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Rearing performance of *Spongia officinalis* on suspended ropes off the Southern Italian Coast (Central Mediterranean Sea)

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Abstract

The availability of bath sponges has been recently reduced due to the depletion of natural banks due to the high fishing pressure together with some local epidemic events. At present, the commercial supply is far below the demand. The main purpose of this work was to estimate the rearing performance of *Spongia officinalis* var. *adriatica*, one of the most common Mediterranean commercial sponges, testing two different variants of culture on suspended ropes: a horizontal system placed close to the seabed, and a vertical system extended along the water column. The trials were carried out in Southern Italy (Ionian coast of Apulia, Central Mediterranean) from April 1997 to April 2000. Wild specimens of sponge were cut into pieces of different weight to test possible differences in growth and survival. During the study period, both systems resisted deterioration due to water movement and other ecological factors. In general, the growth performance (average weight, specific growth rate) did not significantly vary between the cultivation systems, nor were statistical differences in growth detected between the cuttings of different initial size. The mean growth observed was rather variable among sponge cuttings, even considering the same rearing condition and size range. The measured variations of hydrological parameters did not seem to affect survival, growth performance, or reproductive activity, which was detected almost all year round. Larger explants (about 50 g in wet weight) reached the commercial size after three years of rearing, thus identifying this initial size as the most suitable for cultivation

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purposes. At the end of the study period, the survival rate was 75%, with a more apparent decrease during the first year of rearing.

Keywords: Spongia officinalis; Growth rate; Rearing; Survival

1. Introduction

The current world market for bath sponges is dominated by the artificial products, although the value and the advantages of natural sponges are widely recognised. The present supply of natural sponges is outstripped by demand and is sustained worldwide by the wild Caribbean product, which has replaced the more precious Mediterranean sponge since the 1980s. Indeed, the availability of Mediterranean sponges was dramatically reduced by the depletion of natural banks, due both to high fishing pressure and devastating epidemic events (Gaino and Pronzato, 1989, 1992; Gaino et al., 1992, 1994; Vacelet et al., 1994; Pronzato, 1999). Attempts at bath sponge cultivation have been performed since the end of the nineteenth century (Osinga et al., 1999; Brümmer and Nickel, 2003), although only more recently have such investigations identified proper rearing techniques of sponge culture (Stevely et al., 1978; Verdenal and Verdenal, 1987; Verdenal and Vacelet, 1990; Grovas, 1998; Scalera Liaci et al., 1999). However, the available data on the rearing performance especially in terms of growth are not strictly comparable.

Sponge farming, which is an easy low-technology activity (Scalera Liaci et al., 1999), could play a notable role in the context of Mediterranean aquaculture, where the diversification of species and rearing systems is considered an important challenge for the future (Paquotte, 1998). Moreover, at present, the need for good-quality bath sponges is accompanied worldwide by a high demand for other sponge species which produce bioactive compounds useful for medical purposes (Duckworth et al., 1997; Brümmer and Nickel, 2003).

The Mediterranean bath sponges of the genus *Spongia* are generally considered of high commercial value for their characteristics, such as the fine texture of their fibres and absorption properties (Verdenal and Verdenal, 1987). Moreover, the decline of natural populations of the Mediterranean commercial sponges has led to their inclusion in the list of organisms requiring specific management measures (Annex 3 of the Bern Convention on the protection of Wildlife). Farming of these endangered species could thus contribute to their conservation and restocking, as larvae produced by reared specimens can act as new recruits able to re-colonise adjacent coastal areas (Manconi et al., 1998). Furthermore, knowledge on growth patterns may contribute to designing restoration and conservation plans. Indeed, experience in the cultivation of *Spongia officinalis* var. *adriatica* goes back to the beginning of the past century (Cotte, 1908) and was more recently updated by Verdenal and Vacelet (1990). Despite this, estimates of growth performance of reared sponges are still sparse and not standardised, making the comparison between different areas and cultivation techniques difficult.

