Fujifilm Hunt Chemicals USA, Inc

Biofouling Adhesion Report

July 2011

Exposure Date: September 10, 2010

Prepared for:
Hai Wan and Steve Escaravage
Technical Development Center
Fujifilm Hunt Chemicals USA, Inc.
40 Boroline Road
Allendale, NJ 07401

Prepared by:
Kelli Zargiel and Geoff Swain
Center for Corrosion and Biofouling Control
Florida Institute of Technology
Melbourne, FL

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Methods

Methods

- On September 10, 2010, four double sided panel treatments were submerged 0.5 m below the water surface at the Florida Institute of Technology's static immersion test site. Panels were kept in a caged environment to deter predation and grazing by fish. This panels will be referred to throughout the report as 'Static'.

- On September 10, 2010, replicates of two panel treatments were exposed in the Florida Institute of Technology's dynamic seawater ager. Panels were subjected to moving seawater for four months and removed and placed at the static immersion site on January 14, 2011. These panels will be referred to throughout the report as 'Dynamic'.

- A description of panels and the acronyms used throughout this report are on slide 5.

- On April 13, 2011 and June 30, 2011, hard fouling adhesion was measured using ASTM method D5618-94. A description of the method is seen on slide 6. Results from this method are on slides 10-13. In April only tubeworm data was collected, however, in June measurements for both barnacles and tubeworms were collected. Panels were then cleaned back and redeployed on both sampling dates.

- The Biofouling performance of the panels was assessed on June 30, 2011 using the ASTM method D6990. A description of this method is seen on slide 7 and 8. A graph of these results can be seen on slide 14 and 15.

- Pre adhesion photographs for both April 13 and June 30 begin on slide 16.

- A summary of results is located on slide 29.

List of Panels

Table 1: List of coatings, replicates, and panel orientation in the water column.

Treatment	Coating	Coating Color	Replicates	Orientation
Static	Sample 1	Black	2	North and South
Static	Sample 2	Black	2	North and South
Static	Sample 3	Red	2	North and South
Static	Sample 4	White	2	North and South
Dynamic	Sample 1	Black	2	North and South
Dynamic	Sample 2	Black	2	North and South

Hard Fouling Adhesion ASTM D5618-94

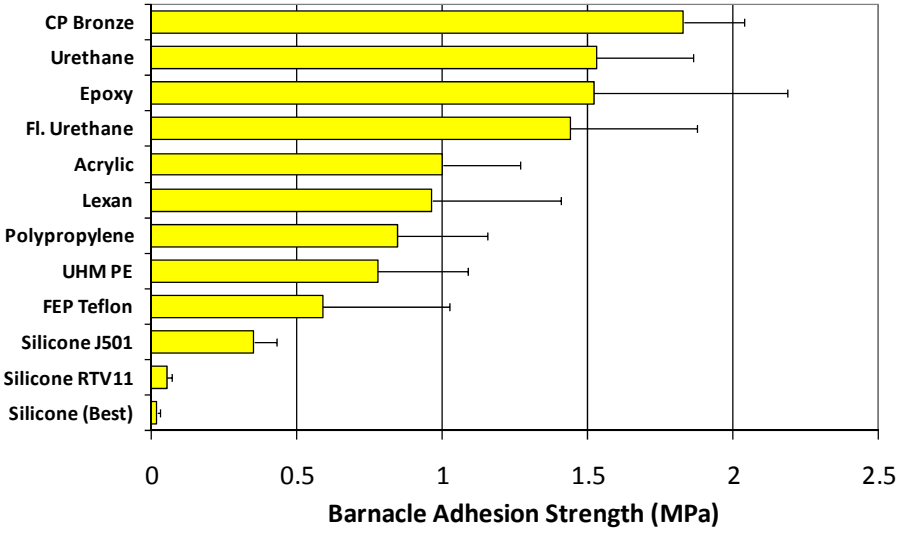


Figure 1: Average barnacle adhesion measurements for a range of surfaces. Measurements were made using ASTM D5618.

- Live hard fouling organisms are selected.
- A shear force is applied to the base of the organism.
- The force required to remove the organism is measured.
- Adhesion failure must be between the organism and the surface for the reading to be valid. The whole organism must be removed intact with no damage to the surface or the base plate.
- The organism is retained and returned to the laboratory.
- The base surface area is measured using a scanner.
- The shear strength of adhesion (MPa) is calculated by dividing the force for removal (Newtons) by the area of the organism base (square millimeters).

Biofouling and Physical Condition ASTM D6990-05

- Only organisms directly attached to the coating system are recorded.
- Absorbed organic and inorganic chemicals, trapped silt and detritus, are recorded as “silt” but are not included in calculations of “foul rating”.
- Diatoms, initial algal germination and low form algae are recorded as “biofilm”. Regardless of how much of the panel is covered, presence of a biofilm leads to a “foul rating” of 99.
- Immature foulers are recorded as incipient fouling but are not included in calculations of “foul rating”.
- Mature forms of foulers are recorded as percentage cover.
- Percent cover of gammarid amphipods is not considered when generating “fouling rating” but may be reported as a footnote
- Physical condition of the coating is reported according to the definitions provided in the standard as a percentage of surface affected by film defects

Common Fouling Organisms

Table 2: A list and description of common fouling organisms observed at the Florida Institute of Technology static immersion site.

