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Research Article

Sponge Farming Trials: Survival, Attachment, and Growth of Two Indo-Pacific Sponges, *Neopetrosia* sp. and *Stylissa massa*

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Sponges, an important part of the reef ecosystem, are of commercial value for public aquaria, pharmacology and chemistry. With the growing demand for sponges, natural resources are at risk of being overexploited. Growing of sponges in artificial or semi natural farms is an alternative. In this study different farming methods were tested on two Indo-Pacific sponge species, *Neopetrosia* sp. and *Stylissa massa*. Survival, growth and attachment ability were observed with different substrates (suspended ropes, coral boulders and artificial substrate), two types of aquaria with different water volume and two different field sites in Indonesia. The two species responded differently to their individual locations and environmental stresses. Survival, growth and attachment rates of *Neopetrosia* sp. at the field site are depending on the cultivation method, we found highest volume increment (27–35%) for a horizontal line in the field. Whereas the volume increase for *S. massa* did not show any differences for the different transplantation methods, *Neopetrosia* sp. generally showed higher rates than *S. massa*. Further aquaria experiments, for example, on nutrient supply, should be tested to receive more detailed data about sponges, particularly because almost all fragments of both species showed a decline or steady state in mean length.

1. Introduction

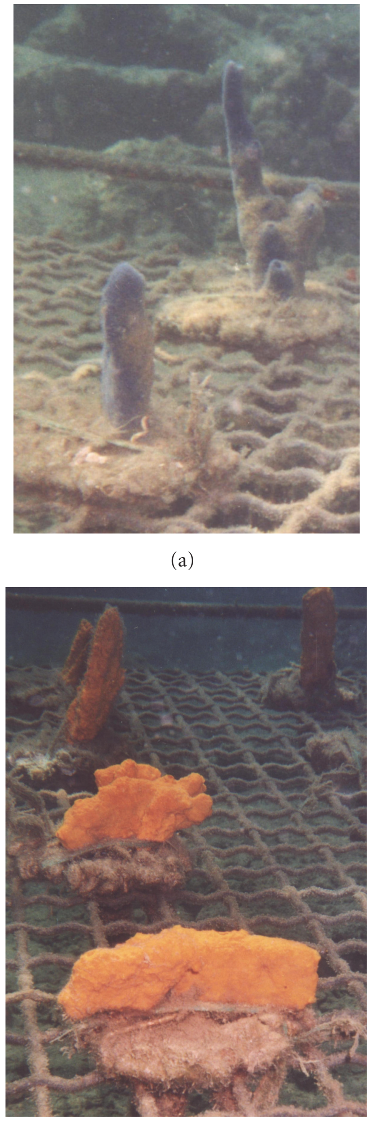
As filtering organisms, sponges play an important role in reef ecosystems. Like other benthic suspension feeders, they are responsible for a large share of the energy flow from the pelagic to the benthic system [1, 2]. Sponges actively move water through their body, an advantage that enables sponges to inhabit different types of habitats also at different depths [1]. Sponges were used successfully for reef rehabilitation because of their ability to clean water by filtering small particles like detritus, algae, and bacteria, and they also hold rubble and corals together [3, 4]. Sponges are also commercially important for farming (bath sponge) and ornamental trade and as a new resource of chemicals for pharmacology [5–9].

Sponges are very effective active filter feeders. The volume of water passing through a sponge can be enormous; a sponge with 10 cm in length and four cm in diameter can filter 80 L water in 24 h [10]. Due to that sponge farms are tested for their potential as biofilters near fish farms or land-based sewage water [9].

Their ability to reproduce from small pieces makes sponges very attractive for commercial farming [11, 12]. Sponges with symbiotic relationships are of high interest for public aquaria because they are more colourful, less expensive to keep, and easier to sell than asymbiotic species [11]. Some sponge species have symbionts supplying the host with nutrients and need less additional feeding [13]. In the last 20 years numerous bioactive metabolites synthesized by symbiotic microorganisms in sponges have been extracted and identified [9]. Bioactive substances in some sponges have potential uses in medicines, bactericides, pesticides, cosmetics, fungicides and antifoulings [11, 14]. Aldisine alkaloids, discovered in *S. massa*, were shown to be a potent inhibitor of mitogen-activated protein kinase kinase-1 that can inhibit the growth of certain tumor cells [15]. Peptides from a sponge in Papua New Guinea (*Neopetrosia* sp.) can inhibit amoeboid invasion by human tumor cells [16].

Sponges usually only produce trace amounts of the bioactive compound; therefore large-scale production from aquaculture is necessary to avoid overexploitation of the native stock [6, 17]. Several studies have examined the best growing methods for certain sponge species. MacMillan [12] and Corriero et al. [5] suggest attaching sponge fragments to horizontal lines, while Page et al. [18] tried mesh arrays and Duckworth and Battershill [19] favoured the use of mesh bags after they tried to grow different New Zealand sponge species (*Latrunculia* sp. nov, *Polymastia croceus,* and *Raspailia agminata*) on ropes and in mesh bags.

This study compares growth, survival, and attachment rates of two Indo-Pacific sponge species, *Neopetrosia* sp. and *S. massa*, on three different substrates: horizontal rope (as suggested by MacMillan [12]), live rock, and artificial substrate (cement plate) placed on a metal grid. The experiment was carried out in Indonesia for five months (November 2002 to March 2003) to determine a suitable method and site for culturing selected species, with the hope of using it for reef rehabilitation and/or for export trade to public aquaria. Because little is known about most sponge species and farming methods are often species specific [20], this study will also contribute to a better understanding of sponge survival, attachment, and growth performance of the selected species.



(a)

(b)

Figure 1: *Neopetrosia* sp. (a) and *Stylissa massa* (b) fragments attached to the artificial substrate and placed on a metal grid at Teluk Pegametan.

2. Material and Methods

2.1. Sponge Species. Neopetrosia sp. (de Laubenfels 1949) is a hard blue sponge with a rough porous surface [21] (Figure 1). It has a branching growth form with more than one osculum per branch. It can grow from 10 to 20 cm in length and two to four cm in diameter [21].

Stylissa massa (Carter 1881) is a soft yellow sponge, ranging in size from 7 to 20 cm in length and 5 to 11 cm in diameter [21] (Figure 1). It has an irregular but vertically extending growth form, which narrows to the attachment surface and several oscula are distributed irregularly over the sponge body.

2.2. Sampling and Study Sites

Pulau Pari—Sampling and Study Site 1. Pulau Pari is an island located in the Thousand Island reef complex north of Jakarta, the capital of Indonesia. The sampling and study site (5°51′55′′S, 106°36′18′′E) was located in the sandy lagoon of Western Pulau Pari, at a depth of 2.5 m and about 200 m from the main island (Figure 2). 24 donor sponges of *S. massa* with a length of 10 to 20 cm were collected in the lagoon and on the reef flat at a depth between 0.5 and two meters during low tide. These specimens were growing in the sandy bottom of the transition zone between sea grass and the outer reef as well as on coral boulders in the sandy lagoon. At this site survival, growth and attachment only of *S. massa* fragments on horizontal ropes and live rock were tested (Table 1).

