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ENHANCING A LANICE REEF
REPORT OF FIELD TRIALS
2017-2020

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Content

1. Introduction

The project Coastbusters (Sterckx et al. 2019) aimed to develop three nature-inspired design (NID) solutions that enhance coastal resilience by using innovative bio-stabilization methods. The three concepts (tube-building polychaete worms, marine flora and bivalves) were tested, each with specific enhancement methods to create a natural biogenic reef. The purpose of the reef is to induce natural accretion of sand and reinforce the foreshore against coastal erosion thus adding to coastal protection.

The main objective of the reef work package (WP3) was to advise on a methodology for the formation of a tubeworm reef that locally acts as a bioconstructor. This has the potential to act as a seed source, which will induce the growth of additional tubeworm reefs in the vicinity of the artificial reef area. Furthermore the reef would serve as a substrate for biodiversity development.

Aggregations of the ecosystem engineer *Lanice conchilega* (Pallas, 1766) (Sand mason worm) stabilizes the sediment bed of sandy shorelines (Zühlke 2001; Rabaut 2009). Therefore, this polychaete is considered as an interesting target species in the search for NID in coastal zone management (Borsje et al. 2011). In contrast with march plants and mangroves, *L. conchilega* aggregations cannot be planted. These tube worms undergo a pelagic larval phase prior to their settling in the bottom. This settlement process is facilitated by the presence of epi-benthic structures, shells or tubes of adult conspecifics. To induce and enhance adult aggregation developments, larval settling needs to be enhanced in the area of use. This can be done by using a substrate mat designed in such way that larval settlement and survival is optimized.

Three complimentary objectives are formulated in this WP3 with the common goal to develop a generic exportable method to form sandmason worm reefs. The first objective, a more fundamental research phase, was to develop a standard protocol for culturing *L. conchilega* juveniles and thus producing high quality and quantity of larvae (Wyns et al. 2020). As young sand mason worms prefer tubes of adult conspecifics, shell fragments or other hard epi-benthic structures to settle, these settlement conditions were examined and build on by providing artificial settlement substrate for the larvae. Different designs of geo-textiles with necessary biological - and mechanical properties were investigated and tested in controlled laboratory conditions to test the effectivity of optimal settlement in the purpose of our second objective (Wyns et al. 2020). The last objective of this WP3 was to optimize the further design of a *Lanice* inducing reef to the dynamic circumstances that occur in the intertidal zone of a selected beach along the Belgian coast. Further on, to actually build, install and monitor their performance in the field, first on a small scale and finally on a pilot scale that should allow for the validation of the concepts. This report is tackling this last objective, as the previous objectives are published (Wyns et al., 2020).

The following steps were undertaken for the field study. In August 2017 a first “blind” step was performed at the low water line in De Panne. All partners were invited to provide a micro-reef design – based on their own ideas, competence and operational insights, to ensure the initial small-scale pilot covers a wide range of ideas and designs. Afterwards, in September 2018, a follow up In-Situ small scale pilot test was performed at the low water line in Bredene and Heist. 1m^2 patches were placed with the use of wooden sticks (Rabaut et al. 2009), wooden sticks with shell fragments and a designed 3D geo-textile. Because of the first positive visual results of using geo-textiles and the goal of this work package, further trials were maintained with the use of geo-textiles in 2019. In June 2019, a last follow up In-situ scale pilot test was performed at the low water line in Bredene and Lombardsijde. 5m^2 patches were placed with the use of coconut material, 3D geo-textiles and geo-textiles ‘felt’, following the laboratory trials and used materials for the Master thesis of Liam Wyns (January-June 2019).

This report summarizes the past 3 In-situ scale pilot test reports (Semeraro, 2017, 2018, 2019, see Annex 1) with a more detailed data analyses on the field trials of 2018 and 2019.

2. Materials and methods

2.1 Implementation of the set-ups

Every detail of the experimental set-ups (reef design, test sites, locations and control moments) can be found in the previous reports (Semeraro, 2017, 2018, 2019, see Annex 1). Whereby the reef development trials were performed during one month, except in 2017 over a time of 4 months. Location Bredene is exposed directly to wave backlash and therefore adopted as non-sheltered area versus semi-sheltered area (Heist and Lombardsijde). The monitoring is determined and executed by eCoast.