Fouling Type	Abbreviation	Definition
Incipient fouling	IF	Recently settled and juvenile forms of macrofouling
Silt	Si	Adsorbed organic and inorganic chemicals, trapped silt and detritus, and unidentified slimes
Biofilm	Sl	Diatoms, initial algae germination, and low form algae, bacterial growth
Algae	Al	Fully established alga types and larger forms, e.g. *Ulva* sp., *Enteromorpha* sp. and *Ectocarpus* sp.
Encrusting Bryozoans	EB	Colonial animals forming an encrusting layer over the surface; these layers are generally 1-2 mm thick and have rough texture
Arborescent Bryozoans	Br	Colonial animals forming a turf like mat rarely exceeding 3 cm in length; they may be mistaken for plants
Barnacles	Barn	A hard shelled crustacean that cements itself permanently to a substrate, and is difficult to remove; the outer shell is generally whitish in color and shaped like a truncated cone. The barnacles in this area may grow to 2 cm in height and 2 cm in width at the base; the most abundant species at the FIT test site is *Balanus eburneus*
Polychaete Calcareous	TW	Tubeworms that form a hard calcareous exoskeleton which becomes cemented to the substrate; the individuals rarely exceed 2 cm in length and may show some coiling .
Sponges	Sp	Soft animals with sponge like texture forming thin surface cover or thicker accumulations, often brightly colored.
Tunicates	Tun	Soft animals that may be solitary or colonial; solitary types may reach several centimeters in height and colonial forms tend to form a think cover over the surface.
Molluscs	Mol	Animals with two hard shells, hinged along one edge; typical examples are oysters and mussels.
Hydrozoan	Hyd	Low form, highly branching organisms.

Results

Tubeworm Adhesion Results 4.13.2011 and 6.30.2011

Table 3: Tubeworm adhesion measured on 4.13.2011

Treatment	Sample #	Panel Color	Average	Std Dev	n
Static	1	Black	0.0740702	0.010709	3
Static	2	Black	0.024	0.012241	5
Static	3	Red	0.029	0.011253	3
Static	4	White	0.0279		1
Dynamic	1	Black			0
Dynamic	2	Black			0

Table 4: Tubeworm adhesion measured on 6.30.2011

Treatment	Sample #	Panel Color	Average	Std Dev	n
Static	1	Black	0.026		1
Static	2	Black	0.041	0.002534	2
Static	3	Red	0.041	0.031985	4
Static	4	White	0.021		1
Dynamic	1	Black	0.088	0.008335	2
Dynamic	2	Black	0.046	0.050296	2