The experiences of sponge culture reported in the literature so far are generally based upon sponge cuttings sustained by suspended ropes and placed in the water column (e.g.

Verdenal and Vacelet, 1990) or laid close to the sea bottom (e.g. Grovas, 1998), depending on the different cultivation environments (e.g. open sea or lagoons).

The main purpose of this work is to estimate the rearing performance of *S. officinalis* var. *adriatica*, one of the most common Mediterranean commercial sponges, testing structures differently placed along the water column, in order to simultaneously compare the growth performance of reared sponges in relation to the two spatial orientations reported above.

In addition, the resistance of the two differently oriented rearing structures to water mechanical stress was also verified as well as the practical implications in terms of space occupation and availability. Thus, sponges were suspended on ropes, horizontally near the seabed and vertically along the water column. The trials were carried out in a coastal site of the Apulia region (Gulf of Taranto, North Western Ionian Sea; Central Mediterranean).

2. Methods

The experiments were performed using *S. officinalis* var. *adriatica*, a species which is black or deep grey in colour, lobed, highly variable in body shape and size and with small conules and large oscules on the surface. The culture trials were performed from April 1997 to April 2000 in a nearshore site at 30-m depth, located along the coast of Apulia (Porto Cesareo, Lecce; 40°15′ .15 N–17°52′ .50 E, 40°15′ .16 N–17°52′ .21 E; Fig. 1) and characterised by a sandy seabed. The seed supply was collected by SCUBA divers who only removed the upper portion of the sponge body, leaving a large fragment attached to the substrate to allow regeneration. From hard bottoms adjacent to the cultivation site, we collected 52 wild sponges that were each cut into explants of three sizes: 22.6 g ($n = 404$; coefficient of variation: CV% = 21.7), 34.5 g ($n = 256$; CV% = 14.2), and 55.3 g ($n = 180$; CV% = 16.6). A nylon rope was sewn through the sponge cuttings, which were placed about 20 cm apart, operating onboard a boat in a 200-l plastic tank filled with seawater and continuously renewed. Working under the sea surface, the nylon ropes were then tied up to a plastic frame.

Two different types of rearing structures were prepared: in the former the plastic frames were vertically assembled (vertical system) along the water column and anchored to the bottom (− 30 m), with floaters on the upper end (− 18 m). The sponge cuttings were thus placed between about − 20 and − 25 m. In the latter (horizontal system), the plastic frames were positioned about 50 cm above the sea bottom (Fig. 2). In both the types of rearing structures, the plastic frames were placed at a distance of about 50 cm from each other.

About 70 small, 40 medium and 30 large explants were placed on three plastic frames (Fig. 2), in three replicates positioned 3 m apart. A total of 202, 128 and 90 cuttings were thus arranged in nine plastic frames per rearing system, which were situated 7 m from each other.

According to a random sampling procedure, every 6 months, a sample of 30 reared sponges from each cultivation system were cut from the ropes and collected using SCUBA. Then, the main biometric parameters (wet weight and length expressed as major axes diameter) were measured. The wet weight was assumed as a reliable and non-destructive