2.2 Sampling methodology

Macro benthos organisms are considered to be those that live in the sediment and are retained on a 1 mm mesh size sieve. For these in situ trials they are sampled by a core (0,00785m^2). The core is pushed 15 cm into the soil, dug out and emptied into the sieve. The samples were sieved on a 1 mm mesh size sieve on site in 2018. This switched to 0.5 mm mesh size sieve for the trials in 2019, as the goal of these in situ trials was to observe the number of settled Lanice larvae and/or juveniles by the use of different geo-textiles. Whereby the use of a 1 mm mesh size sieve introduces a margin of error by not being able to retain all larvae or juveniles of *Lanice conchilega* due to the mesh size of the sieve.

For these trials with specific purpose to attract larvae/juveniles through the use of an artificial substrate, the geo-textiles themselves were also completely analysed. Thoroughly cleaned of all found individuals of 1 m^2 geo-textile in 2018 and 3 subsamples of 16 cm x 16 cm.

2.3 Sampling overview

Furthermore there are differences in the amount of samples taken between 2018 and 2019, and between T_0 and T_1, regarding the amount of reference core samples, core samples (under the textiles) and textile samples, summarized in Figure 1 and Table 1. It was not feasible of following the same sampling pattern at all time. This has some consequences on the comparability of the analyses over the years, locations and patches, which is taken into account as much as possible.

In 2018, 6 patches (wooden sticks (4) and 3D geo-textiles of 1m^2 (2)) were installed at both locations; Bredene and Heist. The geo-textile 3D was retrieved and entirely analyzed in Bredene and Heist (resp. CB1809_B_5_MAT & CB1809_B_6MAT1 and CB1809_H_6_MAT), whereof the analyses of geo-textile sample CB1809_H_5_MAT itself was not feasible. The patches in Heist installed with wooden sticks (patch 1) and wooden sticks shells (patch 2 & 3) were also retrieved. No patches of wooden sticks could be retrieved in Bredene. Following figure 1, 3 core samples (0,00785m^2) are sampled by patch. This differs in 2018, where for every core sample an added core of 0,00785m^2 was taken. Subsequently giving in total of 6 T_0 & T_1 core samples (table 1). Whereas, the reference core samples T_0ref & T_1ref are sampled twice each for Ref1 and Ref2.

In 2019, 5 patches of 5m^2 in Lombardsijde (cocos (1), felt geo-textile (2) and 3D geo-textile (2)) and 6 patches of 5m^2 in Bredene (cocos (2), felt geo-textile (2) and 3D geo-textile (2)) were installed. Before installation, only 1 core sample (0,00785m^2) was taken on the patch itself and used in the analyses as T_0 and T_0ref. At T_1, the felt geo-textiles are retrieved and analyzed by subsampling (3 samples of 16 cm x 16 cm; 0,0768 m^2). No other geo-textiles could be retrieved at both sites. Following figure 1, 3x T_1 core samples (0,00785m^2) are sampled by patch and only 1 core sample for T_0 -and T_1ref core samples.

The analysis procedure of the samples in the laboratory is done according to a standard operational protocol for the analysis of marine benthic samples (eCoast 2018 and 2019 field campaign reports). The thorax width of the individuals of the sandmason worm found are measured to have a proxy for their age.