Teluk Pegametan—Sampling and Study Site 2. Bali is one of the bigger islands of Indonesia (140 by 80 km) and located eight degrees south of the equator. The sampling and study site (8°08′12′′S, 114°36′E) was located in the Bay Teluk Pegametan in the north of Bali, on one of the sandy reef flats at a depth of 2.5 m at low tide and about 750 m from the mainland (Figure 3). 50 donor sponges of *Neopetrosia* sp. and 41 of *S. massa* with a length of 10 to 20 cm were collected at the same depth as in Pulau Pari. *S. massa* was found growing on coral boulders while *Neopetrosia* sp. was more often found on live corals.

Two types of aquaria were used, a glass tank and a cement tank. The glass tanks, located at CV. Dinar Goris, Northern Bali, were 80 cm in length, 40 cm high, and 25 cm deep. The cement tank was 2400 cm in length, 70 cm high, and 140 cm deep with a water depth of 40 cm. Both types of aquaria were supplied daily with seawater from the Bay Teluk Pegametan, five km from the facility. The seawater was filtered through a

Table 1: List of application methods of fragments at the different study sites associated with the number of transplants and the days of culture.

Species	Place	Field/aquaria	Attachment method	Cutting method	No. of transplants	Days in culture
Neopetrosia sp.	Field	TP	HL (t/m/b)	HC	36 (12/12/12)	108
Neopetrosia sp.	Field	TP	LR	HC	12	108
Neopetrosia sp.	Field	TP	AS	HC	12	83
Neopetrosia sp.	Aquaria	GT	HL	HC	24	107
Neopetrosia sp.	Aquaria	GT	LR	HC	24	107
Neopetrosia sp.	Aquaria	CT	AS	HC	12	45
S. massa	Field	PP	HL (t/m/b)	HC/VC	18/18 (6/6/6)	131
S. massa	Field	PP	LR	HC/VC	6/6	131
S. massa	Field	TP	HL (t/m/b)	HC/VC	18/18 (6/6/6)	108
S. massa	Field	TP	LR	HC/VC	6/6	108
S. massa	Field	TP	AS	HC/VC	6/6	83
S. massa	Aquaria	GT	HL	HC/VC	12/12	107
S. massa	Aquaria	GT	LR	HC/VC	12/12	107
S. massa	Aquaria	CT	AS	HC/VC	6/6	45

TP: Teluk Pegametan, PP: Pulau Pari, GT: glass tank, CT: cement tank, HL (t/m/b): horizontal line (top/middle/bottom), LR: live rock, AS: artificial substrate, HC: horizontally cut, and VC: vertically cut.

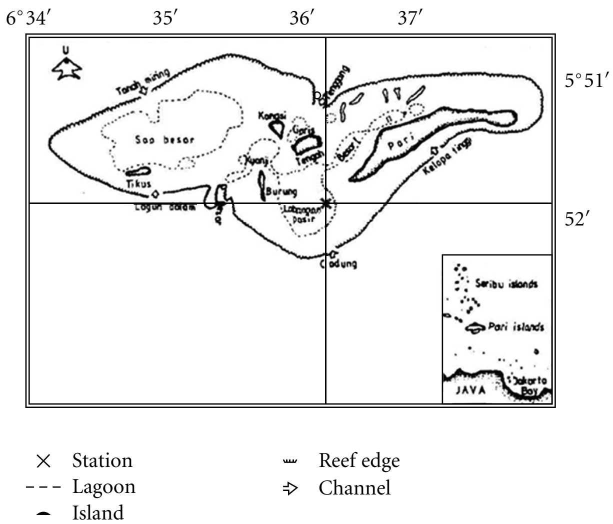


Figure 2: Map of Pulau Pari, Thousand Islands, North of Jakarta [30] the X marks the study site.

biological filter consisting of coral boulders. No additional nutrients were added to the aquarium seawater. A roof protected the aquaria from rainfall and solar radiation.

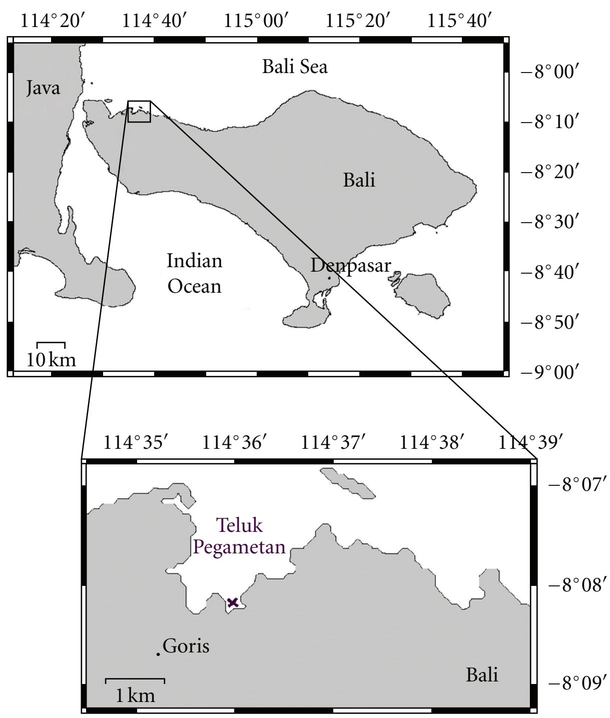


Figure 3: Map of the sampling and study site (X) at Teluk Pegametan, Northern Bali [31].

2.3. Substrata and Attachment Methods

Neopetrosia sp. The fragmentation of *Neopetrosia* sp. was always done in the same way by cutting horizontally to provide fragments of approximately equal size. Before the fragments were attached, the length and diameter of *Neopetrosia* sp. fragments were measured with a plastic calliper.

Stylissa massa. The fragmentation of *S. massa* was done in two different ways; half of the collected sponges were cut horizontally, the other half vertically. The fragments were approximately of equal size. Before the fragments were attached, the length, diameter, and cutting width of *S. massa* were measured with a plastic calliper.

Nine specimens of each species were left uncut as controls; three of each were placed in the field (Teluk Pegametan), glas and cement tank.

Three horizontal nylon ropes (Ø = 0.7 cm) with the same length (120 cm) were tied on each end at two bamboo sticks (length = 130 cm, Ø = 4 to 5 cm) that were fixed on the seabed. The three horizontal nylon ropes were tied to the sticks at different depths, the first rope started 30 cm above the sea bottom and the next two ropes followed every 30 cm. Twelve sponge fragments were tied to the rope with cable ties, four in each line (Figure 4, Table 1). To prevent shifting of the fragments every cable tie was tied to the nylon rope with a plastic ribbon.

Two horizontal ropes were placed parallel in one aquarium. Four sponge fragments of each of the two species were placed on each of the horizontal ropes in the same way as in the field (Table 1).

Four sponge fragments of each of the two species were attached to coral boulders by using toothpicks and elastics (Figure 4, Table 1). The toothpick was pushed through the fragment, placed on the boulder, and tied to it with elastics. In the aquaria eight sponge fragments of each of the two species on coral boulders were placed in two parallel lines.

In the field, four sponge fragments were tied on artificial substrates (round plates, made of pebbles and cement) in the same way as on coral boulders and placed on a metal grid (200 × 100 × 50 cm) that was set on the sea bottom (Figure 5, Table 1).

In the cement tank the four sponge fragments on artificial substrates were placed on the bottom (Table 1).

Three replicates were used for each method, both in the aquaria and at the field sites.