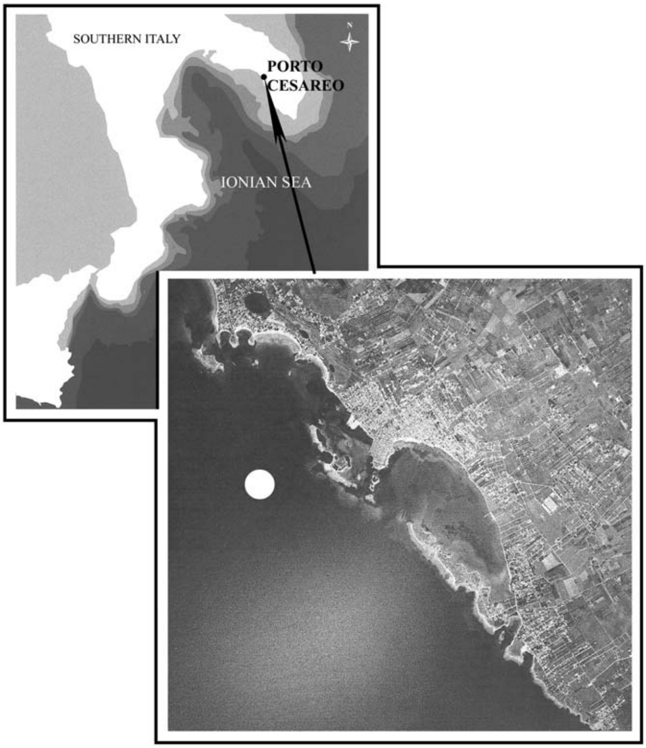

Fig. 1. Porto Cesareo: map of the study area with location of culture site.

method for growth estimate, according to Duckworth et al. (1997). After measuring, the sponges were re-utilised for restocking purposes in a different location and for a different project.

The weight gain in two consecutive time intervals 6 months apart (final weight – initial weight) and the specific growth rate in weight were estimated, the latter as follows:

$$\mathrm{SGR} = (\log_e W_{t_2} - \log_e W_{t_1})/(t_2 - t_1) \times 100;$$

where $\log_e$ are the natural logarithms, W_{t_2} and W_{t_1} the average wet weight at the two different times, and $(t_2 - t_1)$ the time interval in days.

The occurrence of significant average-weight-at-time and growth (SGR) differences between the two cultivation systems (vertical and horizontal) was evaluated by analysing the three sizes of cuttings using the Friedman and post-Dunn tests (Siegel and Castellan, 1992), after having proved the non-homoscedasticity of the variances by the Cochran test. A seasonal effect on growth was also tested, using the Mann–Whitney U-test.

The relationship between total wet weight at time t_2, as a function of the same variable at time t_1 ($t_2 - t_1 = 6$ months), as well as the regression between diameter and weight ($n = 84$) were estimated on $\log_e$-transformed data (Draper and Smith, 1981), testing for the significance of the square root of the coefficient of determination.