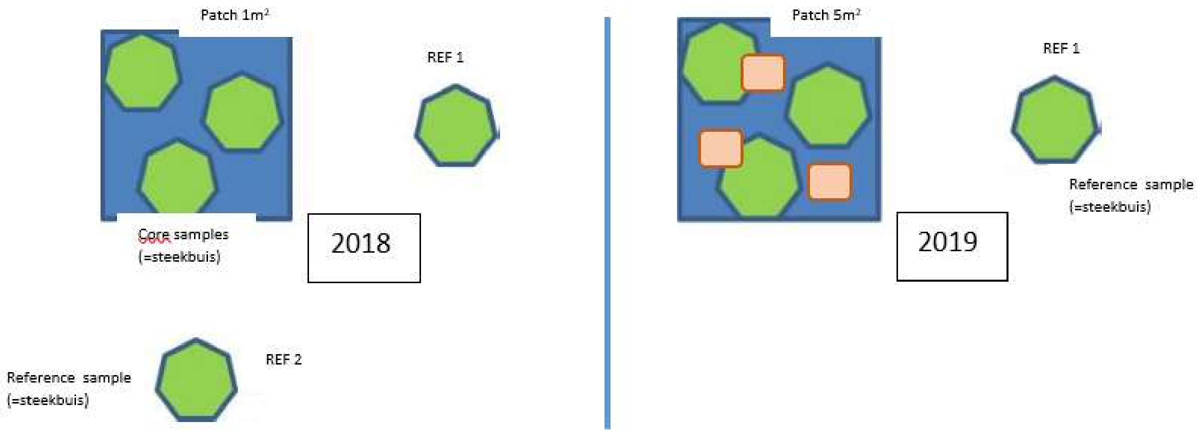


Figure 1 Sampling pattern per patch. In 2018: 1m² sample of textile - In 2019: 3x 16cmx16cm sample of textile (orange squares). REF2: this reference point on a higher location to ensure that any effect outside the installation is measured. Or, in case of no differences in species composition with other reference point REF1, as an extra reference. For further information: referring to Schellekens et al. 2018 and Semeraro, 2018, 2019, see Annex 1.

2.4 Analyses

2.4.1 Data processing

All raw data from the different campaigns were, to the extent possible, standardized for the analyses. A total of 146 taxa were found. 58 taxa were excluded from the analyses for various reasons: not macrobenthos taxa (Ostracoda, Platyhelminthes, fish, Nematoda, Pycnogonida,...), non-quantitatively sampled species (Bryozoa, Hydrozoa, Nemertea, dinoflagellate,...) and individuals that couldn't be determined to the lowest taxonomic level (genus/species level). For certain species (Amphipoda, Bivalvia, Ophiuroidea and Polychaetes: Nereididae, Polynoidae, Spionidae,...), difference was made between life stage stadia (juvenile/spat and adult species).

				Bredene	Heist
2018	**cores**	**m²**	**Textile m²**	**samples**	**samples**
T0	3 * (2*0,0078)	0,0468		4 patches (each 3 replicas)	4 patches (each 3 replicas)
T1	3 * (2*0,0078)	0,0468	1	CB1809_B_6MAT1 & CB1809_B_5_MAT	CB1809_H_6_MAT & **only core** H_5_MAT & wooden sticks patch1 -2 -3
T0ref	2 * 0,0078	0,0156		4*ref1 - 4*ref2	4*ref1 - 4*ref2
T1ref	2 * 0,0078	0,0156		6 * ref1 - 3 * ref2 (patch4-5-6)	5 * ref1 - 5 * ref2 (patch4 not)
				Bredene	**Lombardsijde**
2019	**cores**	**m²**	**Textile m²**	**samples**	**samples**
T0	0,0078	0,0078		6 patches	5 patches
T1	3 * 0,0078	0,0234	3 * 0,16*0,16	Patch B (4 replicas)- Patch E (3 replicas)	Patch A - Patch C (both 3 replicas)
T0ref	none	none		none	none
T1ref	0,0078	0,0078		4 * ref1	4 * ref1
Note					
1 core sample = 0,0078539816 m²				2018: 4 patches at T0 but 6 patches installed	
ref1 (in between) en ref2 (high measurement)				2019: T0 is taken as T0ref / no ref2	
T1: analysed patches after 1 month					

Table 1 Overview of available samples and amount, sample size and at which location and patch for Bredene in 2018 & 2019, for Heist 2018 and Lombardsijde 2019. Amount of reference samples (=T_0ref & T_1ref), core samples under the textiles (=T_0 & T_1) and textile samples (textile) with area (2018 only 3D textile retrieved; 2019 only felt).

2.4.2 Univariate and multivariate analyses

The different amount of samples and the low sampling effort does not allow to reliably perform statistical analyses. To enable a comparison between the different measurements, the number of individuals is converted to the number of individuals per m^2. Results are expressed as mean ± standard deviation. The following biological characteristics are determined through diversity indices, the number of taxa (species richness - Margalef index). The total number of species is very dependent on sample size (the bigger the sample, the more species there're likely to be). Therefore Margalef's index (d) is used, which also incorporates the total number of individuals (N) and is a measure of the number of species present for a given number of individuals. Our sample size is lower than a m^2 and with data expressed as number of individuals per m^2, the Species richness – Margalef index is sub estimated (Gamito, S. 2010).

For the multivariate analysis, the data has been transformed (square root) to give less weight to the dominant species (Field et al. 1982). To visualize the community structure, a multi-dimensional scaling analysis (nMDS) is drawn up, based on a Bray Curtis resemblance matrix. Whereby, points that are very close together represent samples that are very similar in community composition, and points that are far apart correspond to very different values of the dataset.