2.4. Abiotic Factors. Temperature, salinity, pH, and dissolved oxygen were measured with a WTW MultiLine P4 set (conductivity cell, pH combined electrode, D.O. probe) and turbidity with a turbidity meter (Lovibond). Ammonium, carbonate, and nitrite content were measured with a standard test from Merck (Merck KGaA, Darmstadt). Surface currents were measured in the field by recording the time required for an object to float a distance of 6 m.

2.5. Analyses of Data. Growth was expressed in an increase in volume; therefore, length, diameter and cutting width (cutting width only for *Stylissa massa*) of the fragments were measured with a plastic calliper every two weeks when visiting the sites at Teluk Pegametan and Goris, Northern Bali, and every two months at the site Pulau Pari.

For both species the volume was calculated with the following factors and formulas:

for *Neopetrosia* sp.:

$$V = \frac{1}{3} * \pi * l * r^2 \quad (1)$$

(l = length, r = radius of the fragment),

for *S. massa*:

$$V = l * d * w \quad (2)$$

(l = length, d = diameter, w = width of the fragment).

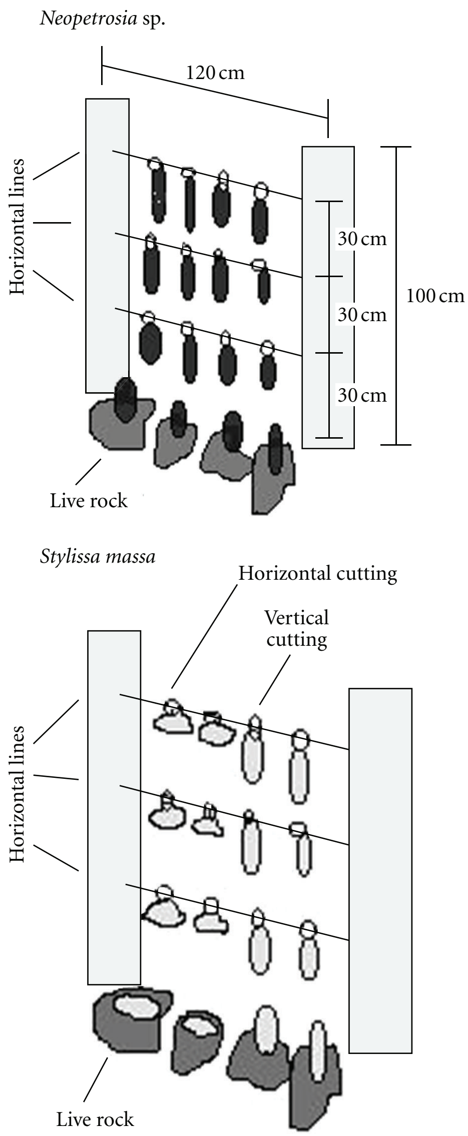


Figure 4: A scheme of *Neopetrosia sp*. (top) and *S. massa* (down) fragments on horizontal lines and live rock at the field sites.

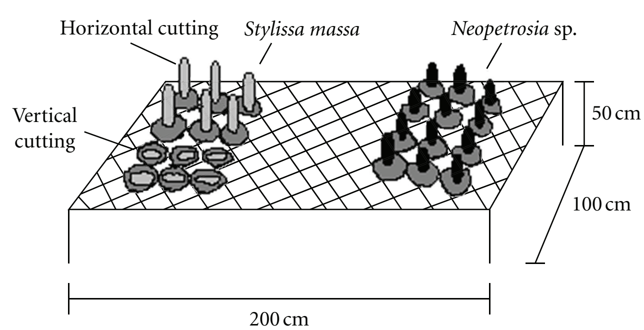


Figure 5: A scheme of *Neopetrosia sp*. (right) and *S. massa* (left) fragments on artificial substrate, placed on a metal grid at the field site Teluk Pegametan.

Table 2: Mean initial and end values of length and volume of fragments at the different sites for all methods.

Species	Place	Mean initial length [cm]	Mean end length [cm]	Mean initial volume [cm^3]	Mean end volume [cm^3]
Neopetrosia sp.	Field	5.9	10.8	10.8	48.3
Neopetrosia sp.	Aquaria	4.2	3.7	9.3	8.3
Stylissa massa	Field TP HC	7.1	8.2	39.7	95.4
Stylissa massa	Field TP VC	8.4	9.3	43.5	94
Stylissa massa	Field PP HC	5.9	5.6	40.9	37.1
Stylissa massa	Field PP VC	7.2	7.7	46.1	53.6
Stylissa massa	Aquaria HC	6.2	4.7	37.6	38.9
Stylissa massa	Aquaria VC	7.2	6.1	39.5	40.2

TP: Teluk Pegametan, PP: Pulau Pari, HC: horizontally cut, and VC: vertically cut.

In addition, every time visiting the study site, the following state of the fragments was considered: alive, partly dead, dead, damaged, fretted, covered with sediment, overgrown by, for example, fouling organisms, and attached to the substrates. The survival (S) and attachment (A) rate of *S. massa* and *Neopetrosia* sp. was calculated as the percentage of the number of fragments being alive and accordingly attached at the beginning of the study (N_0) divided by the fragments left in the end of the study (N_E):

$$S = \frac{N_E}{N_0} \times 100,$$
$$A = \frac{N_E}{N_0} \times 100. \quad (3)$$

To calculate the mean percentage growth (V) of fragments, the following formula was used, where N_0 is the initial volume and N_E is the volume of fragments in the end of the study period:

$$V = \frac{(N_E - N_0)}{N_0} \times 100. \quad (4)$$

Before starting statistical analysis, the homogeneity of variances of the different variables (species, places, methods, and cutting method) was tested with Levene's test. It was decisive for the statistical analysis method.

To identify significant differences in monthly length and volume growth between the different species, places, methods, and in case of *S. massa* different ways of cutting (horizontal cuttings and vertical cuttings) a t-test for independent samples with separate variance estimates was done with Statistica-Student Version (Version'99).

3. Results

3.1. Growth Rates. The experiment started in the field at Pulau Pari on 2 November 2002, at Teluk Pegametan, in the glass tanks at Goris in the facility of CV. Dinar on 3 December 2002, in the field at Teluk Pegametan with the artificial substrate on 28 December 2002 and on 03 February 2003 with the artificial substrate in the cement tank. The last measurement of sponge fragments at Pulau Pari took place on 12 March 2003 and at Teluk Pegametan on 20 March 2003. In Table 1 the days of culture and number of fragments associated with the tested methods at the different study sites are listed.

In Table 2 mean initial and end values of length and volume are compared for the two species *Neopetrosia* sp. and *S. massa*, from aquaria and field sites and for *S. massa* between horizontal and vertical cuttings.

3.1.1. Mean Length and Volume Increase at the Field Sites Teluk Pegametan and Pulau Pari

Neopetrosia sp. Neopetrosia sp. fragments grew better on horizontal ropes. Mean length increase for all three transplantation methods was significantly different ($P = 0.02$), as was mean volume increase on horizontal rope and live rock or live rock and artificial substrate ($P = 0.002$).

Stylissa massa. At both field sites (Teluk Pegametan and Pulau Pari) *S. massa* fragments did not show any significant differences for mean length and volume increase for the different transplantation methods (horizontal rope, coral boulders, and artificial substrate) or for the different cutting methods (horizontal and vertical way of cutting) (Figures 6(b) and 6(c)), but fragments on horizontal ropes and coral boulders at Pulau Pari showed significant differences in both mean length and volume increment ($P = 0.001$). On horizontal ropes those fragments grew better. When comparing the two field sites, fragments at Teluk Pegametan showed higher mean length ($P = 0.02$) and volume ($P = 0.01$) increase than those at Pulau Pari.