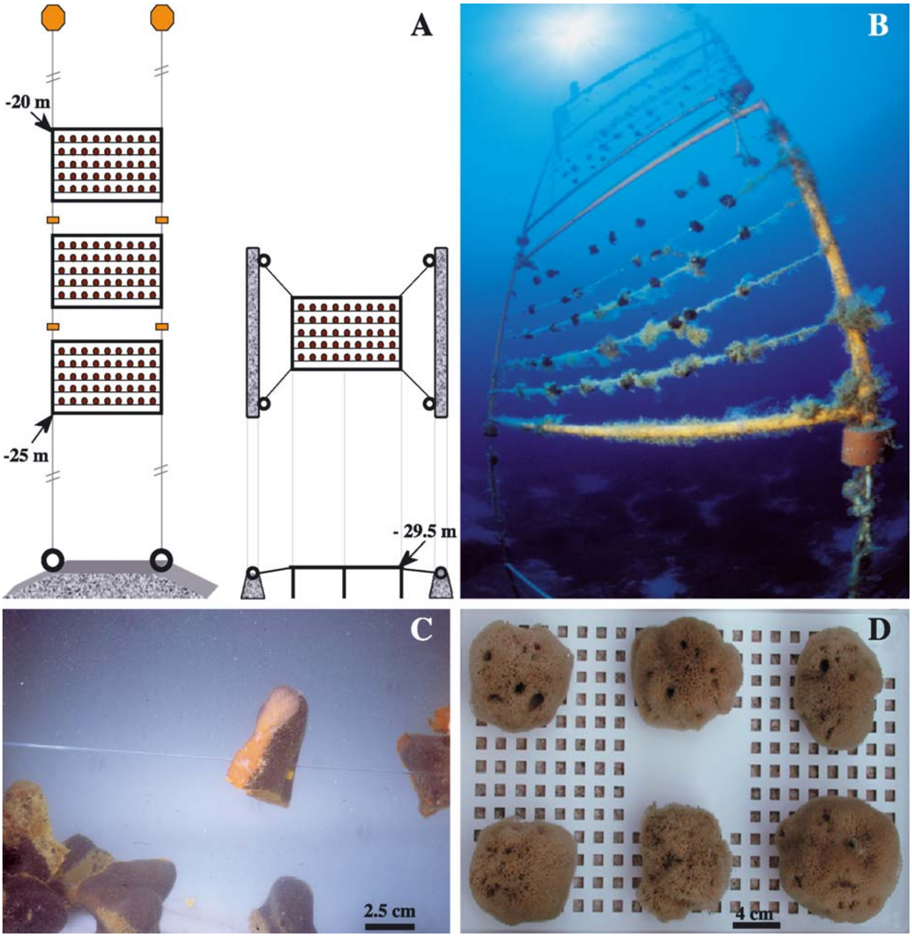

Fig. 2. (A) Scheme of the vertical (left) and horizontal (right) rearing structures. (B) Underwater image of the vertical structure extended along the water-column. (C) *S. officinalis* var. *adriatica* cuttings sewn in nylon ropes. (D) Specimens of *S. officinalis* var. *adriatica* after 3 years of culture.

The percentage survival rate (S) was estimated by considering the number of individuals at the beginning of the experiment (N_0) and the living specimens at the successive steps of the rearing (N_t), correcting the values for the number of sampled sponges:

$$S = (N_t/N_0) \times 100.$$

Every third month, 10 sponges exclusively selected from the small cuttings were sampled for the study of sexual reproduction. Samples of tissue were fixed in 4% formaldehyde in seawater. Once in the laboratory, selected material was rinsed in seawater, dehydrated and embedded in paraffin. The tissue analysis was carried out on histological sections 5 μm thick, stained with haematoxylin–eosin. For each fragment, five tissue sections were observed under a microscope.

During the first year of the study (1997–1998), water temperature, salinity and dissolved oxygen were measured monthly every 0.5-m depth, using a multi-parameter probe (Idronaut Ocean Seven 501). Water movement was measured by a currentometer (RCM9, Aanderaa Instruments, Norway) positioned at 26-m depth for 2 months (5856 measurements were collected).

3. Results

In the study area, the average monthly temperature of the water column (from the surface to 30-m depth), the salinity and the dissolved oxygen showed the typical seasonal pattern of Mediterranean temperate offshore waters. Temperature variations were from 11.9 (February) to 26 °C (August) (Fig. 3). Generally, a homeothermic condition was found in the water column, except during August–September when differences of about 4 °C occurred from the surface to the bottom. The salinity showed low fluctuations (range: 37.9–38.4 ppt in November and March–April, respectively), while high oxygen concentrations were recorded, from 7.1 in September to 9.4 ppm in May (Fig. 3). In general, the differences in the water column were not higher than 1 ppm.

The main current showed a preferential NW–SE direction and a sustained hydrodynamic circulation with a speed often from 10–12 cm s^{-1} (range: 2–16 cm s^{-1}).

The wave dynamics did not represent a limitation for either culture system because the rearing structures were sufficiently elastic and placed under the wave breakdown zone (up to 10 m from the surface).

In these environmental conditions, a better growth performance was generally recorded from the vertical structures (Fig. 4). However, the average weight and the specific growth

