Hywind Scotland is the world's first floating offshore windfarm and Equinor seek to deepen its understanding of how the presence of a floating offshore wind farm can influence the local marine habitat and how those learnings can be applied to future floating wind farms.

The project sought an opportunity during the planned maintenance work to investigate how the zonation and succession on marine growth had taken place on the substructures and on the anchor chains, as well as the anchor chain and seabed interaction, since Hywind Scotland came in operation October 2017.

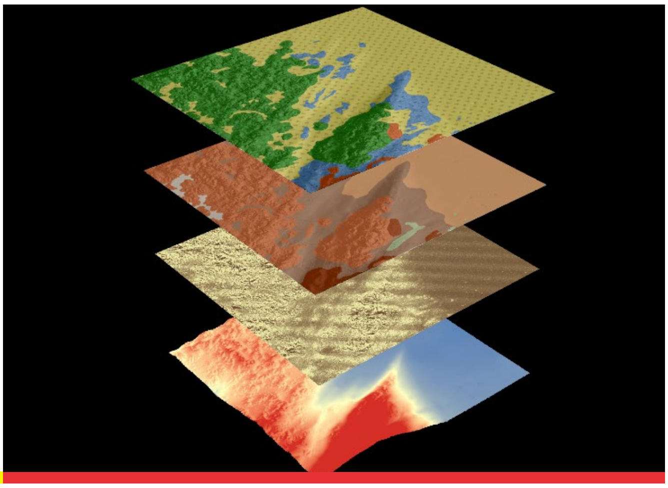
The result was an "artificial substrate colonization survey" (2020).

Main conclusions:

- Approximately the same zonation pattern was observed on all five substructures
- The zonation observed in Hywind Scotland showed resemblance to the zonation found in other European offshore wind parks
- The succession stage of the wind park is believed to be in the "species rich intermediate stage" (year 3-6 after construction), moving towards the third and final climax stage, dominated by M.senile (sea anemone) and less biodiversity (from year 6 after construction)
- As found elsewhere, uncoated structures (like mooring lines) had more diverse fauna than painted substructures
- Only very limited scouring effect was found from the anchor chain – sediment interaction

ENVIRONMENTAL SURVEY REPORT

300152-EQU-MMT-SUR-REP-ENVIRORE
REVISION A | ISSUE FOR USE
SEPTEMBER 2020



ARTIFICIAL SUBSTRATE COLONISATION SURVEY

HYWIND SCOTLAND PILOT PARK
SCOTLAND
JUNE 2020

MMT SWEDEN AB | SVEN KÄLLFELTS GATA 11 | SE-426 71 VÄSTRA FRÖLUNDA, SWEDEN
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REVISION HISTORY

REVISION	DATE	STATUS	CHECK	APPROVAL	CLIENT APPROVAL
A	2020-09-11	Issue for Use	MT	ID	
02	2020-08-14	Issue for Client Review	MT	ID	
01	2020-08-13	Issue for Internal Review	MT	ID	

REVISION LOG

DATE	SECTION	CHANGE
2020-09-10	1.Introduction	Amended as per Client's request
2020-09-10	5.Result	Updated species composition
2020-09-10	Table 9	Amended
2020-09-10	6.Conclusion and Discussion	Amended as per Client's request
2020-09-10	5.Result and 6.Conclusion and Discussion	Taxa *Balanus* changed to Balanoidea
2020-09-10	Appendix A	Amended and updated

DOCUMENT CONTROL

RESPONSIBILITY	POSITION	NAME
Content	Marine Biologist	Malin Tivefälth
Content	Marine Biologist	Rikard Karlsson
Content/Check	Environmental Supervisor	Iris Duranović
Check	Document Controller	Sofie Mellander / Anders Eriksson
Content	Project Report Coordinator	Tobias Elfast / Kris Stoddart
Content/Approval	Project Manager	Stina Palmeby

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ABBREVIATIONS AND DEFINITIONS

