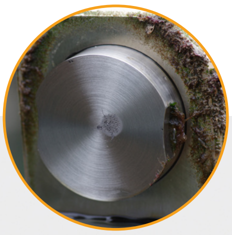

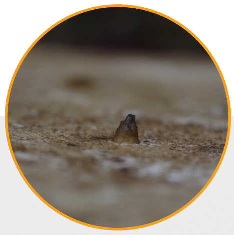

Effect of a 100 Watt ultrasound transmitter on marine fouling

Lodewijk van Walraven & Louis Peperzak

This report is part of project DMEC WP 3.3.

Texel, April 2018
NIOZ Royal Netherlands Institute for Sea Research

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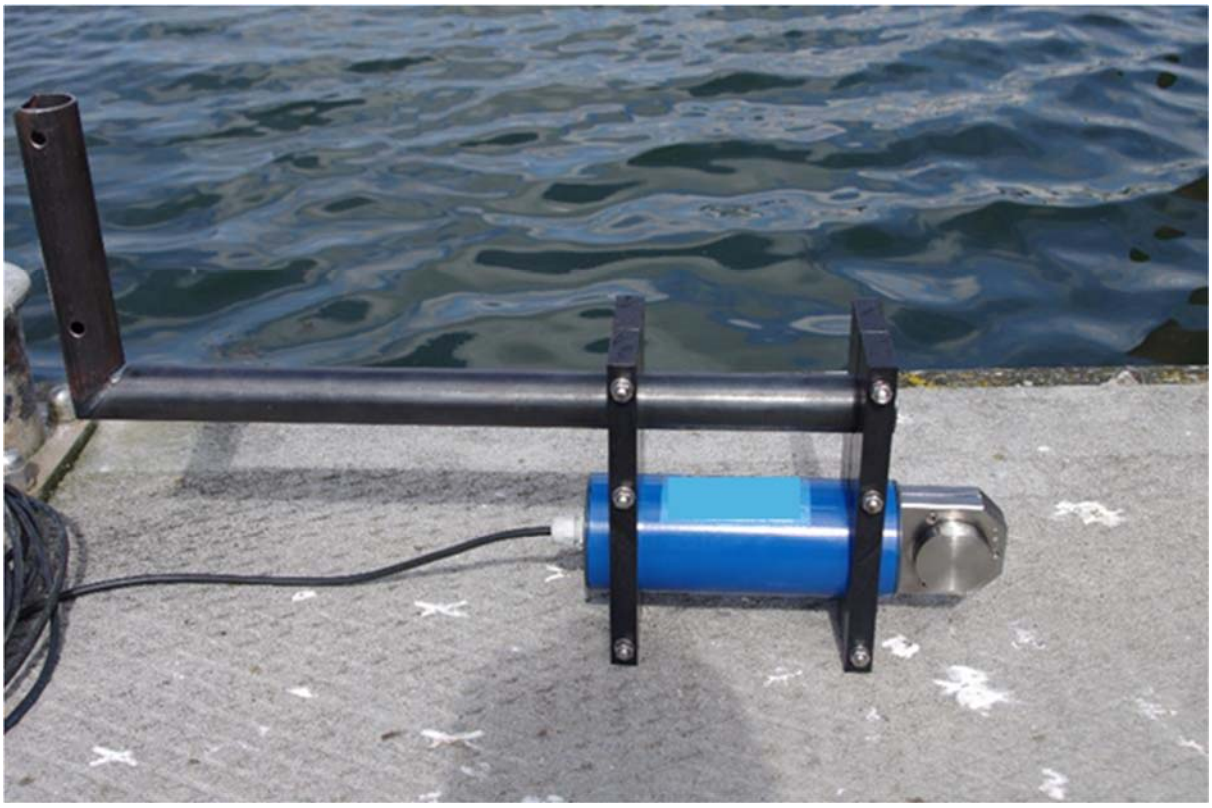

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This report is part of project DMEC WP 3.3.

Contents

Summary

The effectiveness of an ultrasound transmitter (100 Watt) in preventing attachment and growth of fouling organisms on submerged surfaces was tested in 2017 under realistic field conditions in the western Wadden Sea (Royal NIOZ harbor). Additionally, the possible synergetic effect of ultrasonic sound and an antifouling coating (Intersleek 1100SR, International, USA) was investigated.

Three steel test plates were deployed. One control plate was attached to a steel seawall which effectively shielded the plate from ultrasonic sound (0% sound pressure). Two test plates were attached to a floating dock with the ultrasound transmitter in between creating 25% sound pressure at the back and 100% sound pressure at the front of the plates. Proper operation of the ultrasound transmitter was confirmed by underwater sound level measurements at the test plate surfaces. All plates were coated on each side in a 2x2 checkerboard pattern with antifouling coating and a regular (control) non- antifouling coating. During the two month deployment the plates were photographed regularly. At the end of the experiment the abundance and taxonomic composition of fouling communities in each quadrant was determined.

It is concluded that Intersleek 1100SR had a distinct anti-fouling effect. In addition, it is concluded that the ultrasound exposure was not an effective anti-fouling treatment, either alone or in combination with Intersleek anti-fouling paint.

Samenvatting

De effectiviteit van een ultrasoon-zender (100 Watt) in het voorkomen van vestiging en groei van ‘fouling’ organismen op ondergedompelde oppervlakken werd getest in 2017 onder natuurlijke omstandigheden in de westelijke Waddenzee (NIOZ haven). Aanvullend werd het mogelijk synergetische effect van ultrasoon geluid en een anti-fouling verf (Intersleek 1100SR, International, VS) onderzocht.

Drie stalen testplaten werden uitgezet. Eén controle plaat was bevestigd aan een stalen damwand die de plaat effectief afschermde van ultrasoon geluid (0% geluidsdruk). Twee platen waren bevestigd aan een drijvend ponton met de ultrasoon-zender ertussen wat leidde tot 25% geluidsdruk op de achterzijde en 100% geluidsdruk op de voorzijde van de platen. De werking van de ultrasoonzender werd gevalideerd door onderwater geluidsdrukmetingen bij de testplaatoppervlakken. Alle platen werden aan iedere kant geschilderd in een 2x2 dambordpatroon met anti-fouling verf en een gewone verf zonder anti-fouling als controle. Tijdens de twee maanden durende test werden de platen geregeld gefotografeerd. Aan het eind van het experiment werd de abundantie en de taxonomische samenstelling van de aangroei in elk kwadrant bepaald.

Er wordt geconcludeerd dat Intersleek 1100SR een duidelijk anti-fouling effect heeft. Bovendien wordt geconcludeerd dat blootstelling aan ultrasoon geluid, alleen of in combinatie met Intersleek anti-fouling verf, geen effectieve anti-fouling behandeling is.

Introduction

The goal of this test was to investigate the effectiveness of a 100 Watt ultrasound transmitter in preventing attachment and growth of fouling organisms on submerged surfaces under realistic marine field conditions.

As an additional goal, the possible synergetic effect of ultrasonic sound and an antifouling coating, Intersleek 1100SR manufactured by International, was investigated.

Both test goals were discussed with the transmitter supplier. In this report the supplier remains anonymous.

Realistic field conditions are found in the NIOZ harbor in the western Wadden Sea. The Wadden Sea contains a high diversity of organisms from early spring to late autumn. Several anti-fouling tests have been performed in NIOZ harbor in the past. Due to confidentiality the present test results cannot be discussed in relation to any previous tests.

Material & Methods

Location

The test was performed in the harbor of the Royal Netherlands Institute for Sea Research (NIOZ) on the island of Texel, coordinates N 53.0, E 4.8 (Figure 1).

Figure 1. Aerial photo of the test site with locations of test and control plates indicated.

Plate design and coatings

The test was performed with three steel plates, two test plates and one control plate.

The two test plates were attached to a steel frame designed by the transmitter supplier, Louis Peperzak and the workshop of NIOZ and manufactured and installed by the NIOZ workshop.

The plates were coated in a 2 x 2 checkerboard pattern using a non-antifouling control coating and an anti-fouling coating:

1. Control off-white two-component coating (Control paint, Sigmacover™) used on NIOZ vessels, consisting of:
   - Sigmacover™ 280 2-component epoxy primer
   - Sigmacover™ 456 2-component epoxy base layer
   - Sigmacover™ 550 2-component polyurethane top layer
2. Intersleek 1100SR (Slime Resistant) coating system consisting of:
   - Intersleek 300 primer
   - Intersleek 737 base layer
   - Intersleek 1100SR top layer

Plate quadrants were labeled with a number from 1-4 for each side of each plate (Figure 2).