S. massa fragments on horizontal ropes at Pulau Pari showed an initial decline in mean length and volume at the second measuring interval (after one week) before they finally started to grow.

For both mean volume and length increase *S. massa* and *Neopetrosia* sp. fragments on the individual depths of the horizontal ropes did not show any significant differences.

Comparing mean length and volume increase at the field sites, the two species *S. massa* and *Neopetrosia* sp. showed significant differences in mean length ($P = 0.001$) and volume ($P = 0.01$) increase, *Neopetrosia* sp. fragments grew faster.

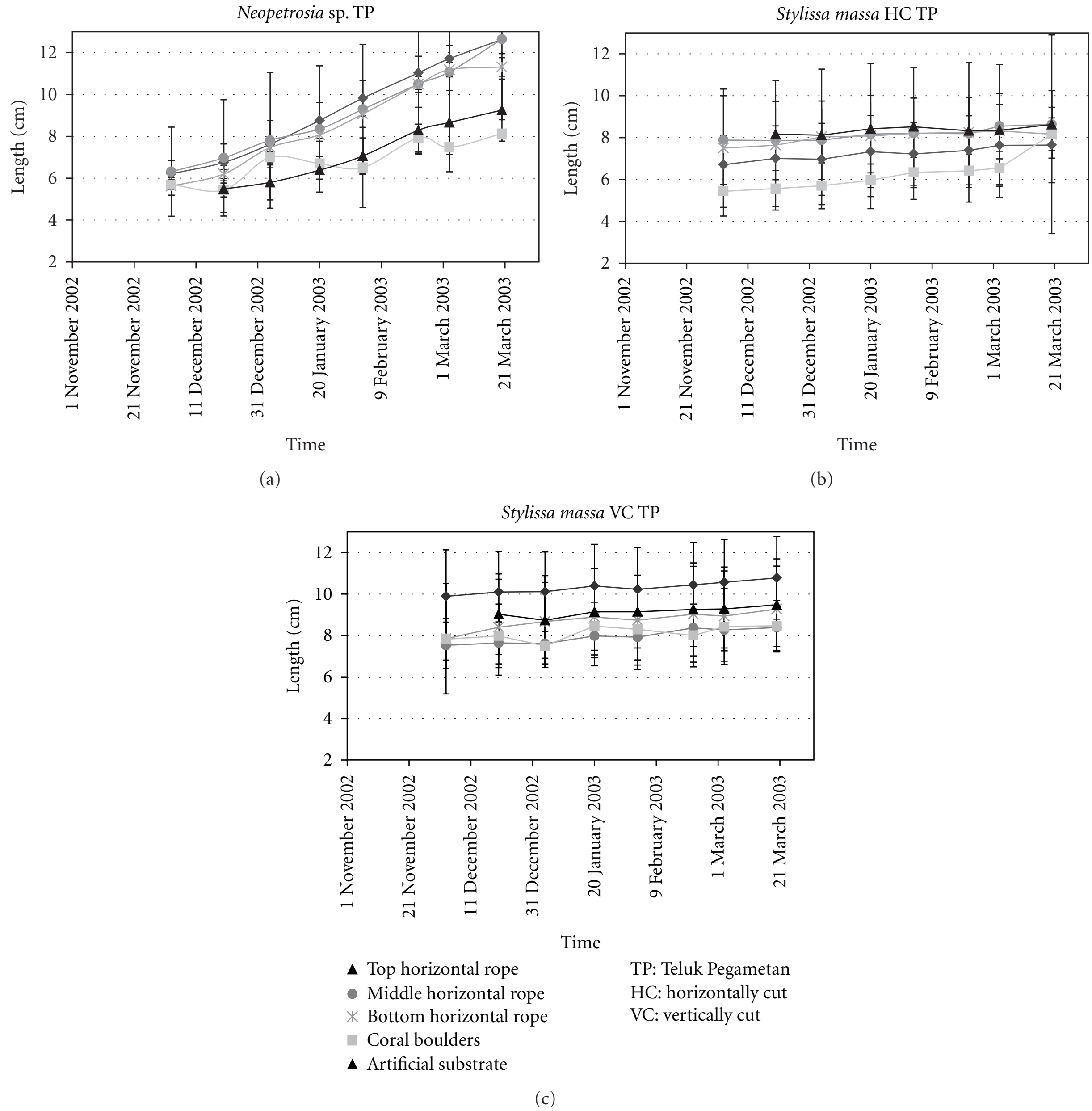


Figure 6: Fragments mean length at the field sites for different attachment methods and different places.

3.1.2. Mean Length and Volume Increase in the Aquaria. In the aquaria the fragments of both species showed a decline or steady state in mean length, except fragments of *S. massa* on artificial substrate in the big tank.

Neopetrosia sp. fragments were significantly different ($P = 0.01$) in mean length for all three transplantation methods, horizontal rope and coral boulders, horizontal rope and artificial substrate and coral boulders and artificial substrate and in mean volume increase only for fragments on horizontal ropes and coral boulders. The fragments of *Neopetrosia* sp. on horizontal ropes developed small tentacle-like branches on top of the fragments in horizontal directions.

The mean length and volume increase differed greatly between the study sites. Significant differences ($P = 0.001$) in mean length and volume increase were determined for *Neopetrosia* sp. fragments between field Teluk Pegametan and aquaria and *S. massa* fragments between Teluk Pegametan and Pulau Pari, whereas a significant difference was found in mean length increase between Teluk Pegametan and aquaria and in mean volume increase between Pulau Pari and aquaria (Figure 7).

In general, *Neopetrosia* sp. and *S. massa* fragments showed significant differences in mean length, but not in volume increase.

Table 3: Mean values for abiotic factors.

Abiotic factors	Teluk Pegametan	Pulau Pari	Glass tank	Cement tank
Salinity	33.52 (±0.09)	33.23 (±0.09)	39.17 (±2.5)	36.2 (±1.02)
Oxygen [%]	94.59 (±0.9)	102.25 (±1.5)	98.84 (±1.6)	102.62 (±4.24)
Oxygen [mg/L]	5.97 (±0.07)	6.47 (±0.13)	6.39 (±0.1)	6.7 (±0.29)
pH	8.15 (±0.02)	8.10 (±0.04)	8.23 (±0.07)	8.36 (±0.06)
Turbidity [NTU/FNU]	0.71 (±0.07)	0.50 (±0.3)	0.43 (±0.1)	X
Temperature [°C]	29 (±0.15)	30 (±0.7)	28 (±0.05)	27.6 (±0.30)
Ammonium [mg/L NH_4^+]	0.1	X	0	0.1
Nitrite [mg/L NO_2^-]	0	X	0	0
Hardness [°d]	8	X	10	10

Standard deviation in brackets; X: no measurements.