DP	Dynamic Positioning
GIS	Geographic Information System
HD	High definition
LAT	Lowest Astronomical Tide
MAC	Mobilisation and Calibration
KP	Kilometre Post
M/V	Motor vessel
POS MV	Position and Orientation System for Marine Vessels
WROV	Work Class Remotely Operated Vehicle
PPS	Pulse Per Second
UK	United Kingdom
UTC	Coordinated Universal Time
FT	Facilities Technologies
HEI	Health and Environmental Impact
NES Ops	New Energy Solution Operations
R&T	Research & Tech
SST	Safety and Sustainability
TDI	Technology Development and Implementation
TPD	Technology Development and Drilling

EXECUTIVE SUMMARY

This report details the results from the visual inspection of marine growth on structures within the Hywind Scotland Pilot Park, located east of Peterhead Scotland.

The survey was performed using a Work Class Remotely Operated Vehicle (WROV) with a mounted High Definition (HD) video camera, deployed from the survey vessel M/V Stril Explorer.

A total of 41 structures, as well as their associated subcomponents, were inspected during the survey, including Turbines (Substructures), Mooring Lines, Suction Anchors and Infield Cables. Data from several of the subcomponents have been pooled to facilitate comparison.

All five turbines showed, generally, a distinct trend in zonation with *Metridium senile* and *Spirobranchus* dominating the bottom to mid-sections of the turbines while kelp and other Phaeophyceae with blue mussel *Mytilus* dominated top sections of the turbines.

The fauna, dominating the mooring lines, varied with depth and general zonation's could be distinguished. Ross worm, *Sabellaria spinulosa* and cnidarian *Ectopleura larynx* dominated the chains where the chains were close to and in contact with the seabed, *Spirobranchus* dominated the middle part of the chains and the upper parts of the chains were dominated by Balanoidea, *M. senile* and *E. larynx*.

The suction anchors were dominated by hydroids and the tube building worm *Spirobranchus*.

The infield cables were mainly buried, however, the section of the cables that were exposed before going into burial were dominated by acorn barnacles (Balanoidea).

No confirmed non-native taxa were noted during the survey. Several individuals of lobster *Homarus* spp. were identified and these could belong to one or both of the species European lobster *H. gammarus* or the invasive non-native American lobster *H. americanus.*

Four mobile taxa featured on the Scottish Biodiversity List and as Priority Marine Features were identified in close proximity of the structures; Cod *Gadus morhua*, Ling *Molva molva*, sand eel *Ammodytes* spp. and Whiting *Merlangius merlangus*.

The habitat "Subtidal Sand and Gravels" featured on the Scottish Biodiversity List and Priority Marine Features was identified in the survey area.

Ross worm, *S. spinulosa* aggregations were identified growing next to and encrusting the structures situated on the seabed surface. These aggregations could potentially form the habitat, "*Sabellaria spinulosa* Reefs", included in OSPAR's List of Threatened Declining Species and Habitats and within the European Commission Habitats Directive Annex I habitat – 1170 Reefs.

A comparison of the current dataset has been conducted with available data collected during 2018, which showed an increase in both hard and soft marine growth coverage.

The visual inspection survey commenced on the 6th of June 2020 and was completed on the 15th of June 2020.

1| INTRODUCTION

1.1| PROJECT INFORMATION

Equinor's TPD Research & Tech FT SST HEI were planning to collect valuable data on biological growth beyond what was scoped by NES Ops for inspection within the wind turbine park Hywind Scotland.

NES Ops performed an inspection campaign using an WROV in order to verify the integrity of systems and identify potential structures in need of maintenance.

As part of the Technology Development and Implementation (TDI) of "Assessment of floating offshore wind impacts on marine life", R&T FT SST HEI was given the opportunity from NES Ops to join the campaign to collect biological data (i.e. species characterization of marine growth on hard substrates like turbine substructures, anchor lines, mooring systems, cables, rocks).

The simultaneous species characterisation required a slower WROV speed than what was required from maintenance perspectives, and the extended scope of species characterisation was estimated to prolong the inspection campaign with 1.5 days (36 hours).