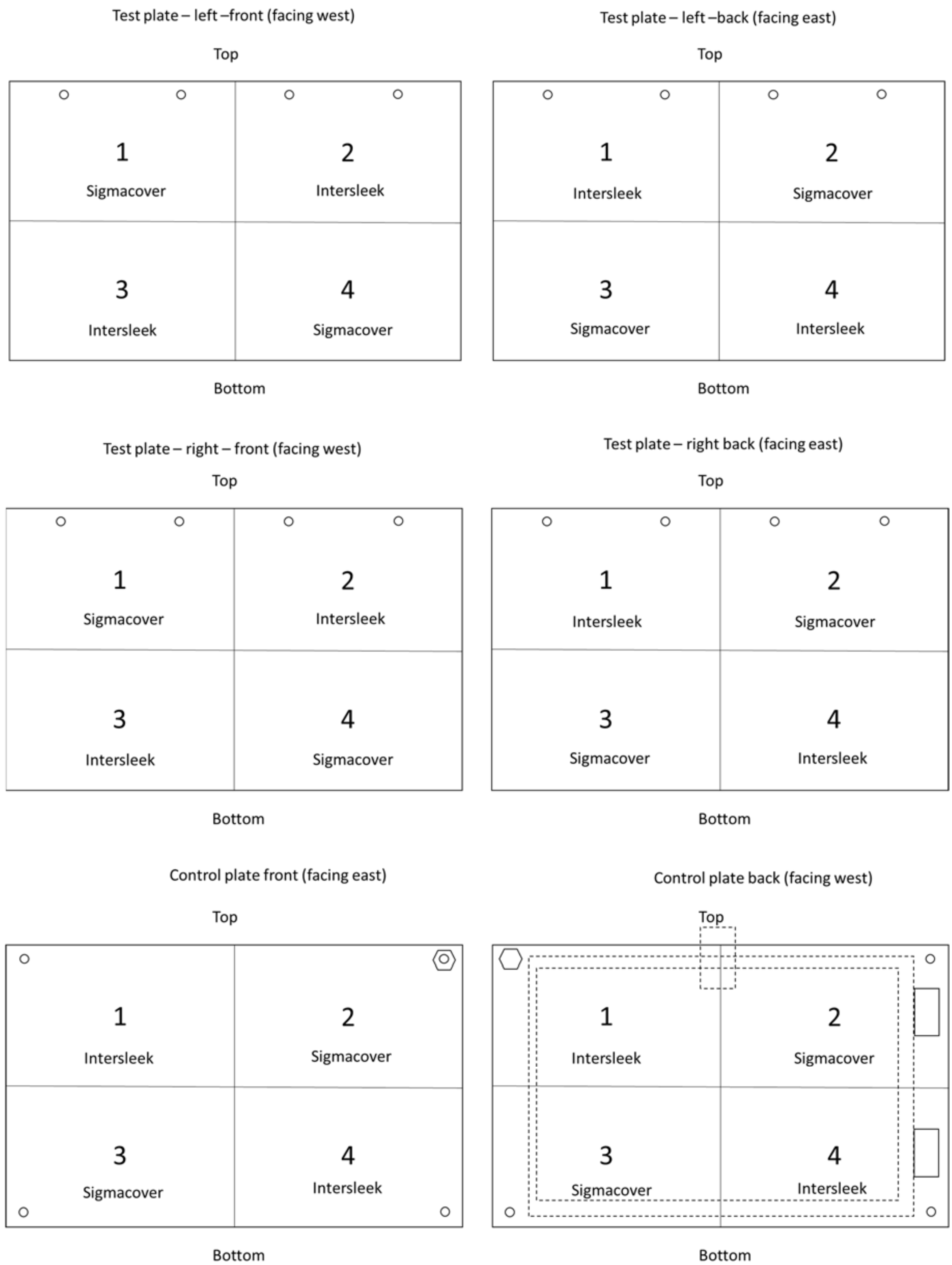


Figure 2. Plate design and coating type per quadrant. The fronts of the test plates received a high solar irradiance and a relative sound pressure of 25% (see Figure 4). The backs of the test plates received a medium solar irradiance and a relative sound pressure of 100% . All test plates experienced a low turbulence. The back of the control plate received a low solar irradiance (it was attached to the harbor sheet piling) a relative sound pressure of 0% and presumably low turbulence. The front of the control plate received a medium solar irradiance, a relative sound pressure of 0% and a high turbulence because it faced the harbor entrance.

Ultrasound transmitter

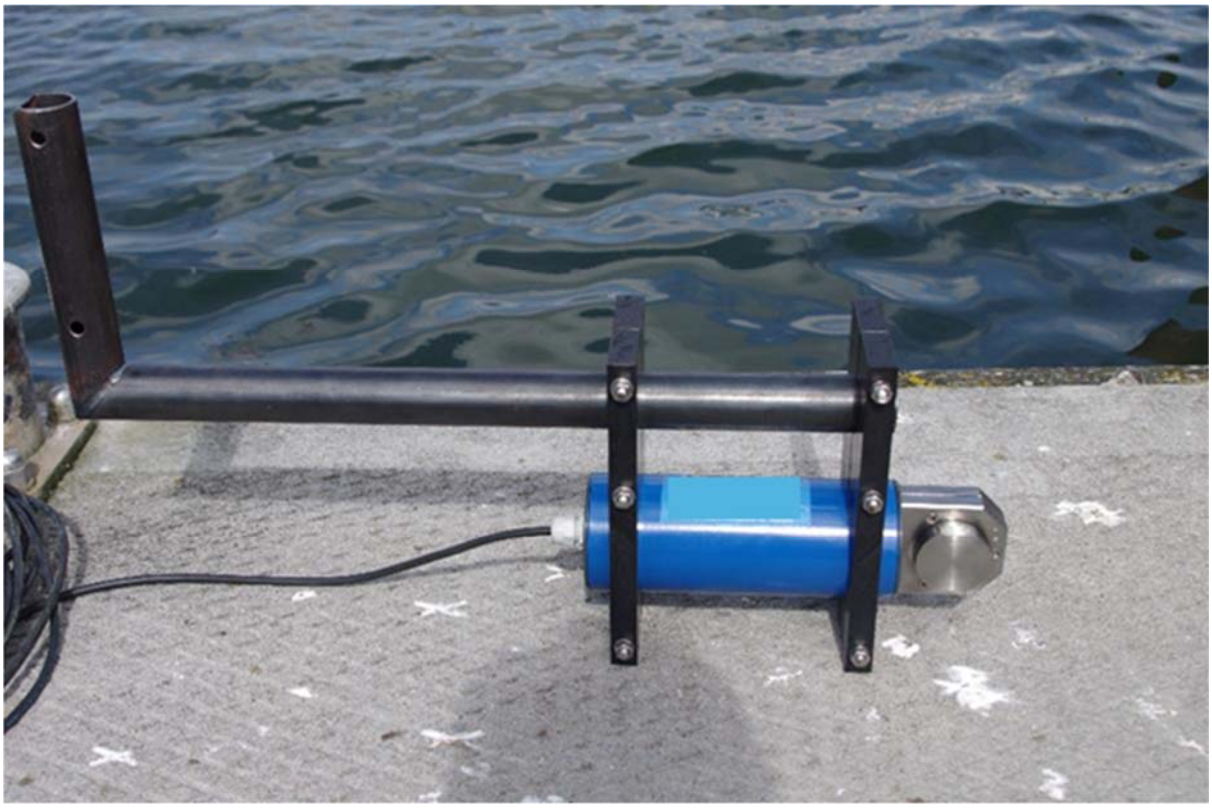


Figure 3. Ultrasonic transmitter out of the water.

A 100 Watt ultrasound transmitter was tested (Figure 3).

The sound pressure (dB) near the plates, as well as at some remote areas of the harbor for future reference locations, was measured on September 22, 2017. By request of the supplier of the transmitter, the values measured were converted to relative pressure (0-100%, Figure 4). The highest values (90-100%) were measured at 1 m to the left and right of the transmitter. On the reverse side of the test plates the sound pressure was reduced to 25%. At the control plate, and at areas inside the harbor 0 dB was measured (Figure 4).

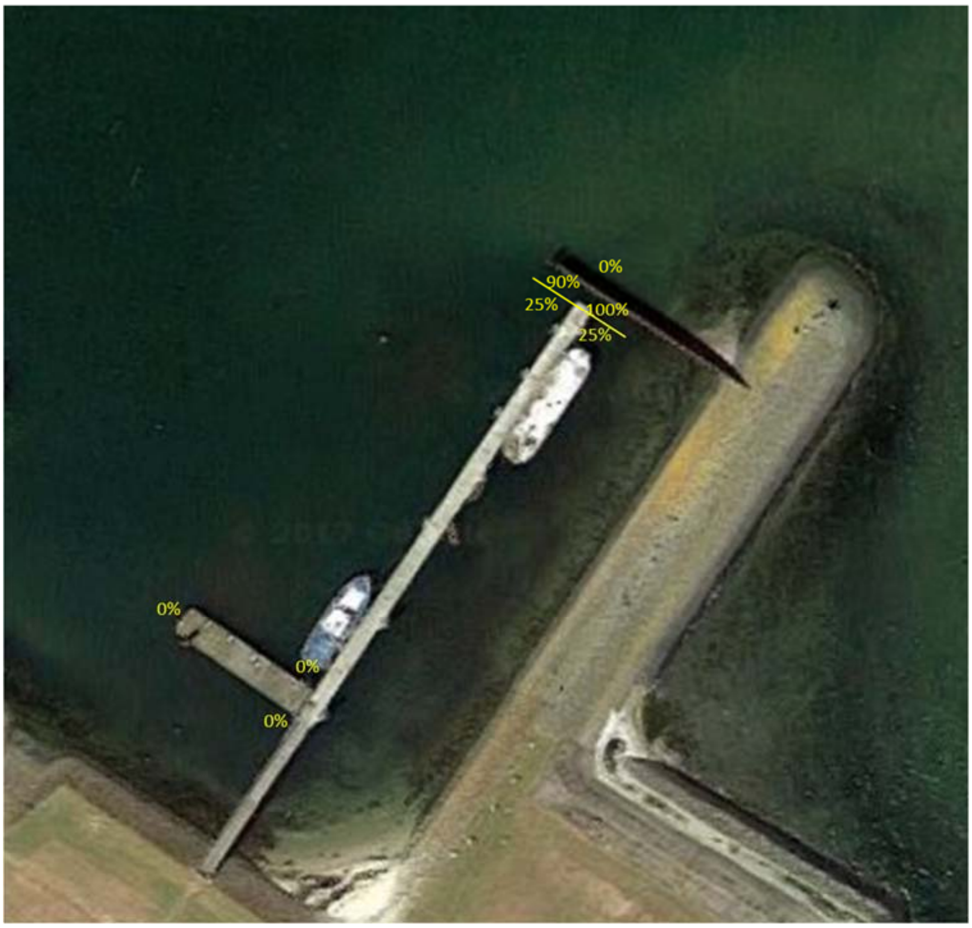


Figure 4. The relative sound pressure (0-100%) near the plates, as well as at some remote areas of the harbor for future reference locations.