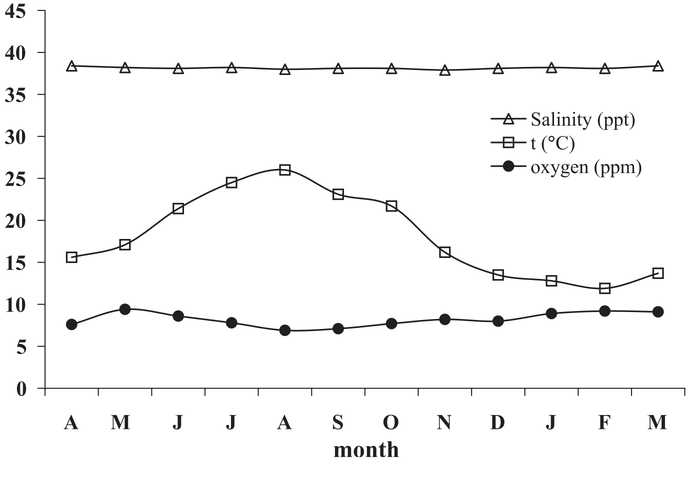

Fig. 3. Seasonal variations of temperature, salinity and dissolved oxygen in the study area (the reported values were averaged on the water column).

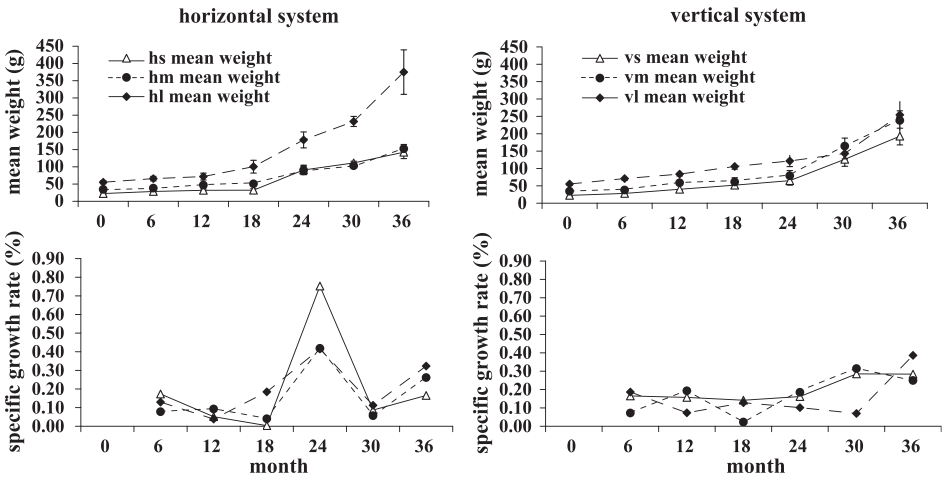

Fig. 4. Growth performance (mean weight in grams and specific growth rate in percentage) of *S. officinalis* cuttings (small, medium and large) by cultivation system (hs = horizontal small; hm = horizontal medium; hl = horizontal large; vs = vertical small; vm = vertical medium; vl = vertical large).

rate did not significantly vary (Friedman test: $\chi^2_{F(df=5)} = 1.91$; $p > 0.05$) between the cultivation systems. In addition, no statistical difference in growth was detected between the cuttings with different initial size.

The data were thus pooled (Fig. 5) and the following growth curve was estimated: $y = 35.441 \times e^{0.0015x}$ ($R^2 = 0.97$; Fig. 6), also using additional information available for the 4th year. The relationship between the weight at any two consecutive times was linear according to the following equation: $W_{t_2} = 0.9923 \times W_{t_1}^{1.068}$.

The relationship between diameter (D) and wet weight (WW) was exponential, describing an allometric growth in weight ($\mathrm{WW} = 1.4188 \times D^{2.06}$) with a significant correlation coefficient ($p < 0.05$). At the end of the rearing experiments, the harvested sponges, despite the initial very irregular shape of the cuttings (Fig. 2C), were characterised by a rounded and regular profile (Fig. 2D), without the typical protuberances of the wild specimens.

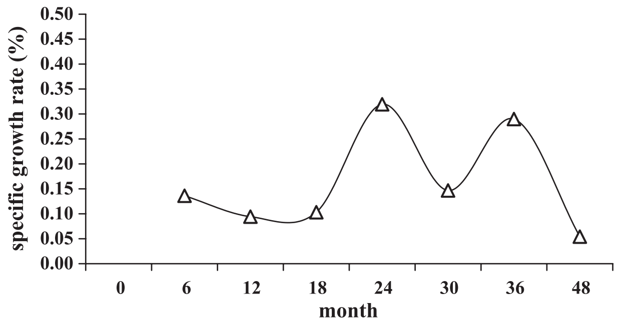

Fig. 5. Growth performance (specific growth rate in percentage) of *S. officinalis* cuttings: pooled data.