The species characterisation required four marine biologists on board the vessel during the inspection campaign.

The project details are summarised in Table 1.

Table 1 Project Details.

CLIENT:	Equinor Energy AS
PROJECT NAME:	Hard Substrate Colonisation (a part of the Equinor Hywind 2020 Inspection and Survey)
MMT PROJECT NUMBER:	300152
SURVEY TYPE:	Visual Inspection
AREA:	Hywind Scotland Pilot Park, UK
SURVEY PERIOD:	June 2020
SURVEY VESSEL:	MV Stril Explorer
MMT PROJECT MANAGER:	Stina Palmeby (MMT)/ Johnny Stiansen (Reach)
CLIENT PROJECT MANAGER:	Kari Mette Murvoll

1.2| SURVEY AREA

The Hywind Scotland Pilot Park is located off the coast of Peterhead, on the east coast of Scotland. Hywind Scotland Pilot Park consists of five (5) floating wind turbines spaced around 1 to 2 km apart (Figure 1).

The water depths in this area range from 100 m to 130 m.

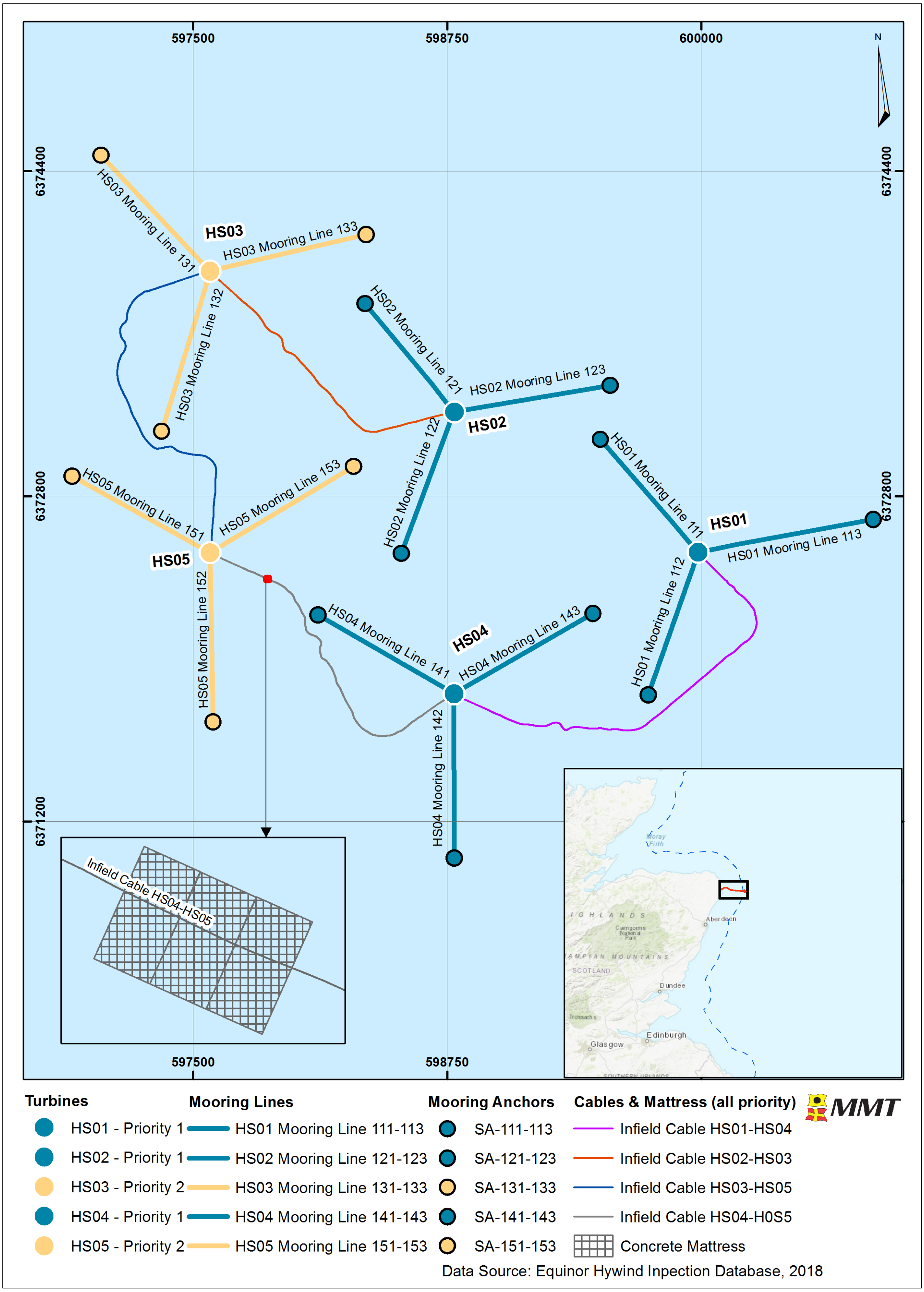


Figure 1 Overview of the survey area.

1.3| SURVEY INFORMATION

The objectives of the current survey were as follows:

- Inspection of Substructures, bridles, mooring lines, bottom chain and suction anchors.

  Each of the turbines has a 3-point mooring spread with mooring lines connected to suction anchors.
- Inspection of Infield dynamic cables, guide tubes, buoyancy modules, clamps and hold down anchors.
- Visual inspection of marine growth for all structures and subcomponents.
- Geophysical Survey (MBES, SSS) of Infield cables, cable crossings, rock dumps and export cable. Nearshore Export cable survey was performed by Xocean USV.

The data from the geophysical survey along the infield cables and export cable as well as visual inspection of marine growth was processed and reported by MMT while the GVI and structure inspection was performed and reported by Reach Subsea, following Reach Task Plans.

1.4| PURPOSE OF DOCUMENT