Analysis

After deployment on August 30, 2017 the plates were photographed on a 1-2 week interval to monitor the settlement and growth of fouling organisms:

- Equipment used:
    - Pentax K-5 APS-C DSLR camera
    - Pentax DA 18-55 mm f 3.5-5.6 WR lens
    - Pentax DFA 100 mm f 2.8 Macro WR lens

- Photos are taken weekly if possible to monitor development of fouling on the plates.
- Plates are photographed out of the water where care is taken to return the plates to the water as soon as possible.
- **Test plates** are checked from the pontoon they are attached to, starting with the left, port side plate, hereafter referred to as “left plate”, followed by the right, starboard side plate, hereafter referred to as “right plate”.
- Attention was given to the presence of bacteria and microalgae on the plates when possible because these organisms form the first phase of the biotic biofilm.
- **Control plate** is checked on foot using waders if weather conditions and water depth (lower than -60 NAP) allow it. Otherwise available NIOZ vessels were used.

- **Camera settings** for the photos are: JPEG Fine, F/8, auto ISO, Av setting, auto white balance, auto focus for 18-55 mm lens and manual focus for 100 mm lens.
- **All plates** are photographed using this protocol:
    1. A series of photographs of the whole plate are taken from which the one with the one with the best focus and least motion blur is selected
    2. Detailed photos of ¼ sections of plate are taken (each of the four 2 x 2 pain squares) starting with top left, followed by top right, bottom left and bottom right.
    3. If possible (from a boat in rough weather this is not possible) macro photos are taken using the 100 mm macro lens at 1:5, 1:2 or 1:1 magnification, of each taxon of fouling organisms found on the plates themselves or the supporting frame.
    4. As test plates are photographed upside down, their corresponding photos are rotated.

    Note that it is only possible to photograph one side of the plates during deployment as the plates are situated on the end of a floating pontoon.

Final analysis

Plates removed on 19-10-2017 were kept in a 4°C fridge, stored upright in plastic bags, until analysed on 20-10-2010.

Analysis protocol was as follows:

- The whole plate was photographed
- A list of organisms present was made. Organisms were identified using a dissecting microscope.
- For every organism present, abundance was scored on all plate quadrants according to the following categories:
    - 0: absent,
    - +: present (<10 individuals/colonies),
    - ++: abundant (>9 individuals/colonies).
- In the case of colonial animals, colonies were counted, not individuals.
- Abundance of non-sessile organisms was not scored.

After the experiment, plates were wiped with the soft side of a dish cleaning sponge to gauge the attachment of the fouling organisms.

The abiotic and biotic data of the final analysis were processed as follows.

The abiotic data was grouped in relative sound pressure: 0-25-100%, i.e. control plates, front test plates and back test plates respectively. Then a distinction between low, medium and high irradiance was made, followed by the coatings: Intersleek and Sigmacover™ (NIOZ paint).

The biotic data was grouped in soft and hard species. Soft species comprised the algae, ascidians, hydroids and plumose bryozoans. The hard species were the barnacles, encrusting bryozoans and the tube worms.

Because the number of quadrants of the control (1 plate, 2 sides with each 2 quadrants/coating) differed from the test plates (2 plates, 2 sides each with each 2 quadrants/coating) the abundance of the organisms (0, 1 or 2 per quadrant, 8 soft species and 5 hard species) was made relative to the maximum abundance for either soft or hard species (100% would mean that all species scored ‘2’ on each quadrant).

Results

Installation and maintenance log

- On **21-07-2017** at 13:20 the installation location in NIOZ harbour was surveyed by Louis Peperzak, Jan-Dirk de Visser, Lodewijk van Walraven (all NIOZ) the transmitter supplier. It was determined that the steel support frame of the initial test plate design were too long for the water depth at the NIOZ harbor pontoon, and also that the plates would be situated on the sides of the pontoon in the "shadow" of the pontoon. It was decided to shorten the support frame and to add a steel spacer segment so the plates extend past the pontoon and are positioned in full view of the ultrasound transmitter.
- On **26-07-2017** at 14:30 the modified system was installed by Jan Dirk and Lodewijk. Modifications to the plates by Jan Dirk:

    1. Support frame shortened by ca. 0.5 m
    2. Steel spacer welded between support tubing and plate attachment
    3. All plates sand blasted

Water depth at this time was 110 cm under the shallowest (starboard, SB, right) plate. SB Plate bottom is situated approx. 50 cm below the water surface, which means there was approx. 60 cm clearance below the SB plate. This means that at low water spring tide the SB plate will sink partly into the sediment which was confirmed by checking again at 17:00 around low tide. We will try to flush away some sediment using NIOZ RV Stern. The control plate was attached too high on its support pole.

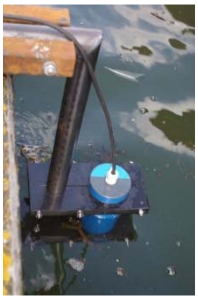


Figure 5. Ultrasonic transmitter deployed

Figure 6. Left plate deployed

Figure7. Right plate deployed

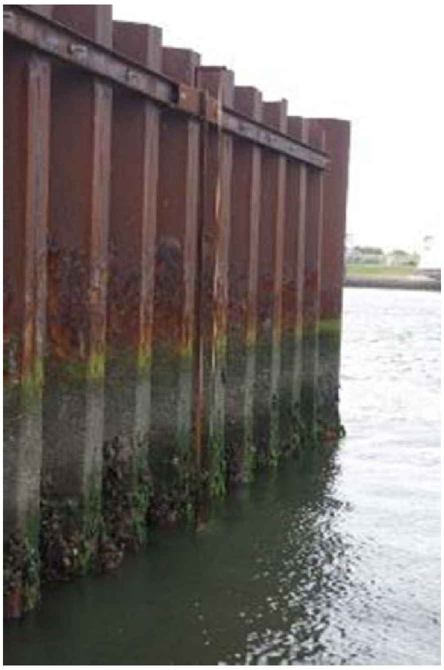


Figure 8. Control plate location

- On **31-07-2017** Jan Dirk moved the control plate ca. 0.5 m lower.
- **On 03-08-2017** the experiment was checked and photographed by Lodewijk. This revealed the plates were covered with a thick layer of rust and what looked like rust-coloured silt. It was decided to terminate the experiment and remove the plates for cleaning and coating.
- **On 09-08-2017** at 11:15 the plates were removed for cleaning and coating. Following, NIOZ RV Stern was used to flush sediment from the study site, resulting in approx. 30 cm increase in water depth at the site.
- On request by the transmitter supplier the plates were coated with two different coatings to compare the effect of combining ultrasound with anti-fouling paint. The plates were divided in four squares and coated in a 2x2 checkerboard pattern using two coating systems:
    1. **Control off-white two-component coating (Control paint) used on NIOZ vessels, consisting of:**
        - **Control paint 280 2-component epoxy primer**
        - **Control paint 456 2-component epoxy base layer**
        - **Control paint 550 2-component polyurethane top layer**
    2. **Intersleek 1100SR (Slime Resistant) coating system consisting of:**
        - **Intersleek 300 primer**
        - **Intersleek 737 base layer**
        - **Intersleek 1100SR top layer**
- **On 25-08-2017** the plates were re-installed by Lorendz Boom (NIOZ).
- **On 30-08-2017** the plates were checked by Lodewijk. The control plate was not reachable because of too high water level. Bolts securing the test plate mounting frame were rusted and stuck. They were hammered out and not replaced.
- **On 07-09-2017** all plates were checked and photographed again.
- **On 15-09-2017** all plates were checked again. Two days earlier (Wednesday 13 September) a SW storm force 8-10 bft occurred. The test plate frame was slightly tilted and the right side had detached from the pontoon. Tilt was temporarily fixed by placing a piece of concrete tile under the frame.
- **On 22-09-2017** the plates were checked again. Control plate gets stuck on rusty frame pole. Some grease helps, but the pole needs to be sanded or ground a bit slimmer. NIOZ workshop have reinforced the attachment to the jetty of the test plate frame.
- **On 16-10-2017** the NIOZ mobily bird observatory (“Wadtoren”) docked next to the test plates. This may have caused some more shadowy conditions in the last few days.
- **On 19-10-2017** the installation was removed. First the control plate, then the test plates. All plates were photographed before and after removal, and then packaged in plastic bags and transported upright to the NIOZ lab.