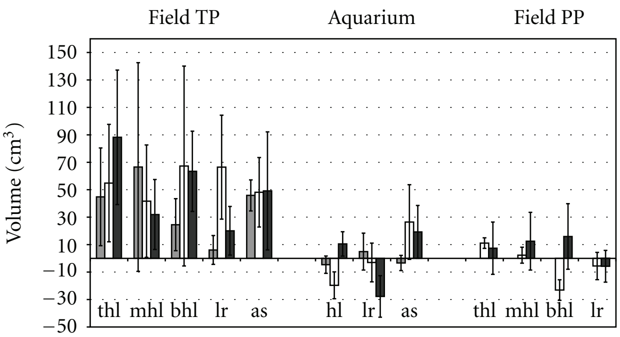


Figure 7: Mean final growth rate (percentage end volume of initial volume) for different methods. Error bars represent the standard deviation between fragments of specific methods (grey: *Neopetrosia* sp., white: horizontally cut *Stylissa massa*, black: vertically cut *Stylissa massa*, TP: Teluk Pegametan, PP: Pulau Pari, thl: top horizontal rope, mhl: middle horizontal rope, bhl: bottom horizontal rope, lr: coral boulders, as: artificial substrate, and hl: horizontal rope).

3.1.3. Mean Final Growth, Survival, and Attachment Rates. Similar results for mean length and volume increase were found in mean final growth rates (end volume minus initial volume) (Figure 7).

As shown in Figure 8, no significant differences for final survival and attachment were calculated between fragments of *Neopetrosia* sp. and *S. massa*. In the field Teluk Pegametan *Neopetrosia* sp. fragments on horizontal ropes and artificial substrate showed the highest final survival and attachment rates, but only one of 12 fragments on coral boulders survived (Figure 8(a)). In the case of *S. massa* the horizontal cuttings showed higher survival and attachment rates than the vertical cuttings for coral boulders and artificial substrate, while vertical cuttings survived and attached more easily on the horizontal ropes (Figures 8(b) and 8(c)).

For both species, the survival and attachment rates of fragments on the artificial substrate at the field site Teluk Pegametan and in the aquaria were highest at 100%, with the exception of 50% attachment of *Neopetrosia* sp. fragments in the big tank.

The mean final survival rates for horizontal ropes and coral boulders in the aquaria for both species were very low, zero percent for *Neopetrosia* sp. fragments and vertical cuttings of *S. massa* on coral boulders and horizontal cuttings of *S. massa* on horizontal ropes, 21% of *Neopetrosia* sp. and 12.5% of horizontally cut *S. massa* fragments on coral boulders, 8% vertically cut on horizontal ropes survived. Almost all fragments of *S. massa* (horizontal ropes: 50% for horizontal cuttings, 92% for vertical cuttings; coral boulders: 58% for horizontal cuttings, 83% for vertical cuttings) in the aquaria which did not survive until the final checking were already dead two weeks after the installation; in the case of *Neopetrosia* sp. fragments, 58% were dead one month after installation.

Although *Neopetrosia* sp. and *S. massa* fragments did not show significant differences in survival and attachment, it is obvious that almost all fragments of *Neopetrosia* sp. which survived attached well.

Already two weeks after *Neopetrosia* sp. fragments were placed on horizontal ropes, coral boulders, and artificial substrates in the field, all of them did attach. In contrast, *S. massa* fragments did not attach as easily.

One month after starting the experiments, 30 of 33 remaining *Neopetrosia* sp. fragments started to encrust the cable ties, attaching them to the horizontal ropes. After encrusting the cable ties, those fragments started to close the gap between them and the encrusted cable tie, while they were also starting to grow vertically towards the horizontal rope. The first two of 36 fragments reached the rope already two weeks after installation. At the end of the study, after 108 days, all 33 remaining fragments had closed the space between fragment and cable tie and 30 of 33 had attached to the rope, eight of them already grew along the rope and 20 above it.

One month after starting the experiments, eight of 12 *Neopetrosia* sp. fragments on artificial substrates at Teluk Pegametan started to encrust their substrate. After two months all of the 12 fragments had already encrusted parts of the artificial substrate.

3.2. Abiotic Factors. As seen in Table 3 salinity, oxygen, pH, turbidity, and temperature for the four different study sites did not vary significantly at the different measuring times. Even daily profiles did not show a great difference between the values. The aquaria showed a higher mean salinity value

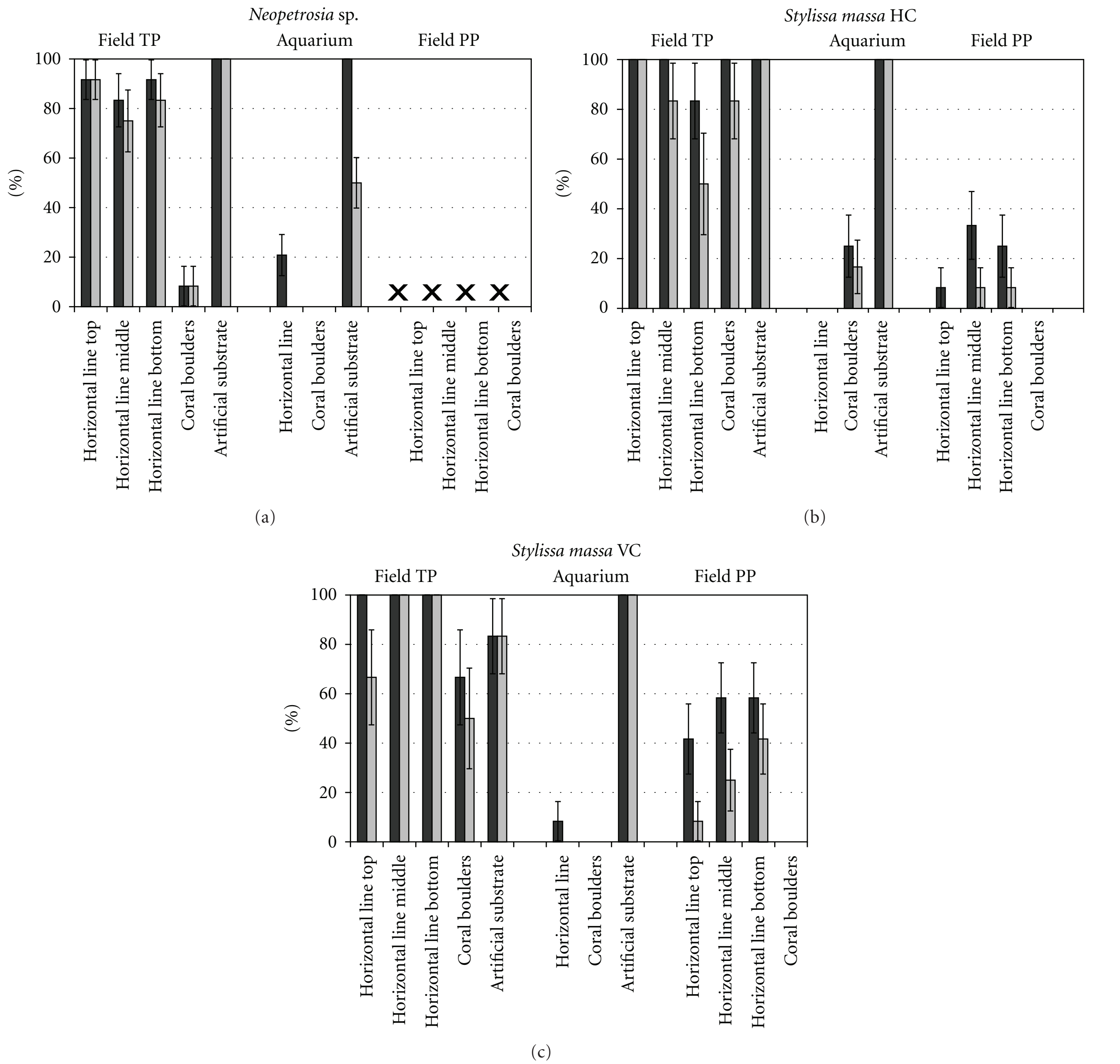


Figure 8: Mean final percentage survival and attachment in the end of the study for different methods. Error bars represent the standard deviation between fragments of specific methods. (X: no fragments were planted, TP: Teluk Pegametan, PP: Pulau Pari, HC: horizontally cut, VC: vertically cut, thl: top horizontal rope, mhl: middle horizontal rope, bhl: bottom horizontal rope, lr: coral boulders, as: artificial substrate, and hl: horizontal rope).