Tubeworm Adhesion Results 6.30.2011

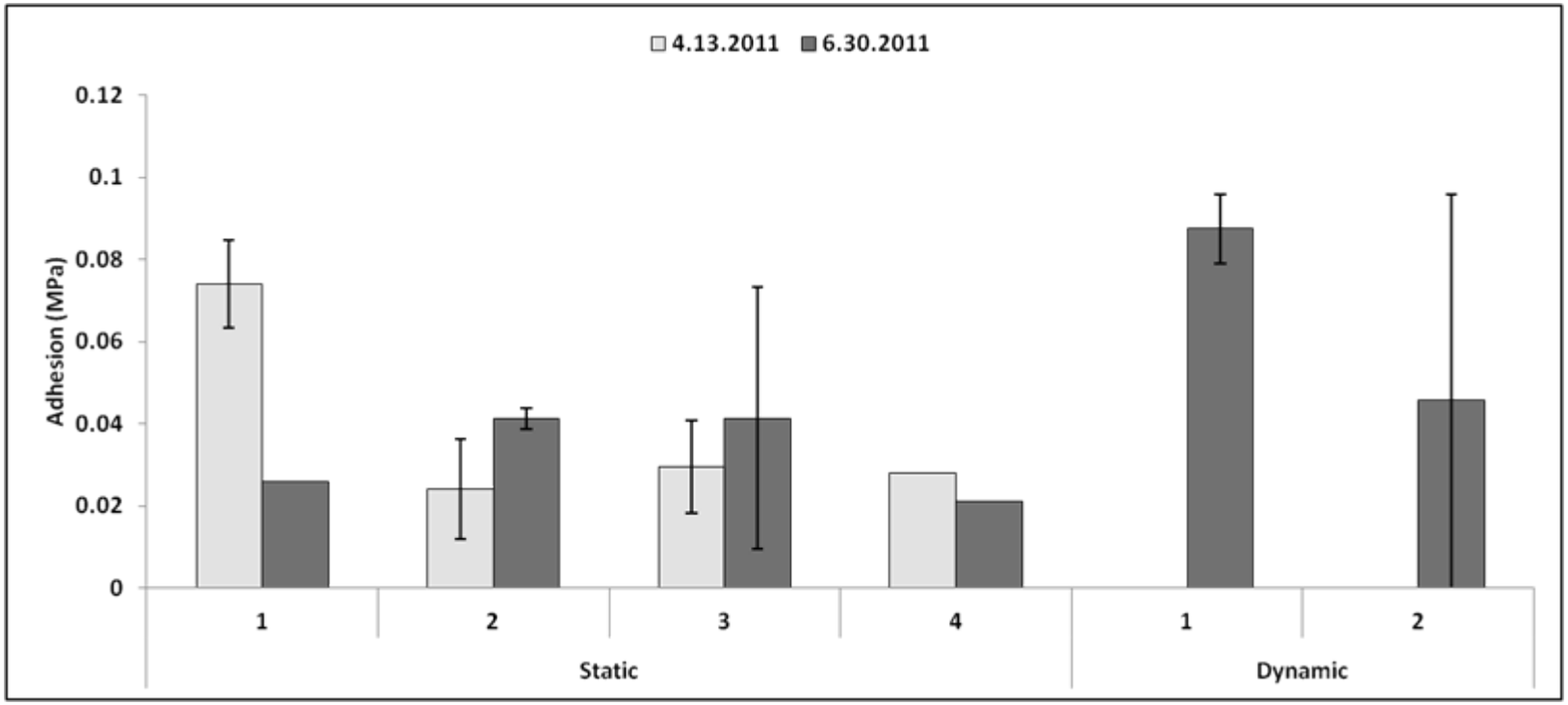


Figure 2: Average tubeworm adhesion and standard deviation for April 13, 2011 and June 30, 2011. There is no significant difference between dates. A significant difference is present among panels ($p<0.05$).

Barnacle Adhesion Results 6.30.2011

Table 5: Barnacle adhesion measured on 6.30.2011

Treatment	Sample #	Panel Color	Average	Std Dev	n
Static	1	Black	0.037	0.018348	5
Static	2	Black			0
Static	3	Red	0.037	0.00109	2
Static	4	White	0.017	0.017	2
Dynamic	1	Black	0.038	0.016726	11
Dynamic	2	Black	0.032	0.015212	9

Barnacle Adhesion Results 6.30.2011

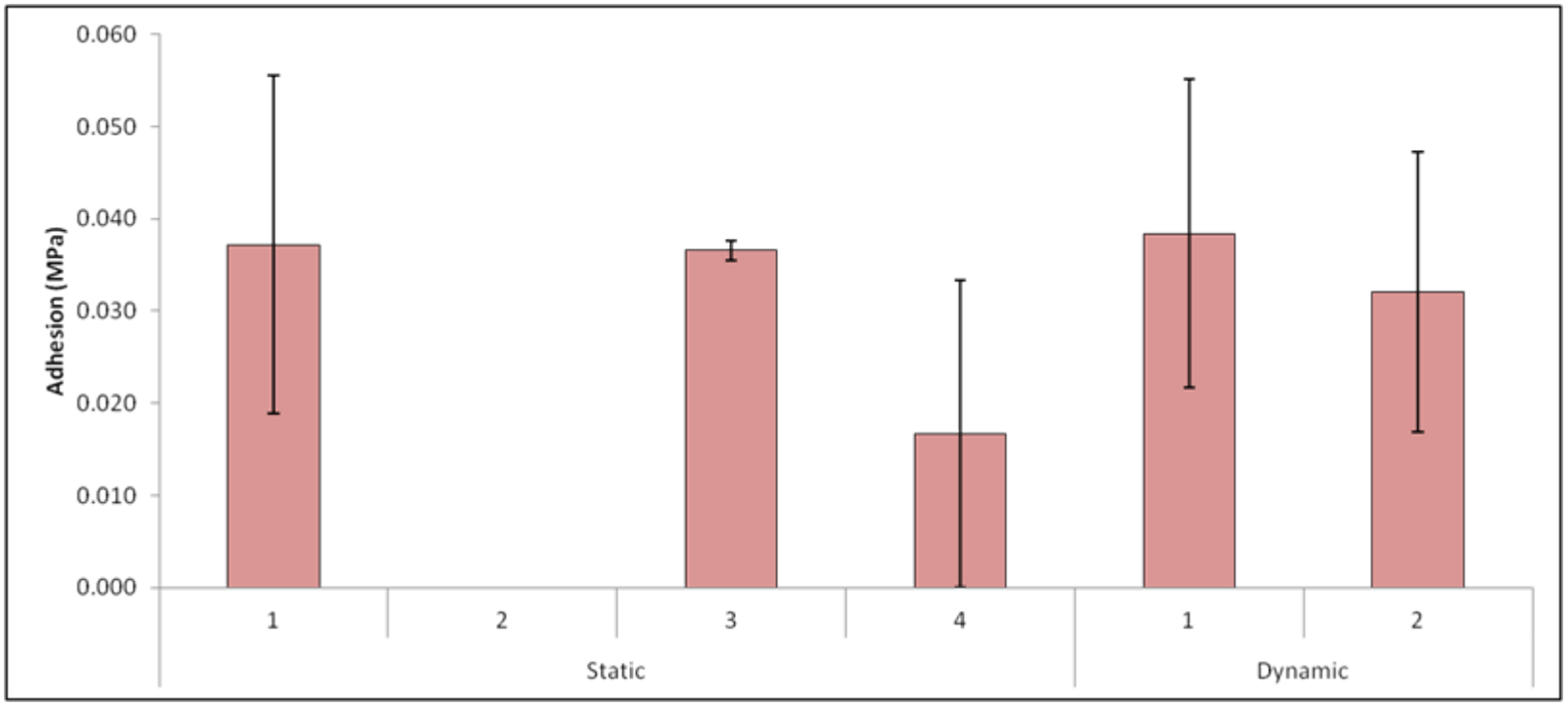


Figure 3: Average barnacle adhesion and standard deviation for June 30, 2011. There is no significant difference among panel treatments.