Weekly monitoring

The first deployment of the plates lasted from 26-7-2017 until 9-8-2017, using uncoated steel plates. The second deployment using coated plates lasted from 26-8-2017 until 19-10-2017. Results of the first deployment using uncoated plates will not be used in further analysis.

Fouling started with the formation of a slimy biofilm consisting of bacteria and microalgae, visible on all surfaces on all plates, the control plate as well as the test plates. Some of these organisms were sampled to serve as test organisms in future NIOZ research.

After the first biofilm a rapid growth took place on all test and control plates (Figure 9). The densest growth was observed on the test plates with control coating exposed to ultrasound, followed by the test plates with anti-fouling coating exposed to ultrasound.

Already after three weeks the biofilm was succeeded by a dense cover of macroalgae on the test plates with control paint. A similar macroalgal cover was observed on the control paint quadrants on the control plate, but it developed slower and the overall “greenness” was lower than on the test plates exposed to ultrasound. Also visible on the test plates were marks made by collision with floating objects, as well as grazing trails by periwinkle snails *Littorina littoralis*.

Intersleek coated surfaces remained only partly covered by slimy biofilms. On parts of the Intersleek quadrants bordering the control quadrants, the Intersleek appeared to be “wiped clean” by the macroalgae covering the control paint quadrants.

On the control plate the biofilm was often absent on upper and lower sides of the plates. This was probably related to the wave and sand abrasion at this more turbulent site compared to the inner NIOZ harbor.

A detailed photographic overview of the plates is presented in the Annexes.

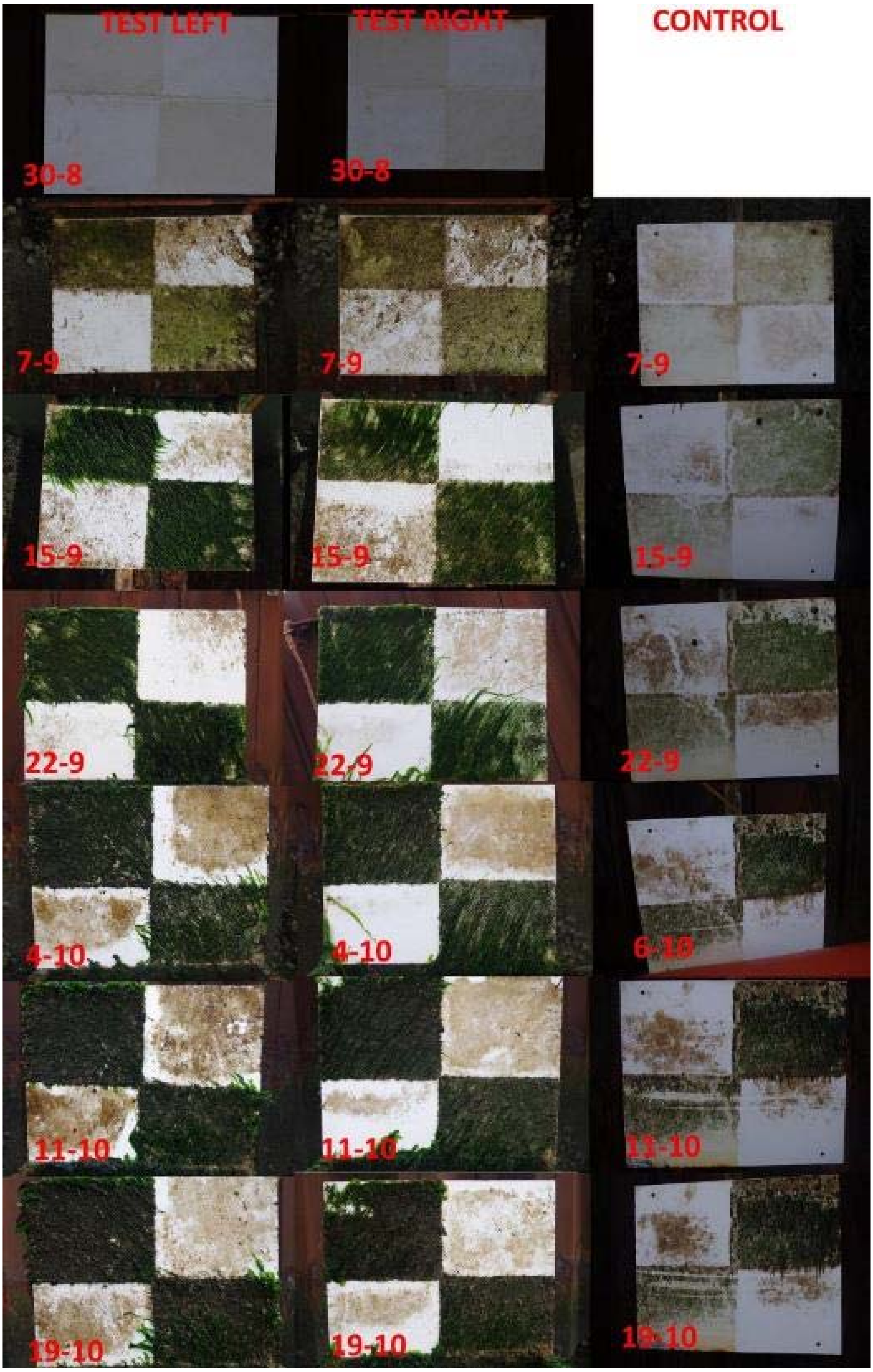


Figure 9. Mosaic of photos taken of

antifouling test plates. Note that weather and water conditions prevented photographing the test plate on this day. The test plates are photographed upside down.

Species observed

The following sessile organisms were found on the plates:

- Green algae (*Ulva* sp.)
- Red plumose algae (*Ceramium* sp.?)
- Brown plumose algae
- Ascidian (*Botrylloides* sp.)
- Ascidian (*Botryllus schlosseri*)
- Barnacle (*Semibalanus balanoides*)
- Barnacle (*Balanus* sp.)
- Stolonous hydroid (*Clytia* sp.?)
- Plumose hydroid (*Obelia* sp.?)
- Plumose bryozoan (*Tricellaria inopinata*?)
- Encrusting bryozoan (*Conopeum reticulum*)
- Tubeworm (*Spirobranchus* sp.)
- Miscellaneous worms and *Jassa* tubes

The following non-sessile organisms were found on the plates:

- Skeleton shrimp (*Caprella mutica*)
- Mud shrimp (*Corophium* sp.)
- Amphipod *Jassa* sp. (Probably *J. falcata*)
- Spionid worms
- One *Mytilus edulis* was found attached to the control plate backside frame, which had likely moved there from the seawall.

Relative abundance of organisms

Table 1. Abundance scores for all plate quadrants and all organisms combined. A detailed overview per plate can be found in the annexes.

Plate	Type	Plate side	Quadrant	Coating	Macroalgae	Ascidians	Barnacles	Hydroids	Bryozoans	tubeworms	miscellaneous sedimentary tubes
Control	Control	Back	1	Intersleek	0	0	0	0	0	0	0
Control	Control	Back	4	Intersleek	0	0	0	0	0	0	0
Control	Control	Front	1	Intersleek	0	0	0	0	0	0	0
Control	Control	Front	4	Intersleek	+	0	0	0	0	0	0
Test left	Test	Back	1	Intersleek	0	0	+	0	0	+	0
Test left	Test	Back	4	Intersleek	+	+	+	+	++	0	0
Test left	Test	Front	2	Intersleek	+	0	+	0	0	0	0
Test left	Test	Front	3	Intersleek	+	0	+	0	0	0	0
Test right	Test	Back	1	Intersleek	0	+	0	0	0	+	0
Test right	Test	Back	4	Intersleek	+	++	+	0	0	+	0
Test right	Test	Front	2	Intersleek	0	0	0	0	0	0	0
Test right	Test	Front	3	Intersleek	+	0	0	0	0	0	0
Control	Control	Back	2	Sigmacove	0	+	++	+	+	+	0
Control	Control	Back	3	Sigmacove	0	+	++	+	+	+	0
Control	Control	Front	2	Sigmacove	++	0	++	0	+	0	0
Control	Control	Front	3	Sigmacove	++	0	++	0	+	0	0
Test left	Test	Back	2	Sigmacove	++	+	++	++	++	0	+
Test left	Test	Back	3	Sigmacove	++	+	++	++	++	0	+
Test left	Test	Front	1	Sigmacove	++	+	++	0	++	0	+
Test left	Test	Front	4	Sigmacove	++	+	++	0	++	0	+
Test right	Test	Back	2	Sigmacove	++	+	++	0	++	0	++
Test right	Test	Back	3	Sigmacove	++	+	++	0	++	0	++
Test right	Test	Front	1	Sigmacove	++	+	++	++	++	0	+
Test right	Test	Front	4	Sigmacove	++	+	++	++	++	0	+

A more detailed analysis of the data is presented below (Table 2 and beyond).

Control plate

The front and back of the control plate showed different fouling community composition. On the back of the control plate no macroalgae were found, likely owing to the fact that this side was always shaded from sunlight.