For these multivariate analyses, the patches wooden sticks and wooden sticks shells (Heist – 2018) have been removed, because of the lack of comparability with the geo-textile tests. Only the data of the reference core samples, the core samples (under the textiles) and the geo-textiles samples are used. Additionally, some samples are removed because they appear to be outliers; for example: CB1808_B2ref2 (only containing *Nephtys longosetosa*, only appears once in the entire dataset), CB1809_B_2ref1 (no specimens found), CB1808_B2ref1 (containing only *Pariambus typicus*),... For these analyses, the software program PRIMER-e packet, version 7.0.13 was used.

3. Field results

3.1 *Lanice conchilega*

In the T_0 samples and reference samples T_0REF of 2018 and 2019, at both locations, no Lanice specimens are explicitly found. Except, 4 adult specimens in a patch location (with only the tail) and in a reference sample (as tail and one head count) in Heist (Table 2).

monstercode		opp	Factor	*Soort*	Klasse	#/monster	#/m2	Opmerkingen
CB1808_H1c	T0_2018	0,015708	1,0	Lanice conchilega	Polychaeta	>0		alleen staart, groot exemplaar
CB1808_H4a	T0_2018	0,015708	1,0	Lanice conchilega	Polychaeta	>0		alleen staart
CB1808_H1ref1	T0_2018	0,015708	1,0	Lanice conchilega	Polychaeta	>0		alleen staart
CB1808_H4ref2	T0_2018	0,015708	1,0	Lanice conchilega	Polychaeta	1	63,66	kapot

Table 2 Present pieces of Lanice only found in T_0 of 2018.

In 2018 in Bredene, a certain amount of Lanice (between 1083 and 5493 ind./m^2) were found in T_1 core samples (under the textile 3D) and geo-textile 3D samples. Only 2 specimens were found in Heist. In 2019, there were no Lanice found in T_1 core samples (under the textile felt) and only in geo-textile felt itself, perhaps due to the too dense material that created anoxic conditions underneath.

Two graphs (figure 2, graph A & B) are being put forward with the thorax width of the individuals in Bredene 2018 and of both locations in 2019. Graph A, shows the actual number of Lanice found and analyzed on $1m^2$ 3D geo-textile while the core sample ($0{,}00785m^2$) is converted to $1m^2$. To perceive graph B we excluded 509 individuals/m^2 with a thorax width of 2mm in reference core sample of Lombardsijde.

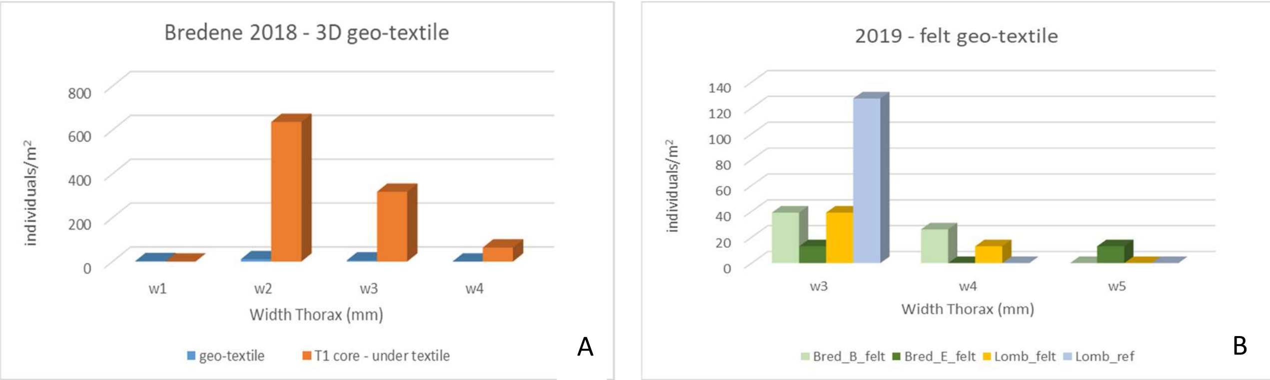


Figure 2 The number of Lanice individuals/m² (with thorax width (w) in mm, no lengths; width classes: 1 mm, 2 mm, 3 mm, 4 mm and 5 mm) in the different patches with textiles (2018 - 3D / 2019 – Felt).