Foul Rating
6.30.2011

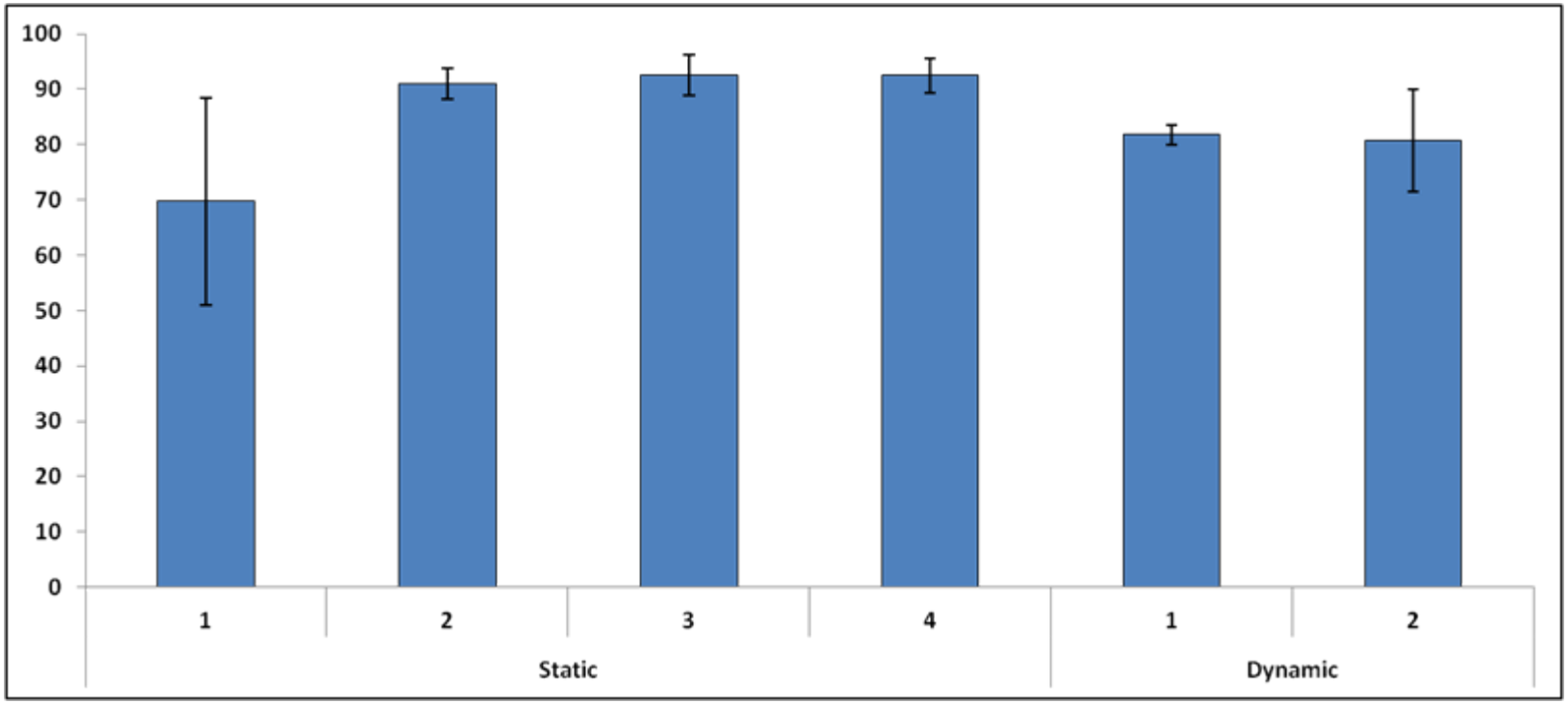


Figure 4: Average foul rating with standard deviation test panels after 78 days of static exposure. There is a significant difference between Sample 1 (Static) with Samples 2, 3, and 4 (all Static).