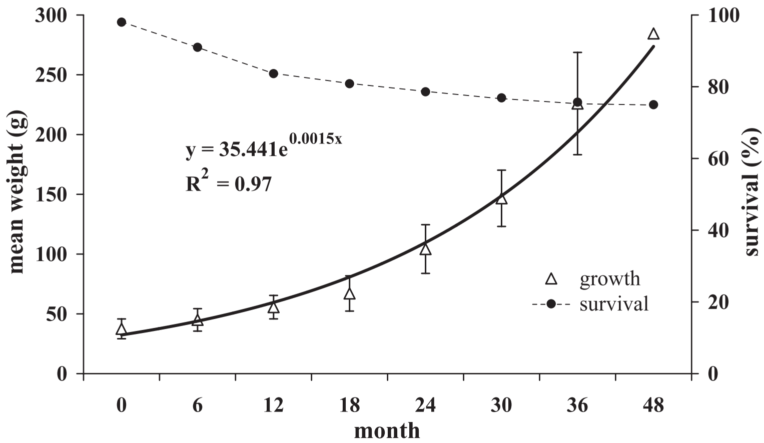

Fig. 6. Growth curve and survival rate of *S. officinalis*.

The occurrence of a seasonal effect on specific growth rates was tested by comparing the pooled time series of summer/autumn with that of winter/spring. The average spring SGR (0.24) was higher than the autumn one (0.13) (Fig. 7), though no significant difference was found (p>0.05).

The survival rate, also including additional information available for the 4th year, was 75%, with a more apparent decrease during the first year (Fig. 6).

During the study period, embryos and larvae were found in the mesohyl of the sponge cuttings in January 1998 (18.5% of the sample) for the first year; in October 1998 and January 1999 (5.4% and 8.1% of the sample, respectively) for the second year, and in April 1999 (15.1%) for the third year of study. Thus, relatively more intense reproductive activity was registered during the cold season.

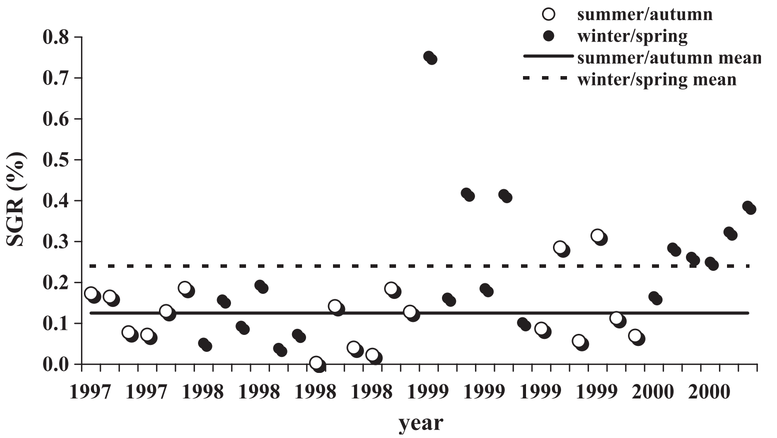

Fig. 7. Seasonal variations of growth (SGR) between pooled time series of *S. officinalis* cuttings.

4. Discussion

The study was carried out in a coastal site well known for the richness of Porifera, and particularly of the bath sponge *S. officinalis* var. *adriatica* (Pronzato et al., 1996; Corriero et al., in press). This richness might be related to the high productivity of the Gulf of Taranto, due to the inflow of nutrient-rich South Adriatic waters, especially during winter. These environmental characteristics might have played a role in influencing the slightly better growth performance, although not statistically significant, observed in spring during this study. Seasonal growth differences, frequently reported for sponges (Stone, 1970; Reiswig, 1973; Elvin, 1976; Johnson, 1979), may be related to different prey availability affecting the food uptake of sponges, as observed for a Mediterranean population of *Dysidea avara* (Ribes et al., 1999).