3.2 Macro benthos

3.2.1 Number of species

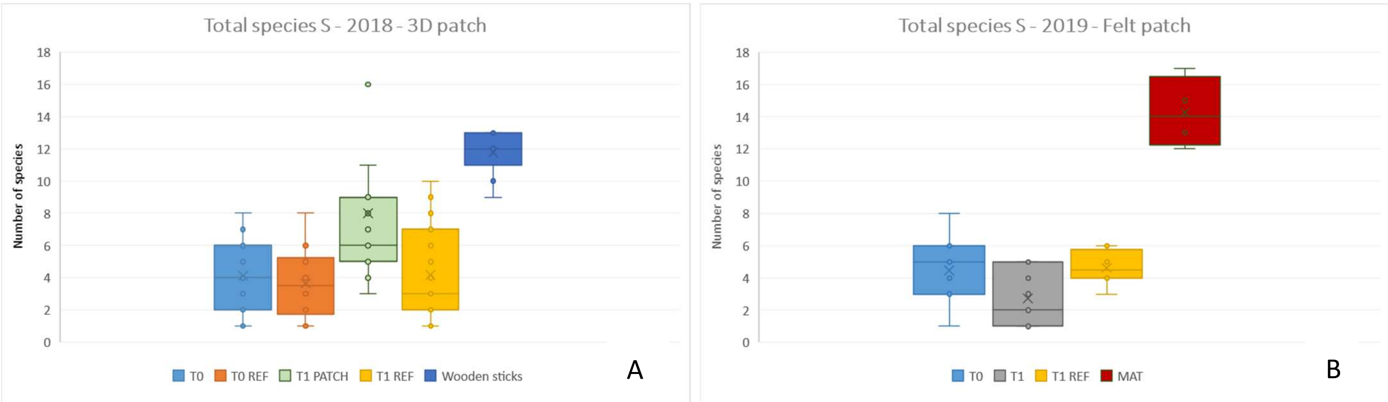


Figure 3 The number of species by year 2018 (graph A) and 2019 (graph B) with used geo-textile. Reference samples T_0REF & T_1REF, core samples T_0 & T_1 under the textiles and textile samples (MAT) and wooden sticks in 2018.
**The data of 2018 – T_1 Patch contains T_1 core samples (T_1) and textile (MAT) as lack of a replicate (sample CB1809_H_5_MAT).*
**In 2019 no T_0ref has been sampled.*

The number of species in 2018 and 2019 found in the core samples T_0, T_0 REF and T_1 REF are similar (blue, orange and yellow). What can be noticed in 2019, is a smaller number of species in the T_1 core samples under the textile felt (grey), most likely due to the anoxic conditions created by the textile type. Which results in prominent quantity of species attracted by the surface of the textile used as artificial substrate with a large number of species (MAT – 2019)(red).

A considerable number of species is clearly noticeable with the use of the 3D geo-textile (T1 Patch – 2018)(green). Whereby species were able to settle mostly under the geo-textile. The T_1 core samples and geo-textile samples are put together by reason of a larger deviation in 2018 geo-textile (MAT). The amount of samples is too small to evaluate those samples separately in a box plot.

An interesting observation is the distinguished number of species due to the use of wooden sticks in 2018 (dark blue).

3.2.2 Species richness – Margalef

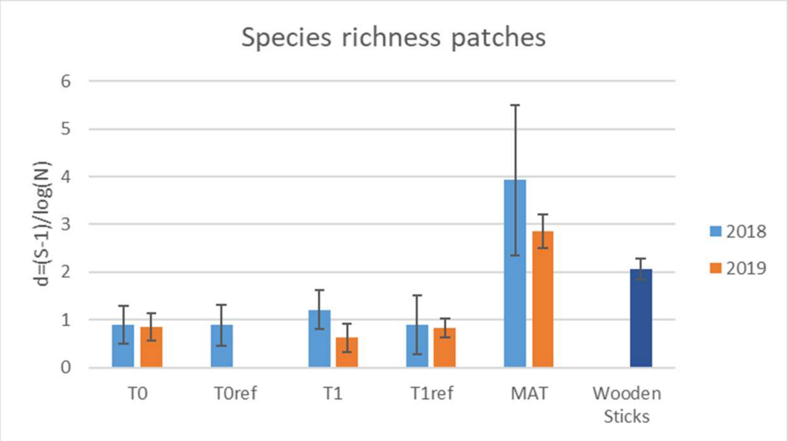
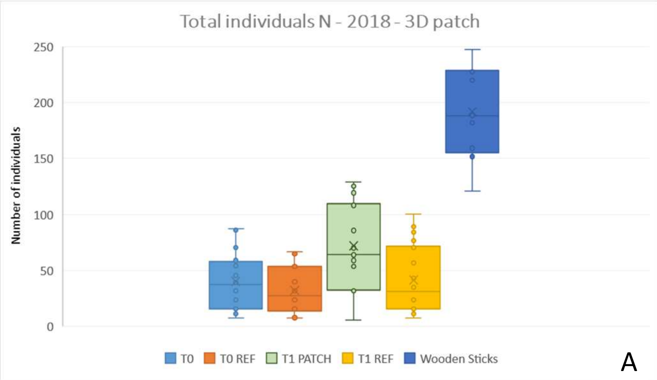