On the Intersleek surfaces at the back of the control plate, no fouling organisms were found. On the control painted surfaces several fouling organisms were found: barnacles, hydroids, bryozoans, and ascidians.

On the Intersleek surfaces at the front of the control plate no fouling organisms were found, except for green macroalgae on one quadrant. On the control paint a dense cover of green and red macroalgae was found, together with *Semibalanus* barnacles and encrusting bryozoans.

Test plates

The front and back of the test plates had a largely similar fouling composition. Overall fouling composition of the left and right test plate showed similar patterns as well.

The Intersleek surfaces of the test plates were mainly covered in slimy biofilm, but fouling organisms were observed in low concentrations on Intersleek on several quadrants: red and green macroalgae, *Balanus* sp. barnacles, colonial ascidians, hydroids and tubeworms.

The control paint surfaces of the test plates were all densely covered in fouling organisms. The most abundant organisms were green, brown and red macroalgae, plumose bryozoans and barnacles. Also common were plumose hydroids, encrusting bryozoans, colonial ascidians and tubes made of silt built by *Jassa* sp. amphipods and polychaete worms.

Plate cleaning

After the experiment, plates were wiped with the soft side of a dish cleaning sponge. Fouling of Intersleek quadrants was easily wiped off in this way, but fouling on control paint quadrants could not be wiped off, and had to be scraped off using a paint stripper.

Table 2. Relative abundance of soft species (top 8) such as algae and hard species such as barnacles (lower 5). The back of the control plate received a low solar irradiance, a relative sound pressure of 0% and presumably low turbulence. The front of the control plate received a medium solar irradiance, a relative sound pressure of 0% and a high turbulence. The fronts of the test plates received a high solar irradiance and a relative sound pressure of 25%. The backs of the test plates received a medium solar irradiance and a relative sound pressure of 100% . All test plates experienced a low turbulence.

Relative sound pressure	0%	0%	0%	0%	25%	25%	100%	100%
Coating	Intersleek	Intersleek	NIOZ	NIOZ	Intersleek	NIOZ	Intersleek	NIOZ
Irradiance	low	medium	low	medium	high	high	medium	medium
Green algae (Ulva sp.)	0	1	0	4	3	8	1	8
Red plumose algae (Ceramium sp.?)	0	0	0	4	0	8	1	8
Brown plumose algae	0	0	0	0	1	2	0	6
Ascidian (Botrylloides sp.)	0	0	0	0	0	4	3	4
Ascidian (Botryllus schlosseri)	0	0	2	0	0	1	2	0
Plumose hydroid (Obelia sp.?)	0	0	0	0	0	4	0	4
Plumose bryozoan (Tricellaria inopinata?)	0	0	0	0	0	8	0	8
Stolonous hydroid (Clytia sp.?)	0	0	2	0	0	0	1	0
soft species sub total:	**0**	**1**	**4**	**8**	**4**	**35**	**8**	**38**
soft species sub maximum:	**32**	**32**	**32**	**32**	**64**	**64**	**64**	**64**
sub%:	**0%**	**3%**	**13%**	**25%**	**6%**	**55%**	**13%**	**59%**
Encrusting bryozoan (Conopeum reticulum)	0	0	2	2	0	2	2	4
Barnacle (Balanus sp.)	0	0	0	0	2	0	3	0
Barnacle (Semibalanus balanoides)	0	0	4	4	0	8	0	8
Tubeworm (Spirobranchus sp.)	0	0	0	0	0	0	3	0
Miscellaneous tube worms	0	0	0	0	0	4	0	6
hard species sub total:	**0**	**0**	**6**	**6**	**2**	**14**	**8**	**18**
hard species sub maximum:	**20**	**20**	**20**	**20**	**40**	**40**	**40**	**40**
sub%:	**0%**	**0%**	**30%**	**30%**	**5%**	**35%**	**20%**	**45%**
Total:	**0**	**1**	**10**	**14**	**6**	**49**	**16**	**56**
Maximum:	**52**	**52**	**52**	**52**	**104**	**104**	**104**	**104**
Maximum%:	**0%**	**2%**	**19%**	**27%**	**6%**	**47%**	**15%**	**54%**

Ultrasonic treatment effects

Table 3. Effects of ultrasonic treatment on relative organism abundance. The control was 0%, the front of the test plates was 25% and the back of the plates was 100%. Relative abundance data extracted from Table 2. The control plate with medium irradiance experienced a high turbulence.

Relative sound pressure	Coating	Irradiance	soft species	hard species
0%	Intersleek	low	0%	0%
0%	Intersleek	medium	3%	0%
0%	NIOZ	low	13%	30%
0%	NIOZ	medium	25%	30%
25%	Intersleek	high	6%	5%
25%	NIOZ	high	55%	35%
100%	Intersleek	medium	13%	20%
100%	NIOZ	medium	59%	45%

At 0% sound pressure the maximum relative abundances were 25% to 30% for soft and hard species respectively on NIOZ control paint (Table 3). These percentages were low compared to ultrasonic treatments, probably because the control plate was situated at a different, more turbulent part of the harbor.

An anti-fouling effect of ultrasonic treatment could not be established. For soft species the relative abundance was on Intersleek even increased from 6% to 13% when the sound pressure increased fourfold. For hard species the increase was even more pronounced: from 5% to 20%. The overall increase was 7% to 15%.

In addition, the relative abundance of soft species on control paint increased from 55% to 59% when the sound pressure increased fourfold. Again, for hard species the increase was even more pronounced: from 35% to 45%. The overall increase was 4% to 10%.

Although an increase in ultrasonic sound pressure resulted in higher relative abundances of both soft and hard species, causality cannot be inferred. For instance, at the 25% sound pressure the plates were exposed to a higher irradiance than at 100% sound pressure, culminating in a high abundance of algae that might have prevented the settlement of other organisms. The relatively small overall increases in abundance of 7% to 15% (Intersleek) and 4% to 10% (control paint) are probably not statistically significant. Therefore, there is no indication of a synergetic effect of Intersleek and ultrasonic treatment.

Intersleek versus Control paint

The differences between Intersleek (anti-fouling) and control paint were clear (Table 4). Control paint coated plates were covered in dense fouling, whereas Intersleek coated surfaces were only partly covered in a silty biofilm, with little fouling organisms growing on them. The relative abundance was 0 to 13% for soft species and 0 to 20% for hard species on Intersleek. In contrast, the relative abundance was 13 to 59% for soft species and 30 to 45% for hard species on NIOZ control paint.

An interesting observation is that on Intersleek coating, only barnacles of the genus *Balanus* were found, and on the control paint coated plates only barnacles of the genus *Semibalanus*. These barnacles have bases made of different materials: *Balanus* have calcified bases and *Semibalanus* have membraneous bases. It appears that only barnacles with calcified bases can settle on Intersleek coating.

Table 4. Effect of Intersleek versus control paint on relative organism abundance. Relative abundance data extracted from Table 2.

Coating	Relative sound pressure	Irradiance	soft species	hard species
Intersleek	0%	low	0%	0%
Intersleek	0%	medium	3%	0%
Intersleek	25%	high	6%	5%
Intersleek	100%	medium	13%	20%
NIOZ	0%	low	13%	30%
NIOZ	0%	medium	25%	30%
NIOZ	25%	high	55%	35%
NIOZ	100%	medium	59%	45%

Test plates versus control plate

The fouling community that settled on the test plates inside the harbor was partly comparable to the community that settled on the front of the control plate at the harbor entrance (0% sound pressure), although most organisms on the control plate such as macroalgae were smaller in size and less abundant. The lower biomass and abundance of fouling organisms on the control plate might be caused by different environmental conditions at the control and test locations. The control plate location was more exposed, and it was mounted on a fixed frame, rather than a floating dock. Because of this, the control plate was exposed to varying water levels because of the tide, leading to less net fouling.

Conclusions

The goal of this test was to investigate the effectiveness of an ultrasound transmitter in preventing attachment and growth of fouling organisms on submerged coated surfaces under realistic field conditions. Three relative intensities of ultrasonic sound pressure were applied: 0%, 25% and 100%. The test showed that macro-fouling organisms settled and grew on all plates exposed to ultrasound. This result applies to both soft (e.g. algae) and hard species (e.g. barnacles). An anti-fouling effect of ultrasonic treatment could not be established.

The antifouling coating Intersleek 1100SR was compared with Sigmacover™, a control paint used on NIOZ vessels. On Intersleek the relative abundance for soft species and hard species ranged from 0% to 20%. In contrast, on NIOZ control paint the relative abundances were 13 to 59%. Intersleek 1100SR had a distinct anti-fouling effect.

As an additional goal, the possible synergetic effect of ultrasonic sound and Intersleek 1100SR was examined. The lowest biomass and abundance of fouling organisms was found on the 0% sound pressure plate which was caused by different environmental conditions compared to the 25% and 100% test location. Comparing the 25% and 100% sound pressure test plates did not reveal a synergetic effect of Intersleek and ultrasonic treatment.

It is concluded that the ultrasound exposure was not an effective anti-fouling treatment, either alone or in combination with Intersleek anti-fouling paint.

Annexes with plate descriptions

Date: 30-08-2017

Time: 13:00
Weather: N 5/6, rainshowers
Water: NAP -10
Researcher: Lodewijk van Walraven

Left plate:

Left test plate. Top left and bottom right: Control paint coated. Top right and bottom left: Intersleek 1100SR coated.