Biofouling Performance 6.30.2011

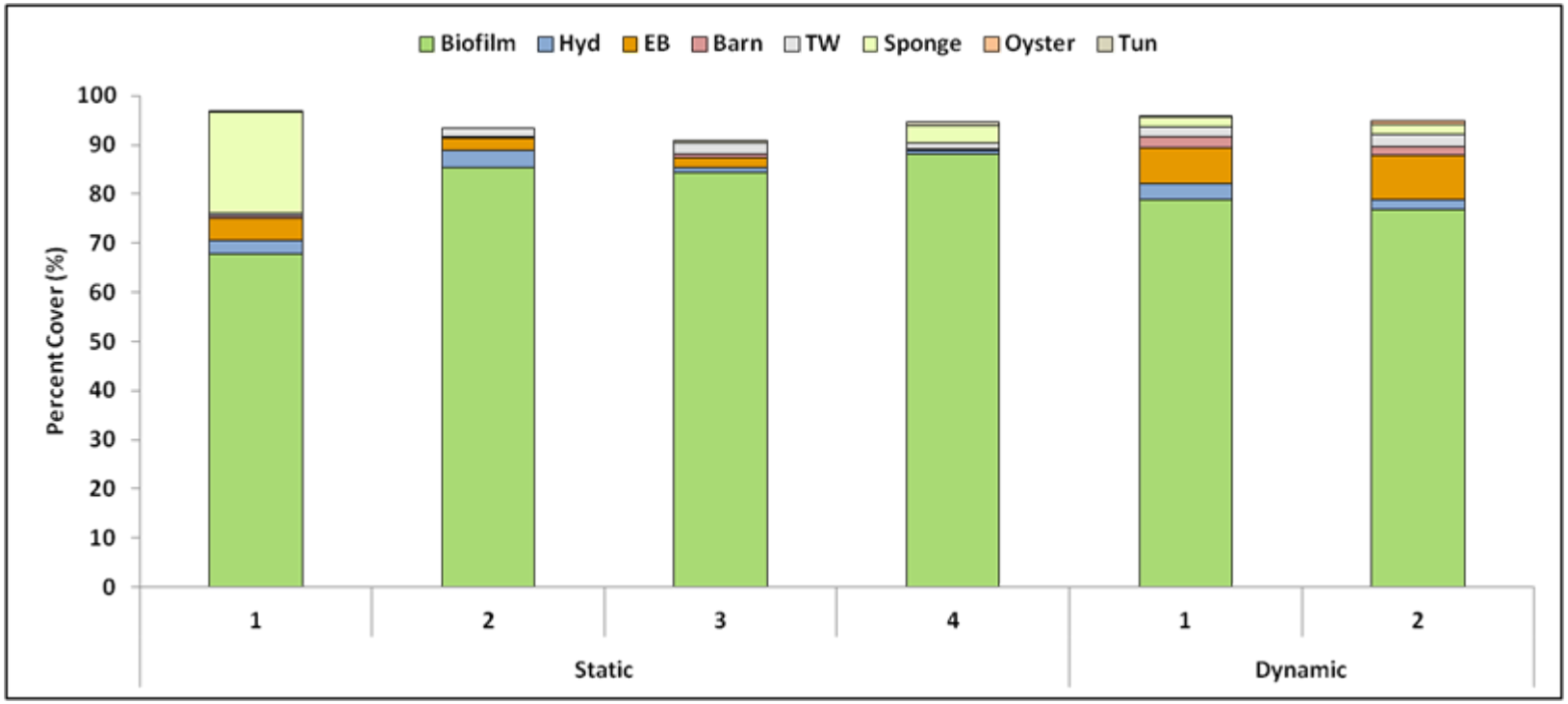


Figure 5: Average percent cover for biofouling organism on test panels after 78 days of static exposure. A significant difference in percent cover of Encrusting Bryozoans and Sponges was observed.