than the field sites, possibly due to evaporation. Ammonium, nitrite, and carbon hardness were very low (<0.1). The only difference between the two types of aquaria was the volume of water, glass tank 80 L and cement tank 23,520 L. The surface currents for both field locations were between 0.07 and 0.075 m/s (highest 0.12, lowest 0.048). Stormy conditions were observed at Pulau Pari in December 2002 and January 2003.

4. Discussion

4.1. Growth, Attachment, and Survival Rates at the Field Sites. Growth experiments in this study tested farming methods on two sponge species, *Neopetrosia* sp. and *S. massa*. The growth behaviour of most sponge species is poorly understood; this study helps to contribute to a better understanding of sponge biology and also to provide information on suitable ways to reproduce sponges for reef rehabilitation, the aquarium trade, and biomedical research. In other studies, sponge farming experiments were conducted to produce bath sponges for cosmetic interest [5, 9, 22] or to receive bioactive metabolites [6, 8, 9, 18].

The horizontal rope method and artificial substrates in the field Teluk Pegametan were shown to be the best method for growth, attachment, and survival rates of *Neopetrosia*

Table 4: Mean percentage growth rates per month [%].

Method	*Neopetrosia* sp.	*S. massa*	*Hippo spongia lachne* [32]	*Dysidea avara* [6]	*Latrunculia welling-tonensis* [17]	*Polymastia croceus* [17]	*Hippo spongia* and *Spongia* spp. [33]	*Mycale hentscheli* [18]
HL-field	106 TP	34 TP	X	7	58	30	X	X
LR-field	12 TP	27 TP	X	X	X	X	X	X
AS-field	122 TP	31 TP	∼13	X	X	X	∼8	X
mesh arrays	X	X	X	28	23	11	X	409
HL-aquaria	−13 GT	−4	X	X	X	X	X	X
LR-aquaria	16 GT	−11	X	X	X	X	X	X
AS-aquaria	−7 CT	10	X	X	X	X	X	X

TP: Teluk Pegametan, GT: glass tank, CT: cement tank, HL (t/m/b): horizontal line (top/middle/bottom), LR: live rock, AS: artificial substrate, HC: horizontally cut, and VC: vertically cut.

sp. For *S. massa* all three methods (horizontal lines, coral boulders, and artificial substrate) have almost equal growth rates. The horizontal rope method was already successfully tested by de Voogd [8] on *Callyspongia biru*, an encrusting sponge, and for bath sponges by Corriero et al. [5] and Çelik et al. [22].

The success of farming sponges requires the knowledge of the optimal environmental conditions of the cultured sponge species [9]. The position of *Neopetrosia* sp. fragments on horizontal ropes and artificial substrates (50 cm above the sea bottom on a metal grid) is similar to its position in natural habitats, where they were observed to grow on other sponges or corals in order to have an exposed position to filter water. *Neopetrosia* sp. fragments on coral boulders had a low survival rate (8.33%). It is assumed that the fragments of this species probably did not like to be placed directly on the sea bottom. The higher sedimentation near the bottom leads to the block-up of ostia, causing the sponge to stop feeding and forcing all its energy toward cleaning [23]. For other sponge species like *Spongia officinalis* no significant differences in growth could be observed for different positions of transplants in the water column [22].

S. massa prefers to live on coral boulders or on the sandy bottom, in the transition zone between coral reef and sea grasses or mangroves. Its habitat preferences are therefore more widespread than those of *Neopetrosia* sp. In the Bay Teluk Pegametan, all *S. massa* fragments showed higher growth, attachment, and survival rates than in the Pulau Pari lagoon. Fragments on coral boulders were totally covered with sand due to wave action and crab movements. Newly built crab burrows can cover sponges and corals in nonelevated positions. Currents ripped off 38% of the fragments on horizontal ropes. Too much wave action and unsuitable farming methods for those areas were the reasons for the low survival and attachment rates. As described by Duckworth [9], in areas with strong water flow or partly stormy conditions the growth behavior of sponge species could be different, there is less feeding, and more energy is used to form a stronger skeletal structure.

Generally, *Neopetrosia* sp. showed higher growth rates on the different substrates than *S. massa*, but they had almost the same attachment and survival rates. It is unclear if there are any differences in growth rates of wild stocks between these two species. There were no differences in growth between uncut sponges (donor sponge) of both species at the field site Teluk Pegametan, but *Neopetrosia* sp. displayed signs of being fed on or taken away by current, while *S. massa* does not show any signs of damage. Like in the study by De Caralt et al. [6], it is difficult to compare the uncut sponges of the studied species due to their much more complex growth forms in comparison to the regularly cut fragments.

Fragments of *Neopetrosia* sp. grow faster after cutting than uncut sponges. Duckworth [24] tested regeneration and growth on wounded *Latrunculia wellingtonensis* sponges and demonstrated that damaged specimens showed better growth than nondamaged ones, which possibly invest their energy in reproduction. Wound size is greater for *S. massa* (massive growth form) than for *Neopetrosia* sp. (branching growth form) due to different morphological appearance. Wound recovery needs energy and reduces growth, and wound size influences survival [24]. Duckworth et al. [25] demonstrated wounds on some fragments of a massive sponge *Psammocinia hawere*, which did not fully recover after 80 days. This could be a reason why *S. massa* grew slower. However, it is difficult to compare both tested species for growth and attachment due to different skeletal structure, habitat preference, growth forms of the donor sponge, and wound size of the fragments.

Other studies have shown that growth of fragments on specific substrates can depend on sponge skeletal structure [7, 8, 18], soft sponges grow better in mesh bags and hard sponges on rope lines [17, 20]. In comparison with other studies (Table 4) growth rates of *S. massa* showed similar results using the suspended rope method, but *Neopetrosia* sp. showed even higher growth rates, 106% growth rate per month. Fragments in mesh bags showed higher growth (over 400% per month [18]) and survival rates, but the ones on the ropes showed higher attachment rates [19]. Fragments can be placed gently in mesh bags, which partly protect fragments against damage, especially for soft and fleshy sponges, but the bags also limit fragments growth and feeding possibility, especially if biofouling species like algae, bryozoans and ascidians were growing on the mesh [9, 17, 19]. In contrast the exclusion of sediment can lead to smaller growth rates; those sponges can grow 50% less than others [23]. In a different study, Duckworth and Battershill [17] showed that two different New Zealand sponge species (*L. wellingtonensis* and *P. croceus*) differed in survival and growth rates, greatest survival rates for meshes (meshes: 61 and 96%, ropes: 22 and 59%) and greatest growth for ropes (weight increment meshes for *P. croceus*: about 50%, ropes: over 100%) after nine months.

