or small-scale areas. A further potential area of sponge biomass valorization is its use for ornamental purposes in the aquarium sector. Furthermore, for some fish families widespread in tropical ornamental aquaria (angelfish or pufferfish), sponges represent over 70% of their diet (Randall and Hartman, 1968), so that sponge-based foods have already been formulated and marketed. Finally, a new and emerging application of sponges grown in IMTA systems is their use in marine restoration. As an example, their use in restoration of wild populations subject to overexploitation, disease or die-off phenomena is desirable, as well as artificial "underwater gardens" that creating new habitats, increase biodiversity and support the ecosystem balances. All in all, considering the rapid expansion of the aquaculture sector, particularly in coastal area, the use of complementary filter-feeder macroinvertebrates such as sponges in the traditional mariculture production would allow to reach an improvement for the environmental sustainability of these areas, with positive effects on animal welfare, human consumption and leading benefit on the entire social-economic sector.

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