Photographs

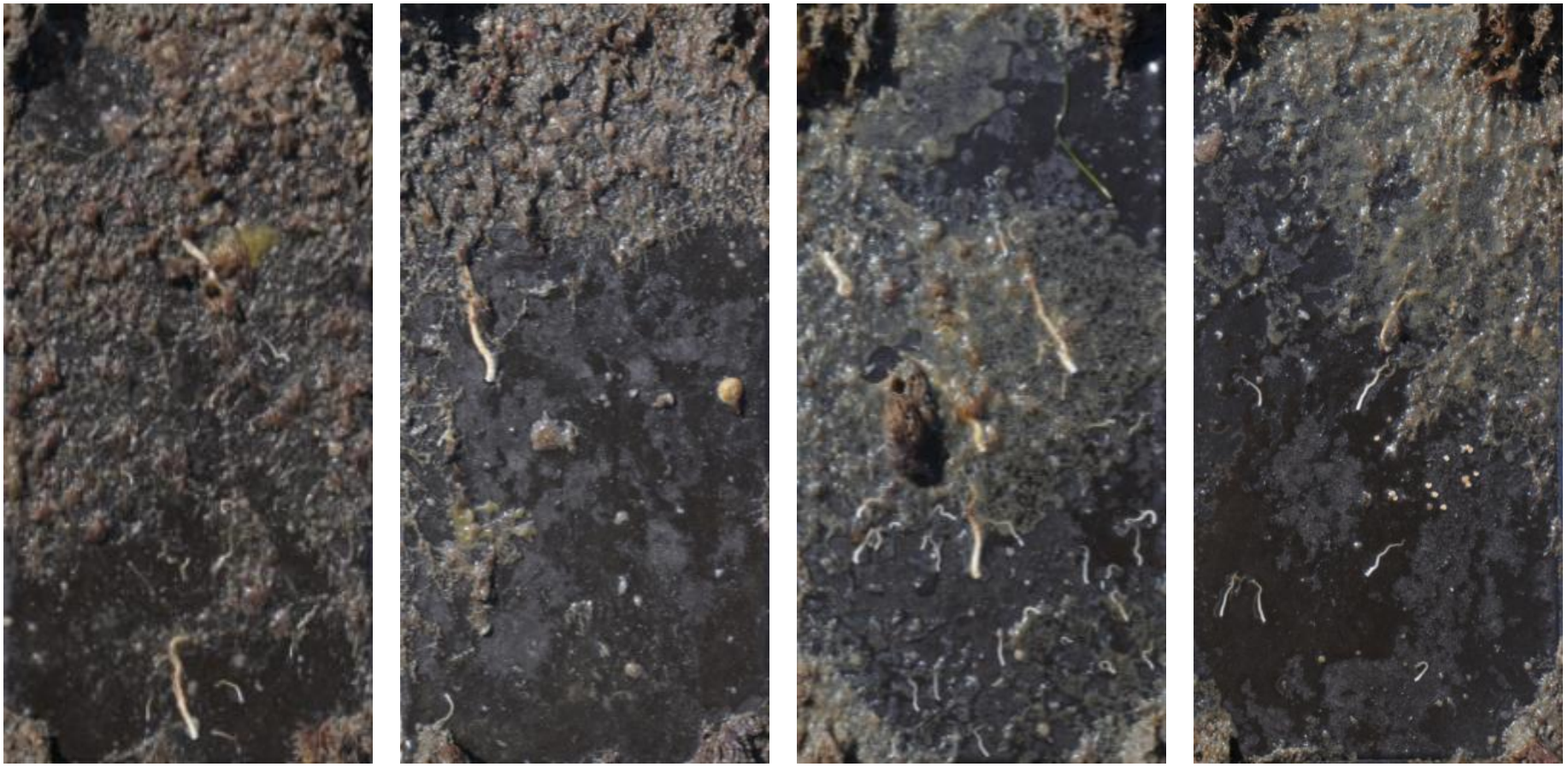
April 13, 2011

June 30, 2011

Sample 1: Static

4.13.2011

North South North South



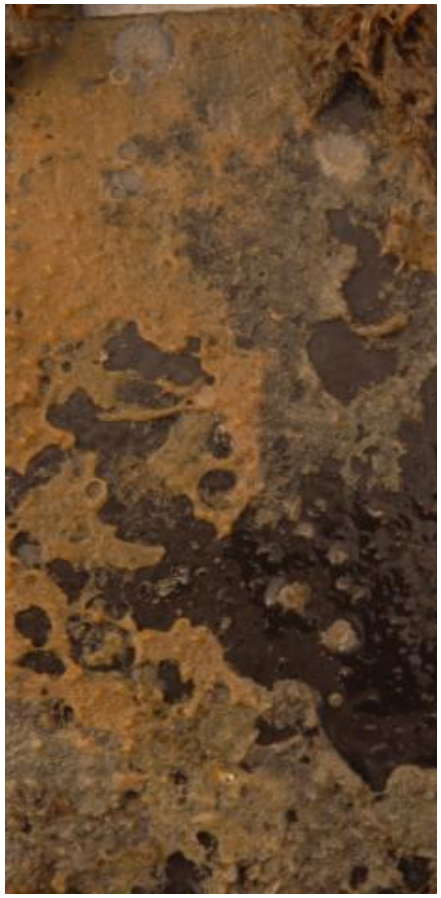
Sample 1: Static

6.30.2011

North

South

North



South

Sample 1: Dynamic

4.13.2011

North

South

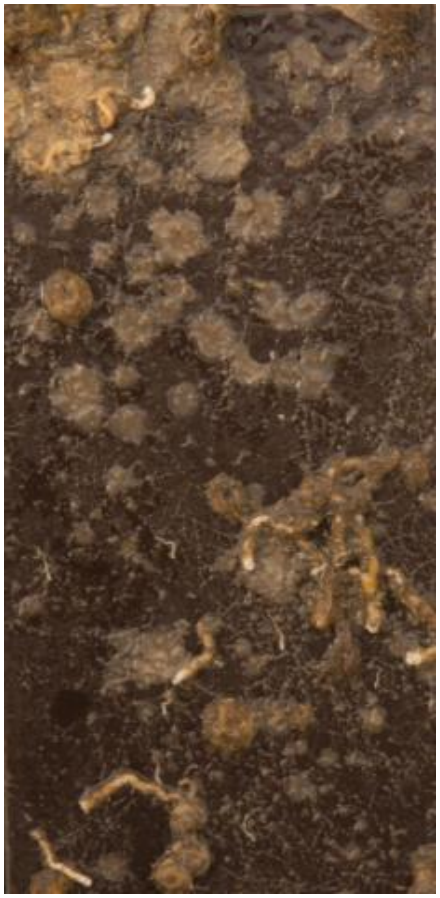
North

South

Sample 1: Dynamic

6.30.2011

North



South

North

South

Sample 2: Static

4.13.2011

North

South

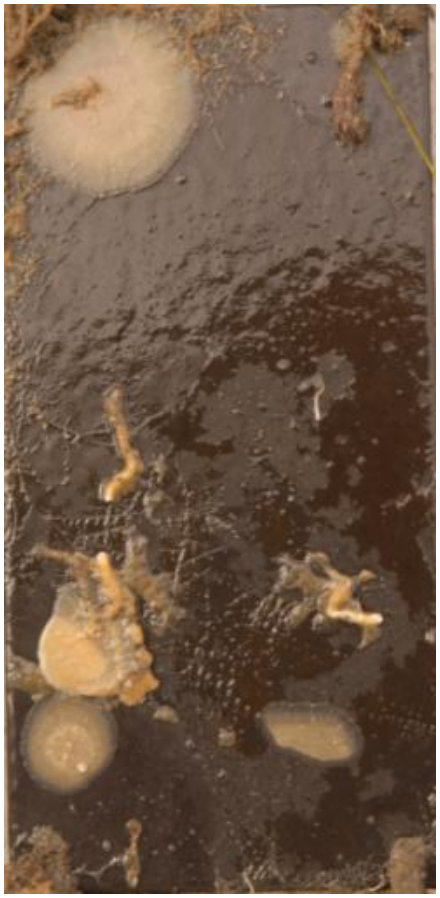
North

South

Sample 2: Static

6.30.2011

North South North South




Sample 2: Dynamic

4.13.2011

North

South

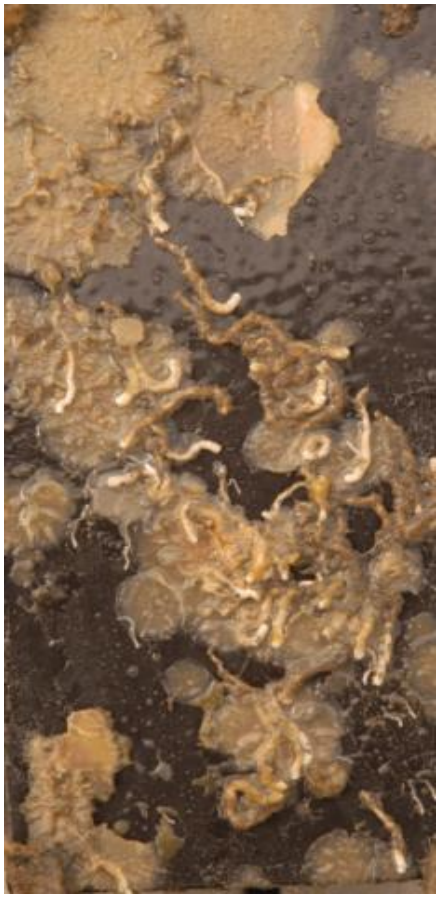
North

South

Sample 2: Dynamic

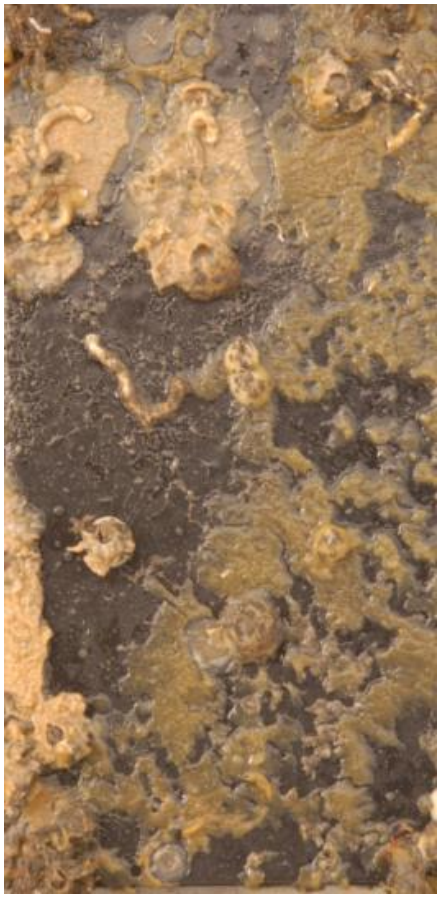
6.30.2011

North



South

North



South

Sample 3: Static

4.13.2011

North

South

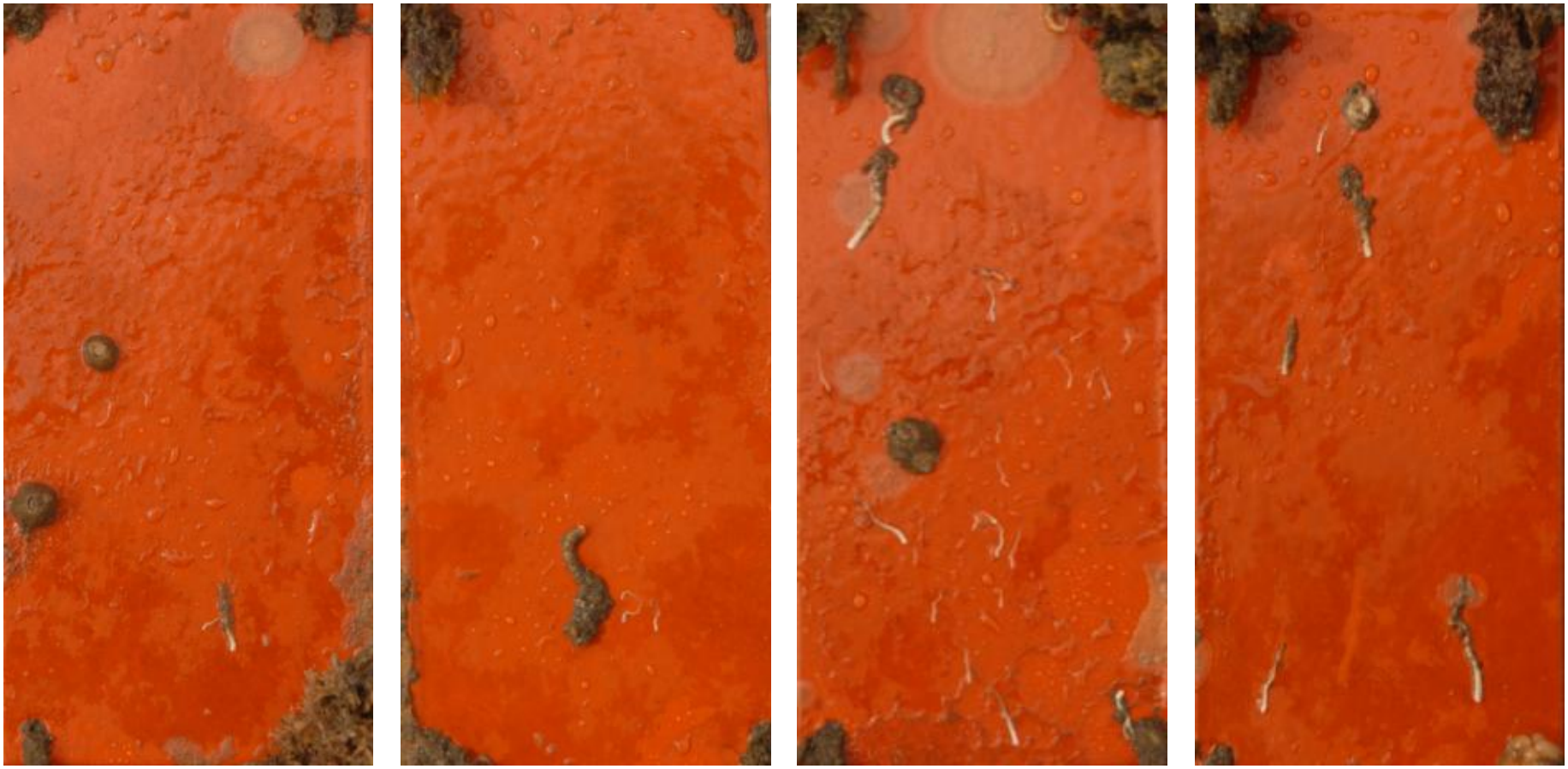
North

South

Sample 3: Static

6.30.2011

North South North South



Sample 4: Static

4.13.2011

North

South

North

South

Sample 4: Static

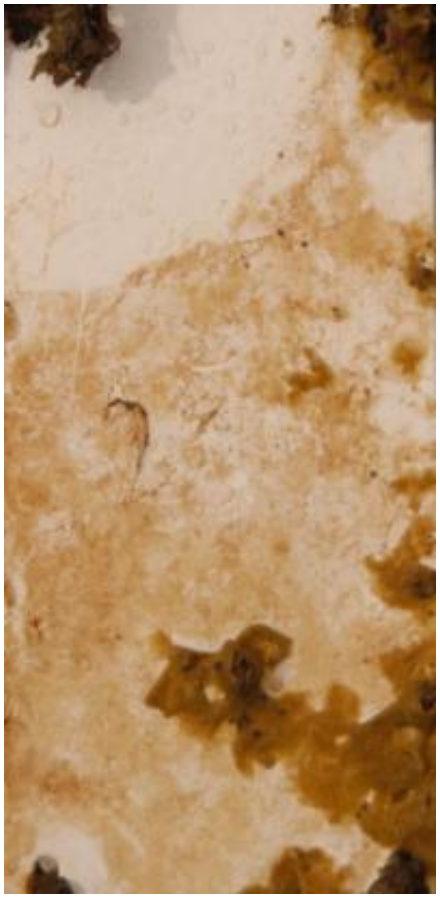
6.30.2011

North

South

North

South



Summary
4.13.2011 and 6.30.2011