Two colonal ascidians are found on quadrant 4 (Control paint):

Otherwise no macroscopic fouling is observed.

Right plate:

Right test plate. Top left and bottom right: Control paint coated. Top right and bottom left: Intersleek 1100SR coated.

No macrofouling observed on the plate, but greenish streaks are seen on the painted surfaces:

Control plate not photographed because of weather conditions and too high water level

Date: 7-9-2017

Time: 16:20
Weather: SW 5, overcast
Water: ca -75 cm NAP
Researcher: Lodewijk van Walraven, Louis Peperzak

Control plate shows biofilm on all surfaces, with some attached sediment and a greenish tinge on the Control painted surfaces. Test plates show similar pattern of biofilm and dense small green algae cover on Control paint surfaces and patches of slime and silt on Intersleek surfaces.

Louis Peperzak took samples of bacteria and algae from the test plates.

Left plate:

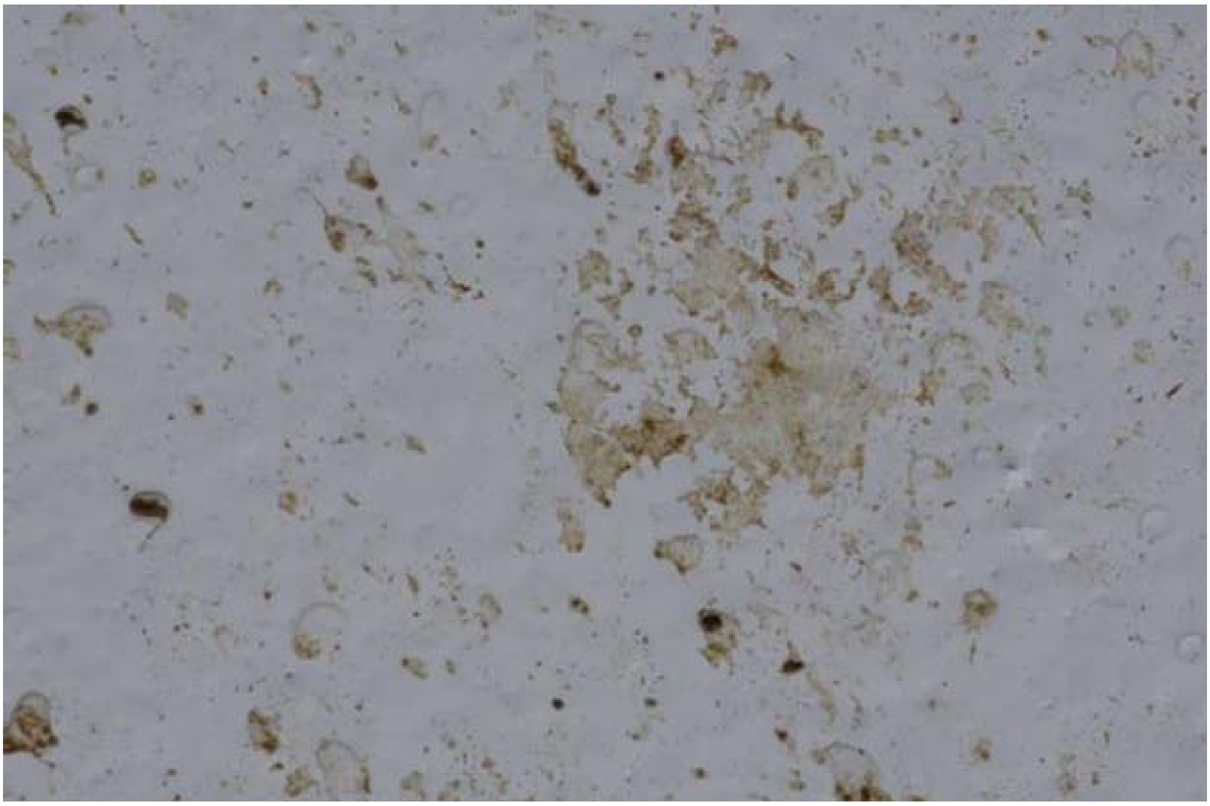
Left test plate. Top left and bottom right: Control paint coated. Top right and bottom left: Intersleek 1100SR coated.

Quadrant 4:

1:5 detail:

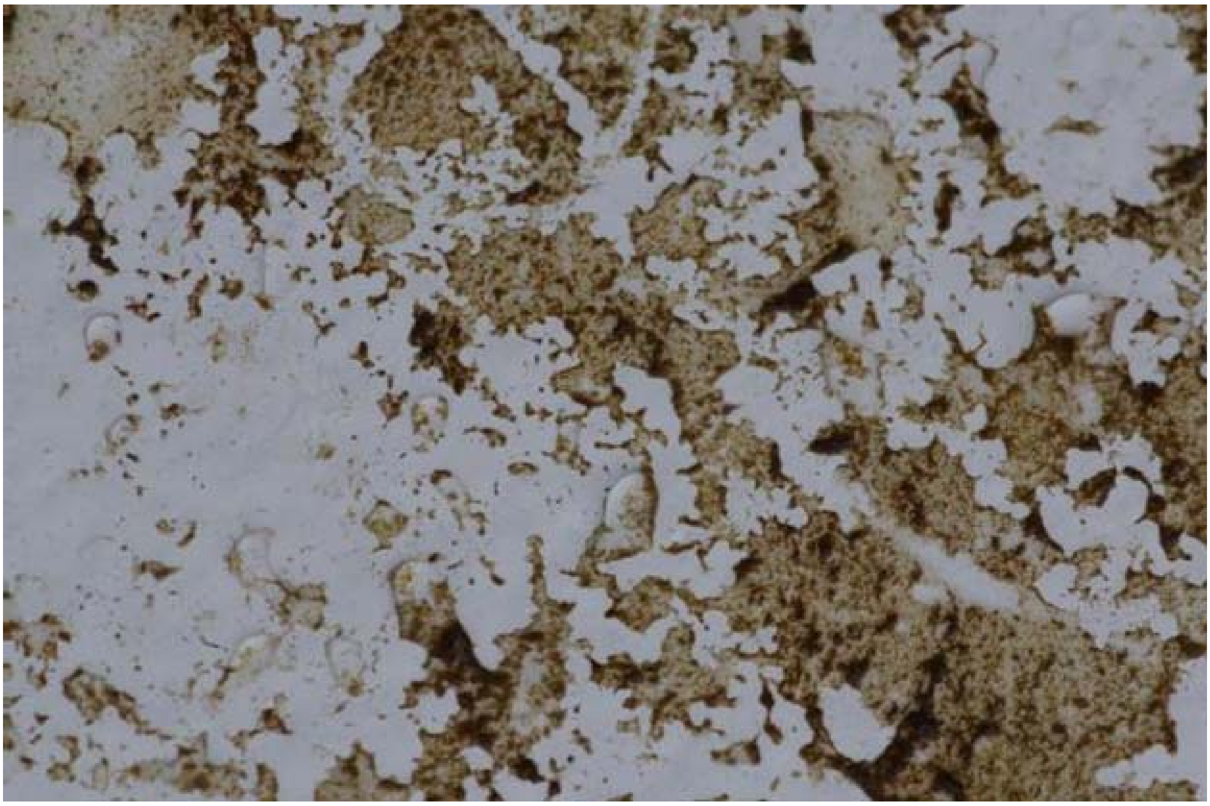
Quadrant 3:

1:5 detail:



Quadrant 2, note zig-zag patterns of grazing organisms:

1:5 detail:



Quadrant 1:

1:5 detail:

Right plate:

Right test plate. Top left and bottom right: Control paint coated. Top right and bottom left: Intersleek 1100SR coated.

Quadrant 4:

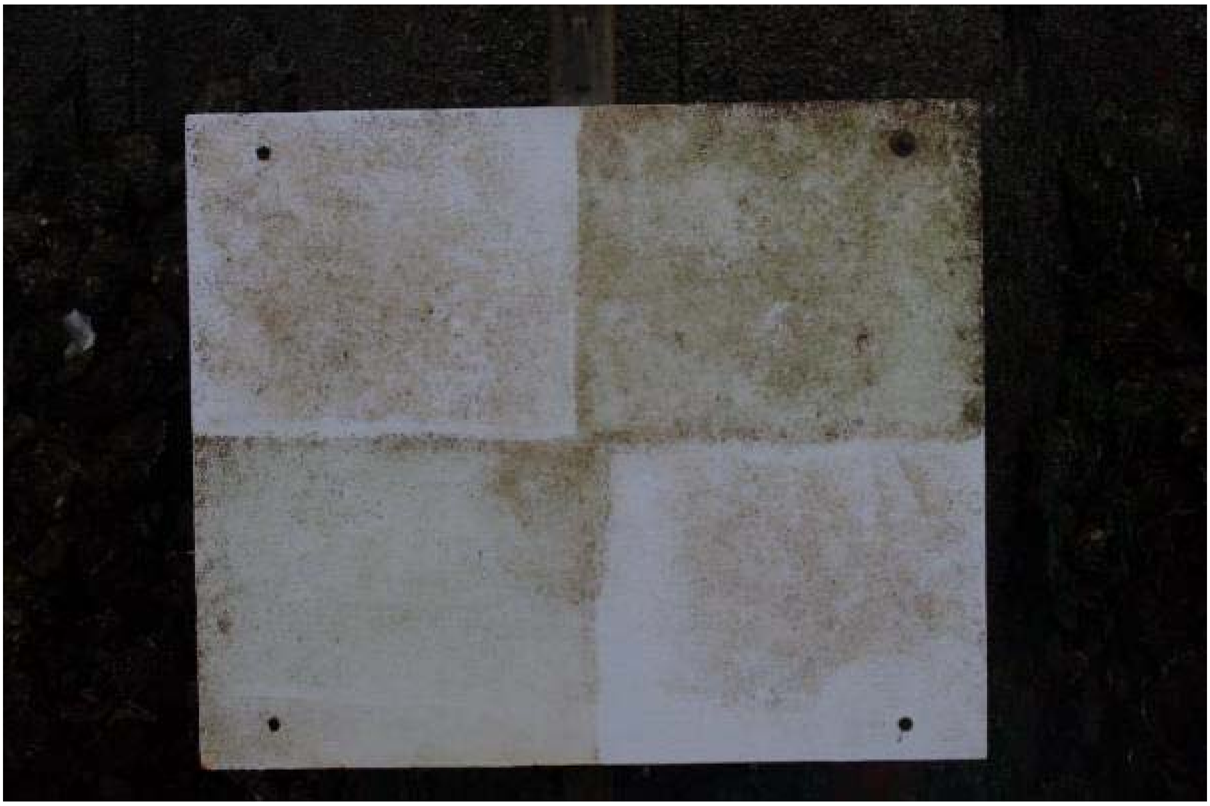
Quadrant 3:

Quadrant 2:

Quadrant 1:

Control plate:

A silty biofilm is visible in all four segments, more pronounced in the NIOZ-paint segments:



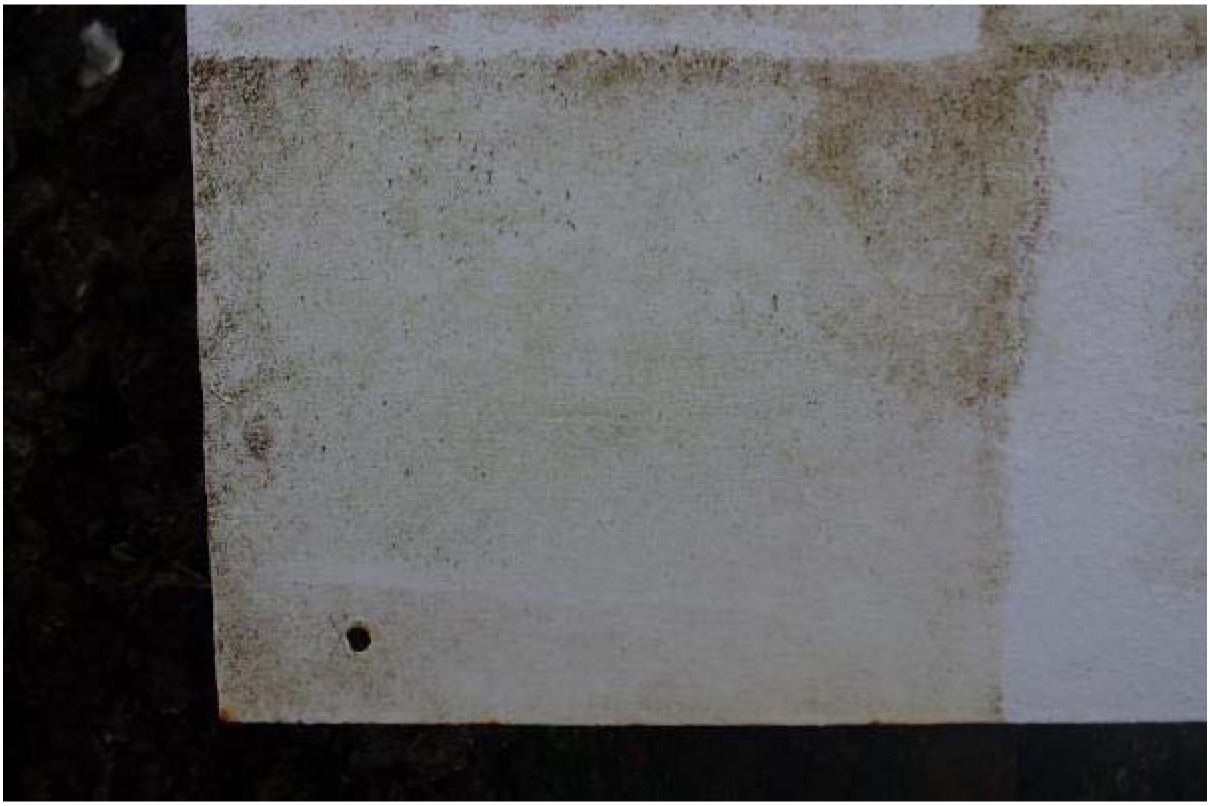
Control plate. Top left and bottom right: intersleek 1100SR coated. Top right and bottom left: Control paint coated.

Detailed photos show a greenish sheen, most clearly seen on the Control painted surfaces.

Quadrant 1:

Quadrant 2:

Quadrant 3:



Quadrant 4:

Date: 15-09-2017

Time: 08:45 (control plate) 11:30 (test plates)
Weather: W4, sunny with some clouds
Water: -50 cm NAP (control plate) +20 cm NAP (test plates)
Researcher: Lodewijk van Walraven

Green macroalgae cover on has increased on Control paint coated surfaces. Also on the control plate small green macroalgae are now visible. Barnacles are visible on Control paint coated surfaces of control plate and test plate. Other fouling organisms observed on test plates: bryozoans, colonial ascidians. Intersleek surfaces only show patches of biofilm/silt and no fouling organisms.

Left plate:

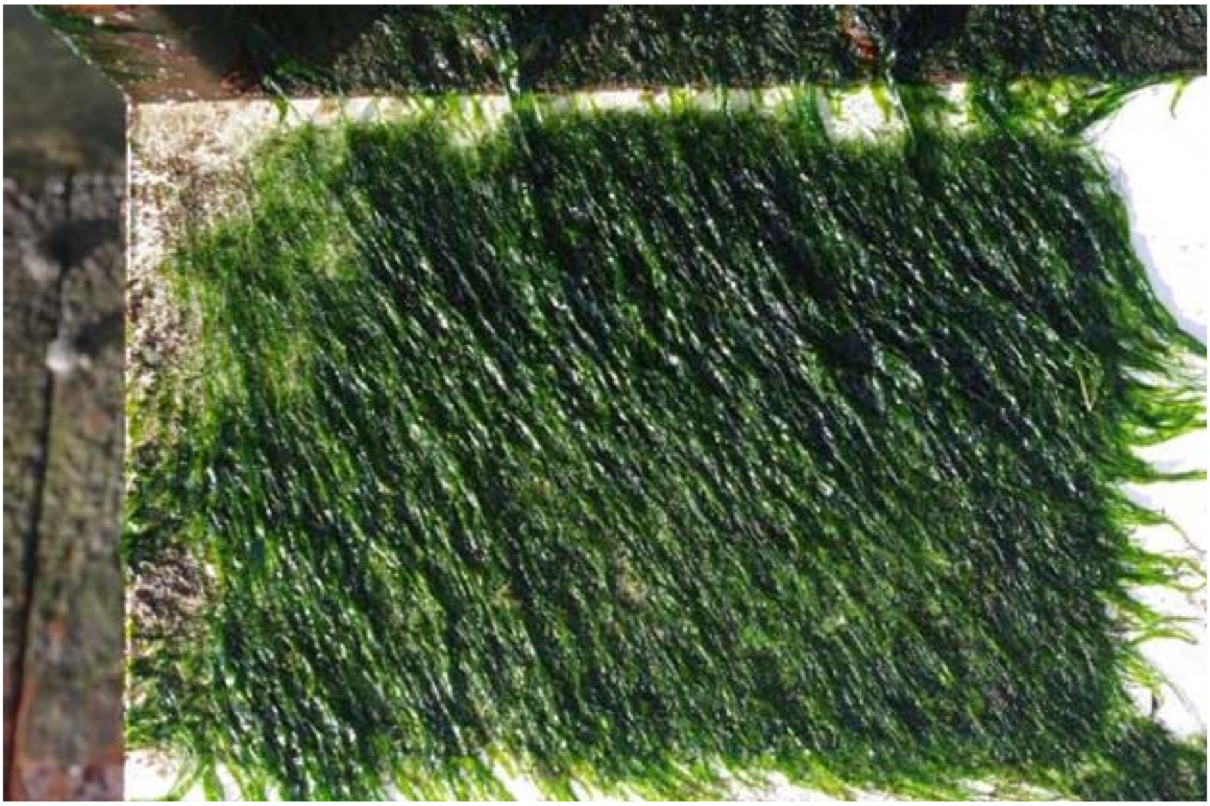
Dense cover of green macroalgae on Control paint coated surfaces. Barnacles visible in lower right corner. Intersleek surfaces show biofilm/silt cover.