The purpose of the report is to present detailed information on survey performance, and processing stages of the work together with the results from the environmental visual inspection. The objective is to provide an overview of marine fauna present on and in close proximity of structures within the wind park area.

1.5| SCOPE OF WORK

The aim of the survey was to perform species characterisation while the WROV is simultaneously used for inspection of the integrity and from maintenance perspectives in the wind park (i.e. inspection of turbine substructures, mooring system, cables).

The turbines were shut down during the inspection, due to need of power generation from wind turbines, the extended biological inspection was restricted to 2 - 3 of the five (5) turbines, as species characterization required slower speed of the WROV than the general inspection requested by NES Ops

R&T had signalled to NES Ops that in case there is a difference between two turbines, the third could give an indication as to which data is skewed with regards to natural variation. These three turbines are labelled Priority 1 in Figure 1.

1.6| REFERENCE DOCUMENTS

The referenced documents for the project are presented in Table 2.

Table 2 Reference documents.

DOCUMENT NUMBER	TITLE	AUTHOR
-	Call-off title: hard substrate colonization – Hywind Scotland	Equinor
MMTRSS-7213-300152-WP-001	Project Manual Hywind Campaign 2020	MMT-REACH
C178-OPS-U-MB-00002	Hywind Scotland Substructure Inspection Record Sheet	REACH Subsea
300152-EQU-MMT-MAC-REP-STRILEXPLORER	Mobilisation and Calibration Report	MMT

2| SURVEY PARAMETERS

2.1| GEODETIC DATUM AND GRID COORDINATE SYSTEM

The geodetic and projection reference parameters used during the survey are presented in Table 3 and Table 4.

Table 3 Geodetic Parameters.

GEODETIC PARAMETERS	
Datum	World Geodetic System 1984 (6326)
Ellipsoid	World Geodetic System 1984 (7030)
Prime Meridian	Greenwich (8901)
Semi-major axis	6 378 137.000 m
Semi-minor axis	6 356 752.3142 m
Inverse Flattening (1/f)	298.257223563
Unit	International metre

Table 4 Projection parameters.