Figure 4 Species richness - Margalef expressed by d=(S-1)/log(N) Mean with standard deviation. Represented data of 2018 (textile 3D) and 2019 (textile felt); core samples T0, T0ref, T1, T1ref and core samples wooden sticks and geo-textiles (MAT).

There's a clear presence of a higher species richness in 2018 and 2019 in the geo-textiles samples (MAT) (figure 4) and wooden sticks samples of 2018, in comparison with T_0 and T_1 core -and reference samples. Better visualization of the data is achievable with mean ± standard deviation through a bar chart by reason of the larger deviation in 2018 geo-textile (MAT).

3.2.3 Density patterns of macro benthos species



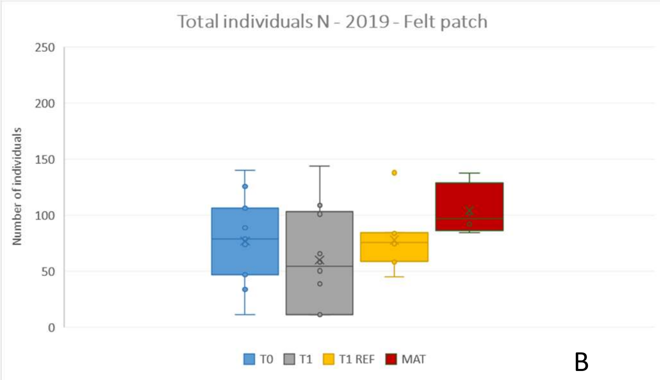


Figure 5 Total number of individuals by year 2018 (graph A) and 2019 (graph B) with used geo-textile. Reference samples T_0REF & T_1REF, core samples T_0 & T_1 under the textiles and textile samples (MAT) and wooden sticks in 2018.
**The data of 2018 – T_1 Patch contains T_1 core samples (T_1) and textile (MAT) as lack of a replicate (sample CB1809_H_5_MAT).*
**In 2019 no T_0ref has been sampled.*

Considering the noticeable higher number of species found with the 3D geo-textile (T_1 Patch 2018) and geo-textile felt 2019 (MAT) (figure 3 A and B), are the observed abundances surprising similar between all samples, except the wooden sticks 2018 (figure 5). Whereby the wooden sticks contain a higher number of species and species richness but also remarkable densities (dark blue)(figure 5).