Detail, quadrant 4:

Detail, quadrant 3:

Detail, quadrant 2:

Detail, quadrant 1:



Right plate:

Dense cover of green macroalgae on Control paint coated surfaces. Barnacles visible in upper left corner. Intersleek surfaces show biofilm/silt covering, most prominent in lower left corner.

Detail, quadrant 4:

Detail, quadrant 3:

Detail, quadrant 2:

Detail, quadrant 1:

Control plate:

Growth of small green macroalagae on Control painted surfaces. Small worm tubes are also visible. These surfaces show a grazing trail of the snail *Littorina littorea*, the snail itself is present in the top right panel. In the path of the snail small barnacles are visible. Intersleek surfaces show patches of silt/biofilm.

Control plate. Top left and bottom right: intersleek 1100SR coated. Top right and bottom left: Control paint coated.

Detail, quadrant 1:

Detail, quadrant 2:

Detail, quadrant 3:

Detail, quadrant 4:

Date: 22-09-2017

Time: 08:45 (control plate) 10:00 (test plates)
Weather: S2, overcast
Water: +80 cm NAP (control plate) +20 cm NAP (test plates)
Researcher: Lodewijk van Walraven

Acoustic measurements were taken by the transmitter supplier, Louis Peperzak and Lodewijk van Walraven.

Control plate recovery from NIOZ fyke boat. Recovery was difficult as rusty support pipe causes plate to get stuck often. Some grease helped.

Control plate:

Quadrant 1:

Quadrant 2:

Quadrant 3:

Quadrant 4:

Test plate left:

Quadrant 4:

Quadrant 3:

Quadrant 2:

Quadrant 1:

Test plate right:

Quadrant 4:

Quadrant 3:

Quadrant 2:

Quadrant 1:

Date: 04-10-2017 (test plates) 06-10-2017 (control plate)

Time: 13:30 (control plate) 14:30 (test plates)
Weather: SW7, overcast (test plates) NW 7 (control plate)
Water: +20 cm NAP (control plate) -55 cm NAP (test plates)
Researcher: Lodewijk van Walraven

Because of a storm the check of the control plate had to be postponed and carried out using the MOB boat of RV Navicula. Weather conditions (NW 7 bft winds) made it very difficult to take good photographs without damaging either the boat or the plate.

Control plate:

Quadrant 1:

Quadrant 2:

Quadrant 3:

Quadrant 4:

Test plate left:

Quadrant 4:

Quadrant 3:

Quadrant 2:

Quadrant 1:

Test plate right:

Quadrant 4:

Quadrant 3:

Quadrant 2:

Quadrant 1:

Date: 11-10-2017

Time: 15:26
Weather: SW 6
Water: +/- 0 cm NAP
Researcher: Lodewijk van Walraven

Control plate checked using NIOZ Vlet.

Control plate:

Quadrant 1:

Quadrant 2:

Quadrant 3:

Quadrant 4:

Test plate left:

Quadrant 4:

Quadrant 3:

Quadrant 2:

Quadrant 1:

Test plate right:

Quadrant 4:

Quadrant 3:

Quadrant 2:

Quadrant 1:

Date: 19-10-2017 the installation was removed

First the control plate and then the test plates. Directly after removal the plates were photographed.

Date: 19-10-2017
Time: 10:50
Weather: Partly sunny, SE 4
Water: +/- 0 cm NAP
Researcher: Lodewijk van Walraven

Control plate:

Quadrant 1:

Quadrant 2:

Quadrant 3:

Quadrant 4:

Test plate left:

Quadrant 4:

Quadrant 3:

Quadrant 2:

Quadrant 1:

Test plate right:

Quadrant 4:

Quadrant 3:

Quadrant 2:

Quadrant 1:

Close-up photos of ultrasonic transmitter:

Final plate check and fouling analysis photos and data

Left test plate:

Plate side	Front	Front	Front	Front	Back	Back	Back	Back
Quadrant	1	2	3	4	1	2	3	4
Coating	Control paint	Intersleek	Intersleek	Control paint	Intersleek	Control paint	Control paint	Intersleek
Organism:								
Green algae (*Ulva* sp.)	++	+	+	++	0	++	++	+
Red plumose algae (*Ceramium* sp.?)	++	0	0	++	0	++	++	0
Brown plumose algae	0	0	0	0	0	+	+	0
Ascidian (*Botrilloides* sp.)	+	0	0	+	0	+	+	+
Ascidian (*Botrillus schlosseri*)	0	0	0	0	0	0	0	+
Barnacle (*Semibalanus balanoides*)	++	0	0	++	0	++	++	0
Barnacle (*Balanus* sp.)	0	+	+	0	+	0	0	+
Stolonous hydroid (*Clytia* sp.?)	0	0	0	0	0	0	0	+
Plumose hydroid (*Obelia* sp.?)	0	0	0	0	0	++	++	0
Plumose bryozoan (*Tricellaria inopinata*?)	++	0	0	++	0	++	++	0
Encrusting bryozoan (*Conopeum reticulum*)	+	0	0	0	0	+	+	++
Tubeworm (*Spirobranchus* sp.)	0	0	0	0	+	0	0	0
misc. *Jassa* or worm tubes	+	0	0	+	0	+	+	0

Right test plate:

Plate side	Front	Front	Front	Front	Back	Back	Back	Back
Quadrant	1	2	3	4	1	2	3	4
Coating	Control paint	Intersleek	Intersleek	Control paint	Intersleek	Control paint	Control paint	Intersleek
Organism:								
Green algae (*Ulva* sp.)	++	0	+	++	0	++	++	0
Red plumose algae (*Ceramium* sp.?)	++	0	0	++	0	++	++	+
Brown plumose algae	0	0	+	++	0	++	++	0
Ascidian (*Botrilloides* sp.)	+	0	0	+	0	+	+	++
Ascidian (*Botrillus schlosseri*)	+	0	0	0	+	0	0	0
Barnacle (*Semibalanus balanoides*)	++	0	0	++	0	++	++	0
Barnacle (*Balanus* sp.)	0	0	0	0	0	0	0	+
Stolonous hydroid (*Clytia* sp.?)	0	0	0	0	0	0	0	0
Plumose hydroid (*Obelia* sp.?)	++	0	0	++	0	0	0	0
Plumose bryozoan (*Tricellaria inopinata*?)	++	0	0	++	0	++	++	0
Encrusting bryozoan (*Conopeum reticulum*)	+	0	0	0	0	+	+	0
Tubeworm (*Spirobranchus* sp.)	0	0	0	0	+	0	0	+
misc. *Jassa* or worm tubes	+	0	0	+	0	++	++	0

Control plate:

Plate side	Front	Front	Front	Front	Back	Back	Back	Back
Quadrant	1	2	3	4	1	2	3	4
Coating	Intersleek	Control paint	Control paint	Intersleek	Intersleek	Control paint	Control paint	Intersleek
Organism:								
Green algae (*Ulva* sp.)	0	++	++	+	0	0	0	0
Red plumose algae (*Ceramium* sp.?)	0	++	++	0	0	0	0	0
Brown plumose algae	0	0	0	0	0	0	0	0
Ascidian (*Botrilloides* sp.)	0	0	0	0	0	0	0	0
Ascidian (*Botrillus schlosseri*)	0	0	0	0	0	+	+	0
Barnacle (*Semibalanus balanoides*)	0	++	++	0	0	++	++	0
Barnacle (*Balanus* sp.)	0	0	0	0	0	0	0	0
Stolonous hydroid (*Clytia* sp.?)	0	0	0	0	0	+	+	0
Plumose hydroid (*Obelia* sp.?)	0	0	0	0	0	0	0	0
Plumose bryozoan (*Tricellaria inopinata*?)	0	0	0	0	0	0	0	0
Encrusting bryozoan (*Conopeum reticulum*)	0	+	+	0	0	+	+	0
Tubeworm (*Spirobranchus* sp.)	0	0	0	0	0	+	+	0
misc. *Jassa* or worm tubes	0	0	0	0	0	0	0	0

Close-up photos of fouling organism photos (test plates)

Plumose bryozoan on Control paint.

Plumose bryozoan from Control paint, photo through dissection microscope

Encrusting bryozoan *Conopeum reticulum* on Control paint

Encrusting bryozoan, photo through dissection microscope

***Ulva* sp. Green macroalgae on Control paint**

***Ceramium* sp. Red macroalgae on control paint**

***Ceramium* sp. Red macroalgae on control paint, photo through dissection microscope**

***Semibalanus balanoides* on Control paint**

***Ulva* sp. Green macroalgae on Intersleek**

Balanus sp. Barnacle on intersleek

Comparison of barnacle bases. Left: Calcified base of *Balanus* so. Right: Membraneous base of *Semibalanus* sp.

Colonial ascidian *Botrilloides schlosseri* found on Control paint

Close-up photos of fouling organism photos (control plates)

Semibanalus barnacles and macroalgae cover on Control paint control plate

Macroalgae cover on Control paint control plate

Semibalanus barnacles and *Spigobranchus* tubeworm tubes.

Japanese oyster on the border between an Intersleek and a Control paint quadrant.

Using and conserving our blue planet, starts with understanding our changing seas. NIOZ conducts excellent marine research for society, from the deltas to the deepest oceans. Our science and national marine facilities help scientific communities businesses, ngo's and policy makers to address some of the biggest challenges ahead.

Royal NIOZ is part of the institutes oranisation of NWO, in cooperation with Utrecht University.

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