- **Tubeworm Adhesion:** In April, the tubeworms on Dynamic panels were small, and broke upon testing. Therefore no data was collected. No statistical difference was seen between the April and June sampling periods. There was a significant difference among panels, however post hoc testing was unable to determine where these differences lay. In general the Dynamic panels had a higher adhesion than the Static panels. The panels tested in this report are comparable to adhesion data from International Intersleek 900, which has an average adhesion of 0.0899 ± 0.0475 (n= 358) MPa.
- **Barnacle Adhesion:** Barnacle adhesion was measured in June 2011 since no barnacles were present during the April sampling. There was also no barnacle settlement on the Static Sample 2 panel. No significant difference was observed among panel treatments. Average barnacle adhesion strength for all panels was less than Intersleek 700 which has an adhesion around 0.06 MPa.
- **Foul Rating:** The average foul rating was calculated for panels after 293 days submergence, 78 days of exposure. At this time the average foul rating was higher than 69 for all treatments. (A foul rating of 100 is the highest rank a panel can receive.) Sample 1 (static) was significantly lower than Samples 2, 3, and 4. No significant difference was seen between static and dynamic treatments.
- **Biofouling Cover:** After 78 days of exposure, fouling organisms consisted of biofilm, encrusting bryozoans, barnacles, tubeworms, sponges, oysters, and hydroids. Significant difference in percent cover was observed with two organisms: encrusting bryozoans and sponges. With regard to sponges, Sample 1 (static) had a higher cover than Sample 2 (static) and 3. The settlement of encrusting bryozoans was significantly higher on Sample 1 (Dynamic) and Sample 2 (Dynamic) than Sample 4.
- **Overall Coating Performance:** After 293 days submergence and 78 days exposure, all treatments are performing similar to the commercially available International Interleek coatings. All treatments have hard fouling adhesion measurements comparable to Intersleek as well as relatively high Foul Ratings. There was little difference between static and dynamic treatments, with the only notable difference observed in tubeworm adhesion. All panels remain under static immersion for comparison in August.