PROJECTION PARAMETERS	
Projection	UTM
Zone	30 N
Central Meridian	03° 00’ 00’’ W
Latitude origin	0
False Northing	0 m
False Easting	500 000 m
Central Scale Factor	0.9996
Units	metres

2.2| VERTICAL DATUM

The vertical reference parameters used during the survey are presented in Table 5.

Table 5 Vertical Reference.

VERTICAL REFERENCE PARAMETERS	
Vertical reference	LAT
Height model	VORF

2.3| TIME DATUM

Coordinated universal time (UTC) is used on all survey systems on board the vessel. The synchronisation of the vessel's onboard system is governed by the pulse per second (PPS) issued by the primary positioning system. All displays, overlays and logbooks are annotated in UTC as well as the Daily Progress Report (DPR) that is referred to UTC.

3 | SURVEY PERFORMANCE

3.1 | SURVEY TASKS

The survey tasks are presented in Table 6.

Table 6 Environmental Survey tasks.

TASK	DATE	DESCRIPTION
Mobilisation	3rd of June 2020 – 6th June 2020	Mobilisation in Malmö, Sweden, 3rd of June. Transit to Aberdeen, UK, where the mobilisation was completed the 6th of June.
Inspection Survey	6th of June 2020 – 15th of June 2020	
Demobilisation of Inspection and Biology Scope	16th of June 2020	

3.2 | MOBILISATION AND CALIBRATION TEST

Mobilisation and calibration (MAC) started on the 5th of May in Karlskrona, SWE.

For detailed description of the calibration performance and results please refer to the Mobilisation and Calibration Report 300152-EQU-MMT-MAC-REP-STRILEXPLORER.

3.2.1 | EQUIPMENT

Equipment utilised during the environmental survey is presented in Table 7.

Table 7 WROV Equipment.

INSTRUMENT	NAME
Primary Positioning and INS System	IXBLUE ROVINS
Secondary Positioning and INS System	IXBLUE Octans 3000
Sound Velocity Sensor	Valeport miniSVS
Conductivity, Temperature, Depth (CTD) Probe	Valeport miniCT
Pressure Gauge	Valeport IPS
Obstacle Avoidance Sonar	Gemini 720is
Altimeter	Tritech PA500 (500 kHz)
USBL Transponder	HiPAP cNODE
Doppler Velocity Log (DVL)	LinkQuest NavQuest microDVL (600 kHz)
Multibeam Echo Sounder	R2Sonic 2024 (200-400 kHz, optional 700 kHz)
Side Scan Sonar	EdgeTech 2200 (300/600 kHz)
Sub-Bottom Profiler	EdgeTech DW-106 (1-10 kHz)

INSTRUMENT	NAME
SIT Camera	Imenco LowLight-HSC
Colour Camera	Imenco Mini Colour Subsea Camera
Colour and Zoom Camera	Imenco 18x Zoom Subsea Camera
Underwater Lasers	Dual DSPL Sealaser 100
LED Flood Light	4 x Cathx Aphos 4 (7000 lumen) 2 x ROS Q-LED III (3500 lux)
LED Spot Light	4 x ROS MV LED (890 lumen)
Manipulators	Schilling T4 and Rigmaster

4| METHODOLOGY

The biological survey was performed in collaboration with REACH Subsea and occurred simultaneously with the structural inspection.

4.1| VIDEO SAMPLING

Video footage was recorded during the entire structural inspection of substructures, mooring lines, suction anchors and infield cables (Figure 2 and Figure 3). Additional video footage, collected solely for the biological survey, was collected for substructures HS01, HS02 and HS04, infield cables QA01, QA02, QA04 and QA05, as well as the concrete mattress located on top of QA01.

Video footage was obtained using a HD colour camera attached to a Work Class Remotely Operated Vehicle (WROV) supported by LED Flood and Spot lights. Two lasers were positioned with 10 centimetres apart. The WROW maintained a general speed of 0.3 knots.

The live feed from the WROV was monitored by one of the marine biologists on shift. This allowed for fauna/areas of interest to be further examined in closer detail.