3.2.4 Multidimensional scaling

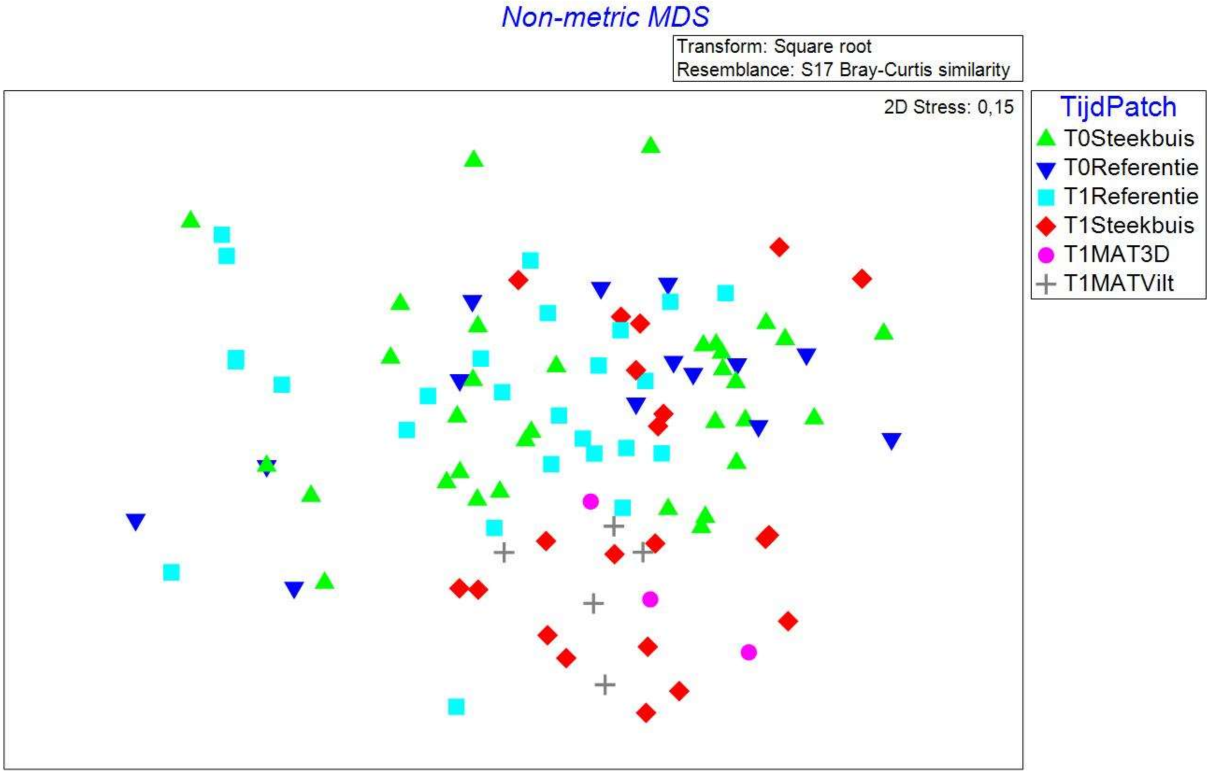


Figure 6 nMDS plot of the macro benthos samples for the in situ trials 2018 & 2019. Stress value = 0.15.

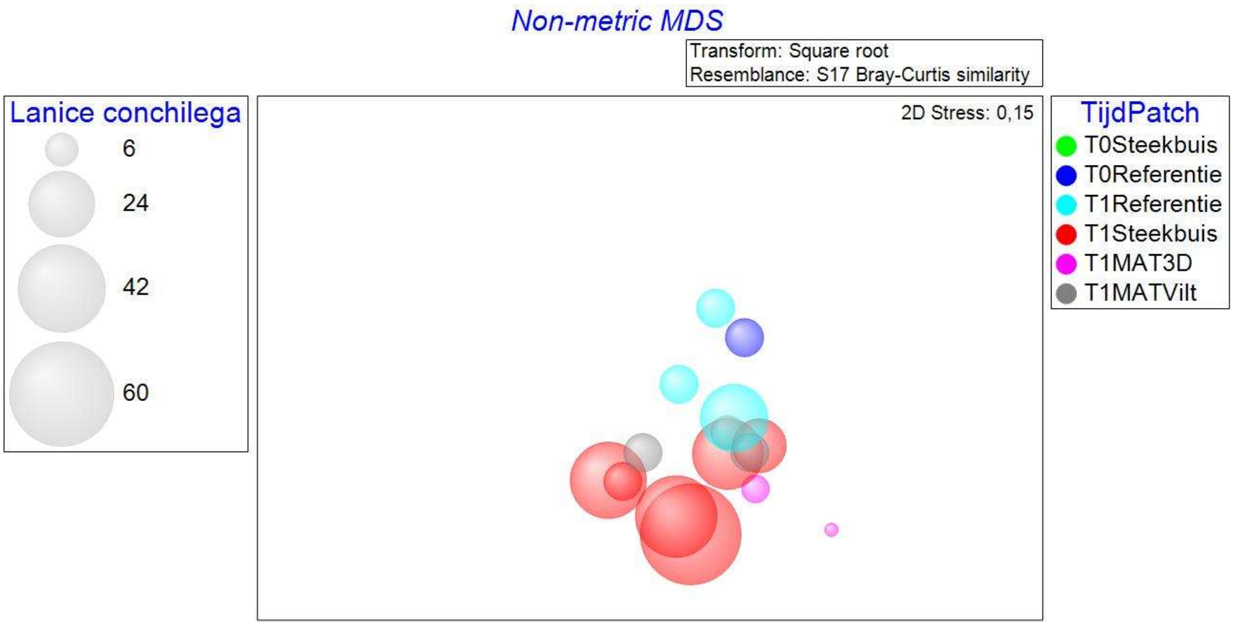


Figure 7 A bubble plot of the species L. conchilega.