Sexual reproduction does not seem to have influenced growth performance. Reproductive explants occurred almost all year round, with the exception of summer, thus confirming the prolonged sexual phase of this species (Scalera Liaci et al., 1971).

The sustained local current regime as measured during this study and the hydrodynamism of the area in general probably generate a rather homogeneous availability of food in the water column, making the growth obtained in the horizontal and vertical rearing structures comparable.

The statistical approach applied in the present study also showed similar growth performance between the experiments, independently of the initial size of the explants. This outcome is in contrast with previous experiences of sponge cultivation performed in the Mediterranean (Moore, 1910), which reported that smaller explants of *S. officinalis* grew more rapidly than larger ones. However, the initial experimental conditions experienced by Buccich (Moore, 1910) could have been different and the analysis of results is not strictly based on a formal quantitative approach.

The mean growth observed in this study was rather variable among sponge cuttings, even considering the same rearing condition and size range. This may be due to the fact that cuttings were obtained from specimens of presumably different age. According to the literature, growth rates of sponges may be greater in younger than in older specimens (Reiswig, 1973). In addition, Verdenal and Vacelet (1990) report a certain degree of growth variability among cuttings of *S. officinalis* var. *adriatica* obtained from the same specimen.

The commercial size of natural bath sponges commonly starts from about 10 cm in diameter (Verdenal and Verdenal, 1987; Grovas, 1998). According to the diameter/weight relationship reported above, such a size corresponds to about 200 g of wet weight, a weight which cuttings of about 55 g reach in 3 years. Thus, this initial size seems the most suitable for cultivation purposes as it reduces the rearing time. Smaller cuttings resulted in lighter sponges (only about 100 g) after 3 years. However, the eventual choice of different initial cutting sizes will depend on a trade-off between several factors, such as the availability of seed, the rearing time up to the commercial size and the total amount of planned production.

The final shape of the cuttings was mainly rounded, lacking the usual lobes and irregularities, the latter caused by the adhesion to the substrate in natural specimens. In addition, the skeleton of the sponges we got showed a more homogeneous texture and size (diameter) of the fibres, due to the scarcity of primary traits of spongin (Corriero et al., unpublished data). The growth, measured in this study as specific growth rate, assuming an exponential growth pattern in the examined period, showed performances comparable to the experiences of Verdenal and Vacelet (1990) for the Mediterranean. Conversely, the growth rate of *S. officinalis* var. *adriatica* was slower than that reported for the Caribbean species (Grovas, 1998).

The obtained survival rate showed a more critical phase during the first year, although the mortality was generally lower in comparison to the data reported by Verdenal and Vacelet (1990) for the Mediterranean *S. officinalis*. During this phase, two main factors were acting on the recovery capability of the sponge cuttings, the first related to the manipulation (collection, cutting, and sewing) and the second to the cicatrisation process of tissue around the nylon ropes. Subsequently, additional but lower mortality occurred as a result of competition with fouling organisms (i.e. *Mytilus galloprovincialis, Ostrea edulis, Sabella spallanzanii* and colonial ascidians) whose larvae can settle near the exposed skeletal tissue emerging from the area of the cutting subjected to abrasion by the nylon rope. In contrast, the epibiontic frondose species of Hydrozoa and Bryozoa did not seem to affect survival of cuttings.

Finally, both the horizontal and vertical systems proved to be resistant to deterioration due to water movement as well as to other ecological factors. Indeed, the wave dynamics do not represent a limitation if the rearing structures are placed under the wave breakdown zone (up to 10-m depth from the surface). In the local conditions and during the experienced time of rearing, fouling did not damage the submerged structures. Thus, the choice of the most suitable system can mainly rely upon considerations related to space availability and local hydrodynamic regime.

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