4.2. Growth, Attachment, and Survival Rates at the Aquaria Sites. Sponge fragments in the field showed higher growth, attachment, and survival rates than the ones in the aquaria. Inhibition of sponge growth can be caused not only by high sediment loads but also by low loads [2], which can be the problem in the aquaria. The aquaria fragments of both species even show a decrease in length and volume. Shrinking is evidence for insufficient food supply. Even if food like bacteria is present, also too gentle aeration, infrequent change of seawater, and the slowness of inflow can affect the availability of food [9, 26]. The higher survival and attachment rate, observed in the cement tank in comparison to the glass tank, may have been due to a higher water volume exchange.

Neopetrosia sp. fragments on horizontal ropes in the glass tank were shrinking, but they also have developed little tentacle-like branches. These branches might be a sign of starvation. However, adding food can help sponges to survive for several years in aquaria [26].

Another reason for the low survival rates in the glass tank is dying sponge fragments, which can be toxic [27] and affect the survival rate of healthy fragments.

Nickel et al. [28] suggest removing specimen with little parts of the attached substrate to have a better recovery in aquaria, because attachment will promote survival [19]. Further proper collection and transportation and more experiments in aquaria, for example, on light, current, and nourishment could help to discover how to maintain, feed, or reproduce species like *Neopetrosia* sp. and *S. massa* in aquaria.

Artificial substrate is easy to install and in the case of *Neopetrosia* sp. the encrusting growth form helps to cover the substrate in order to gain a marketable appearance in the aquaria.

4.3. Recommendations. The precision of calculated volumes is limited due to the nonuniformly morphological appearance. For a new series of studies it is recommended to use additional measuring methods to determine growth, for example weight [8], or other calculation methods depending on the growth form of the sponge species as described by Sipkema et al. [29]. Page et al. [18] measured the growth of sponge fragments of *Mycale hentscheli* via the surface area in correlation with wet weight.

As *Neopetrosia* sp. showed high survival, growth, and attachment rates, it would be interesting to test smaller cuttings. Duckworth [9] has shown that some sponge species (*Latrunculia wellingtonensis* and *Polymastia croceus*) can also recover totally from 90% removal of biomass. As other studies [5, 22] have also shown, growth rates of *Spongia officinalis* between different sized explants are similar. *Neopetrosia* sp. fragments show nearly no algae cover. In case few algae attach, they are easily removable and do not affect their state of health.

As sponges are important for the reef ecosystem, this study could help to reproduce sponges to help a reef to recover, to make it more attractive again to other marine species after destruction, further offering new and hopefully sustainable exploitation for local fishermen.

To minimize harvesting impact, it would be advisable not to harvest the whole sponge stock, but to leave a small part behind to give the sponge the chance to recover and regenerate into a new sponge. Sampling sponges for export trade does not only place extreme pressure on the wild stock, also the attachment surface will be damaged, which could cause injury to other living creatures, mostly corals. The knowledge of how to reproduce sponges on different substrates will contribute to the reduction of wild harvest and its damage to the environment.

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References

[1] J. M. Gili and R. Coma, "Benthic suspension feeders: their paramount role in littoral marine food webs," *Trends in Ecology and Evolution*, vol. 13, no. 8, pp. 316–321, 1998.

[2] C. R. Wilkinson, "Role of sponges in coral reef structural processes," in *Perspectives on Coral Reefs*, D. J. Barnes, Ed., pp. 263–274, 1983.

[3] N. A. Campbell, *Biologie*, Spektrum Akademischer, Heidelberg, Germany, 2nd edition, 1998.

[4] S. A. Fossa and A. J. Nilsen, *The Modern Coral Reef Aquarium*, vol. 3, Birgit Schmettkamp Verlag, 1st edition, 2000.

[5] G. Corriero, C. Longo, M. Mercurio, C. Nonnis Marzano, G. Lembo, and M. T. Spedicato, "Rearing performance of *Spongia officinalis* on suspended ropes off the Southern Italian Coast (Central Mediterranean Sea)," *Aquaculture*, vol. 238, no. 1–4, pp. 195–205, 2004.

[6] S. De Caralt, J. Sánchez-Fontenla, M. J. Uriz, and R. H. Wijffels, "*In situ* aquaculture methods for *Dysidea avara* (demospongiae, porifera) in the Northwestern Mediterranean," *Marine Drugs*, vol. 8, no. 6, pp. 1731–1742, 2010.

[7] N. J. De Voogd, "An assessment of sponge mariculture potential in the Spermonde Archipelago, Indonesia," *Journal of the Marine Biological Association of the United Kingdom*, vol. 87, no. 6, pp. 1777–1784, 2007.

[8] N. J. de Voogd, "The mariculture potential of the Indonesian reef-dwelling sponge *Callyspongia* (*Euplacella*) *biru*: growth, survival and bioactive compounds," *Aquaculture*, vol. 262, no. 1, pp. 54–64, 2007.

[9] A. Duckworth, "Farming sponges to supply bioactive metabolites and bath sponges: a review," *Marine Biotechnology*, vol. 11, no. 6, pp. 669–679, 2009.

[10] R. Wehner and W. Gehring, *Zoologie*, Georg Thieme, Stuttgart, Germany, 23th edition, 1995.

[11] P. L. Colin and C. Arneson, *Tropical Pacific Invertebrates*, Coral Reef Press, Beverly Hills, Calif, USA, 2nd edition, 1995.

[12] S. M. MacMillan, "Starting a successful commercial sponge aquaculture farm," University of Hawaii Sea Grant College Program Communications Office, School of Ocean and Earth Science and Technology, CTSA publication 120, 2002.

[13] Wet Web Media, Sponges, Phylum Porifera, Part 3, 2003, http://www.wetwebmedia.com/spongesii.htm.

[14] P. Bethge, "Füllhorn der Meere," *Der Spiegel*, vol. 17, pp. 112–113, 2003.

[15] D. Tasdemir, R. Mallon, M. Greenstein et al., "Aldisine alkaloids from the Philippine sponge *Stylissa massa* are potent inhibitors of mitogen-activated protein kinase kinase-1 (MEK-1)," *Journal of Medicinal Chemistry*, vol. 45, no. 2, pp. 529–532, 2002.

[16] D. E. Williams, P. Austin, A. R. Diaz-Marrero et al., "Neopetrosiamides, peptides from the marine sponge *Neopetrosia* sp. that inhibit amoeboid invasion by human tumor cells," *Organic Letters*, vol. 7, no. 19, pp. 4173–4176, 2005.

[17] A. Duckworth and C. Battershill, "Sponge aquaculture for the production of biologically active metabolites: the influence of farming protocols and environment," *Aquaculture*, vol. 221, no. 1–4, pp. 311–329, 2003.

[18] M. J. Page, P. T. Northcote, V. L. Webb, S. Mackey, and S. J. Handley, "Aquaculture trials for the production of biologically active metabolites in the New Zealand sponge *Mycale hentscheli* (Demospongiae: Poecilosclerida)," *Aquaculture*, vol. 250, no. 1-2, pp. 256–269, 2005.