The above nMDS (figure 5) draws on all 88 species, shows that there is a gradient created by *L. conchilega.* Whereby the T_0, T_0REF and T_1REF core samples are more similar in community composition than T_1 core samples and geo-textiles. When adding the factor Year, no effect has been marked in the T_1 core samples. The stress value is less than 0.2 which gives still a good representation of the patterns in the data.

The effect of *L. conchilega* in the sample distribution can be seen by a bubble plot (figure 6), in which the circles are size related to the abundance of the sandmason worm in that sample. The presence of *L. conchilega* in T_0 REF 2018 (dark blue bubble) is explained by the 2 adult specimens in a reference sample (as tail and one head count) in Heist (table 2). The large counts of the sandmason worm is visible in the T_1 core samples (under the textiles) and the geo-textiles themselves (red, pink and grey bubbles). There is a remarkable presence of Lanice individuals in 2018 in the T_1 core samples (under the 3D geotextile)(Figure 6; red bubbles).

4. Conclusion and next steps

From the In-Situ small scale pilot tests in 2018 and 2019 that were conducted in non-sheltered and semi-sheltered area, we can conclude the following:

The patches of geo-textile felt in 2019 gave an interesting side effect with an measured elevation of ±0,17m sediment compared to the surrounding beach with reef-like-elevated forming structures appearing in non-sheltered area. Only visual elevation was noticeable in 2018.

A higher number of species were observed with both geo-textiles and wooden sticks (epi-benthic structures). Where the number of species in the T_1 core samples (under the textiles) depends on type of geo-textile. Furthermore, the number of individuals revealed similar species densities between patches and reference samples. However, the species richness and observed densities with the use of wooden sticks in 2018 cannot be left unnoticed.

Friedrichs and Graf 2009 & Borsje et al. 2014 have shown that coverage densities of at least 5% coverage cause sediment stabilization by skimming the flow. This corresponds to a density of 2272 Lanice worms/m^2. This density is used as threshold for successful colonization on the Lanice reef in the Proof of Concept phase of this project. Whereby visual check, together with sediment samples revealed, although not significant, a positive effect of both geo-textiles 3D and felt on the settlement of *L. conchilega*. At the start of both in-situ tests 2018 and 2019, no sand mason worms were found in large numbers on site. These field trials confirm that geo-textiles can be attractive for sandmason worms with a density between 1083 and 5493 ind./m^2 in Bredene in 2018. Where a certain amount of *Lanice* specimens were found in the core samples (under the geo-textile 3D) and on the geo-textile 3D. In 2019, no *Lanice* specimens were found in the core samples under the felt geo-textile. This might be due to the high density of the material, creating anoxic conditions and is therefore maybe not ideal for this purpose, despite the high species richness on the mat.

More insights in the structure and density of the geo-textile itself is needed. Whereby, the experiments (Wyns et al. 2020) revealed that an artificial substratum has the potential to trap larvae and confirm the less-specific behaviour of the larvae to any holdfast, although a preference in substratum type (geo-textile) cannot be excluded yet.

To conclude, the potential of using *L. conchilega* aggregations in coastal defense can offer opportunities in the prospect of resilience of a beach towards future storm events.

For further follow-up, following aspects has to be taken into account:

- One month of observation of reef forming structures gives a first idea of possibilities. Reef forming trials should be incorporated on short and long time periods and at different locations.
- Further substrates designs should be taken into account in regard to the interesting observations with the use of wooden sticks. Certainly looking beyond the fuse of the 3D material and felt geo-textile in order to maintain the establishment of a potential growing reef.
- The biodegradable aspect of geo-textiles as reef patches has to be further investigated.
- Hereby taken into consideration further anchoring possibilities of the patches due to the natural dynamic circumstances and forces that occur in the intertidal zone of a beach.

5. List of Figures

6. List of Tables

7. List of References

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8. Annex 1

Semeraro A., REPORT - LANICE REEF SMALL SCALE PILOT TEST -Test site De Panne, 2017.

Semeraro A., REPORT - LANICE REEF SMALL SCALE PILOT TEST - Test site Bredene - Baai van Heist, 2018.

Semeraro A., REPORT - LANICE REEF SCALE PILOT TEST - Test site Bredene – Lombardsijde, 2019.

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