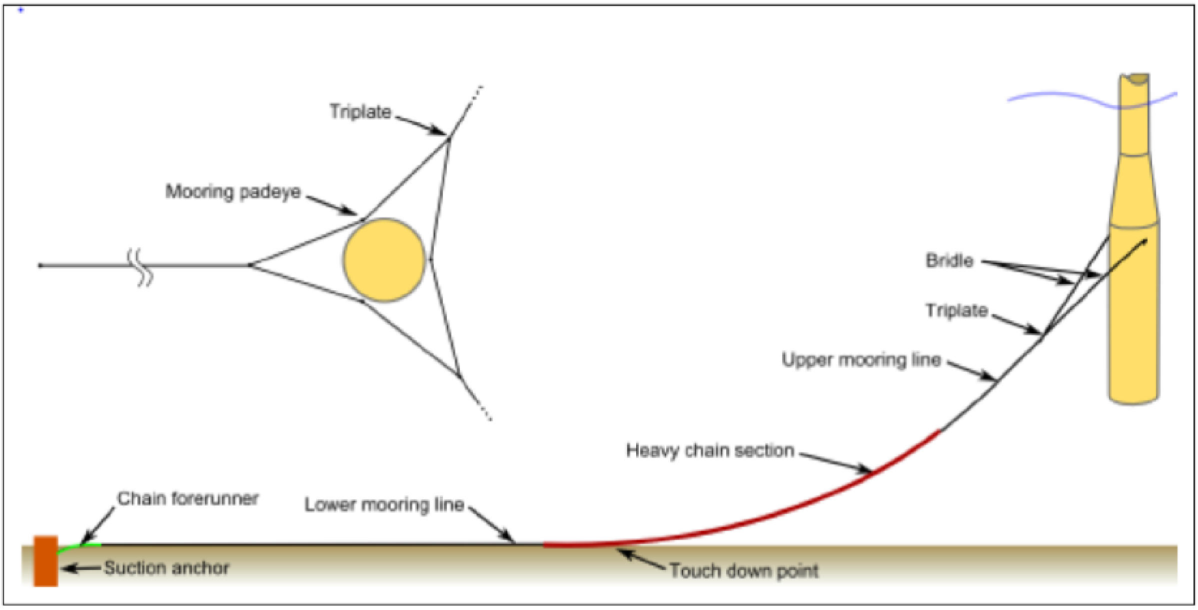


Figure 2 Layout of Turbines, Mooring Lines and Suction Anchors.