[19] A. R. Duckworth and C. N. Battershill, "Developing farming structures for production of biologically active sponge metabolites," *Aquaculture*, vol. 217, no. 1–4, pp. 139–156, 2003.

[20] P. Van Treeck, M. Eisinger, J. Müller, M. Paster, and H. Schuhmacher, "Mariculture trials with Mediterranean sponge species: the exploitation of an old natural resource with sustainable and novel methods," *Aquaculture*, vol. 218, no. 1–4, pp. 439–455, 2003.

[21] J. N. A. Hooper and R. W. M. Van Soest, *Systema Porifera. A Guide to the Classification of Sponges, Volume 1 Introductions and Demospongiae*, Kluwer Academic, Plenum Publishers, New York, NY, USA, 1st edition, 2002.

[22] I. Çelik, Ş. Cirik, U. Altnağaç et al., "Growth performance of bath sponge (*Spongia officinalis* Linnaeus, 1759) farmed on suspended ropes in the Dardanelles (Turkey)," *Aquaculture Research*, vol. 42, pp. 1807–1815, 2011.

[23] C. R. Wilkinson and J. Vacelet, "Transplantation of marine sponges to different conditions of light and current," *Journal of Experimental Marine Biology and Ecology*, vol. 37, no. 1, pp. 91–104, 1979.

[24] A. R. Duckworth, "Effect of wound size on the growth and regeneration of two temperate subtidal sponges," *Journal of Experimental Marine Biology and Ecology*, vol. 287, no. 2, pp. 139–153, 2003.

[25] A. R. Duckworth, C. N. Battershill, and P. R. Bergquist, "Influence of explant procedures and environmental factors on culture success of three sponges," *Aquaculture*, vol. 156, no. 3-4, pp. 251–267, 1997.

[26] W. C. Jones, "Process-formation by aquarium-kept sponges and its relevance to sponge ecology and taxonomy," in *Sponges in Time and Space*, R. W. M. Van Soest, T. M. G. Van Kempen, and J. C. Braekman, Eds., pp. 241–250, A.A. Balkema, Rotterdam, The Netherlands, 1994.

[27] J. C. Delbeek and J. Sprung, *The Reef Aquarium—A Comprehensive Guide to the Identification and Care of Tropical Marine Invertebrates*, Ricordea Publishing, Miami, Fla, USA, 1st edition, 1994.

[28] M. Nickel, S. Leininger, G. Proll, and F. Brümmer, "Comparative studies on two potential methods for the biotechnological production of sponge biomass," *Journal of Biotechnology*, vol. 92, no. 2, pp. 169–178, 2001.

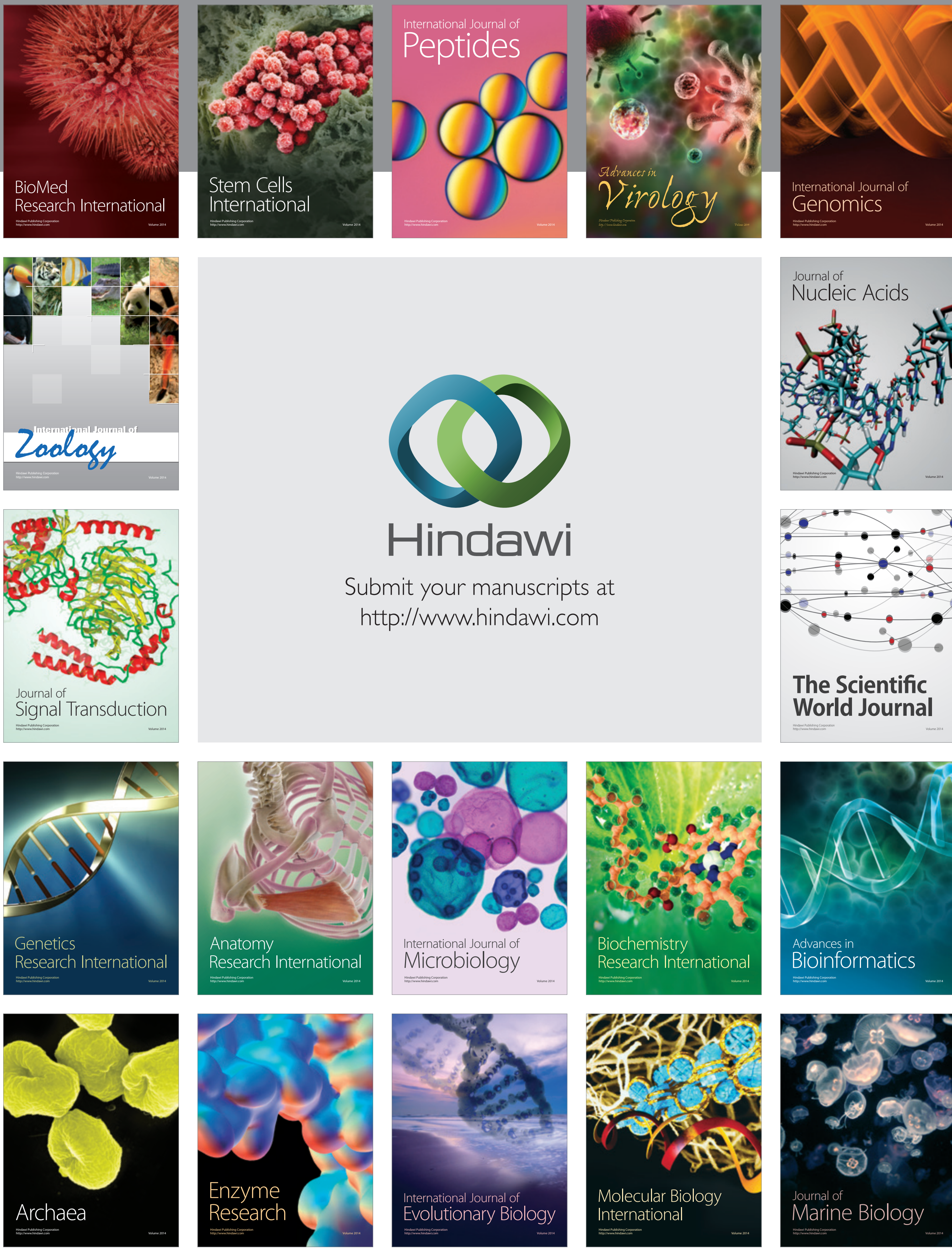
[29] D. Sipkema, N. A. M. Yosef, M. Adamczewski et al., "Hypothesized kinetic models for describing the growth of globular and encrusting demosponges," *Marine Biotechnology*, vol. 8, no. 1, pp. 40–51, 2006.

[30] S. Juwana, "Crab culture technique at RDCO-LIPI, Jakarta, Indonesia, 2001," in *Proceedings of the Workshop on Mariculture in Indonesia*, W. W. Kastoro, S. Soemodihardjo, T. Ahmad, and S. Anggoro Putro Dwiono, Eds., pp. 49–60, Lombok, Indonesia, February 2002.

[31] Seaturtle.org Maptool, 2002, http://seaturtle.org/maptool/.

[32] L. R. Crawshay, "Studies in the market sponges: I. Growth from the planted cutting," *Journal of the Marine Biological Association of the United Kingdom*, vol. 23, pp. 553–574, 1939.

[33] H. F. Moore, "A practical method of sponge culture," *Bulletin of the Bureau of Fisheries*, vol. 28, pp. 545–585, 1910.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