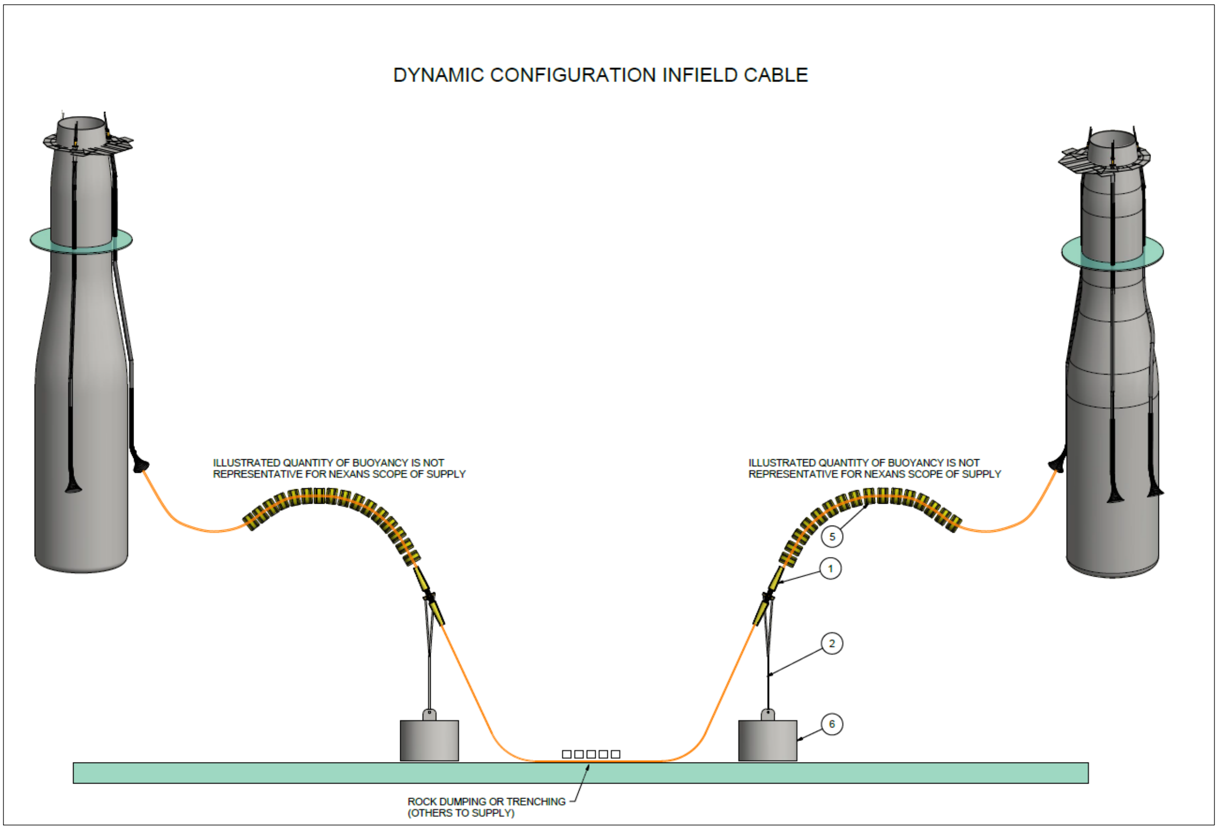


Figure 3 Infield Cable Layout.

4.2| DATA ANALYSES

4.2.1| VIDEO ANALYSES

The analyses of video data acquired was performed in two steps. The first step was analysed in real time, from the live video feed, and included documenting zonation and common species. The second step included QC of the first step as well as enumeration of individuals and assessment of percentage coverage.

4.2.2| FAUNAL ANALYSES

The fauna was identified to the most detailed taxonomic level possible, mainly species and counted. When a species could not be identified with a level of certainty, the specimen was grouped into the nearest identifiable taxon of a higher rank, *i.e.* genus, family, or order etc. Colonial, encrusting faunal species were also identified to the lowest level possible and given a P (present) value.

The scientific names of all taxa were checked against the World Register of Marine Species (WoRMS).

5| RESULTS

A total of 41 structures, with their associated subcomponents, were surveyed during the visual inspection of species characterisation within the Hywind Scotland Pilot Park (Table 8).

Table 8 Inspected structures, not including subcomponents.

STRUCTURE	NUMBER INSPECTED
Turbine substructures	5
Suction Anchors	15
Mooring chains	15
Infield cables	5
Rock dumps (Concrete Mattress)	1

A list of species found within the survey is presented in Appendix A.

The phyletic composition of identified taxa is presented in Table 9. A total of eleven phyla were observed and a total of 121 different taxa.

Taxa included in the phyla Annelida, Bryozoa, Chlorophyta, Cnidaria, Phaeophyceae, Porifera, and Rhodophyta are comprised of epifouling taxa and noted as Present. Epifouling fauna is also found in the phyla Arthropoda, Chordata and Mollusca (Sessilia, tunicates, bivalves, and cephalopods). Fish are noted as Present.

A total of 48 taxa were identified to be epifouling fauna. Eggs from cephalopods, nudibranchs and gastropods identified during the survey are excluded in Table 9. A total of 73 mobile taxa were identified and an estimated number of 15 997 individuals were recorded during the current survey.

The most abundant mobile taxon was Asteroidea, likely the common sea star *Asterias rubens*, followed by small sea urchins. Asteroidea and sea urchins were occasionally present in high abundance and which made it difficult to count each individual causing the calculated numbers to be underestimated.

Different species of crustaceans were present within the whole survey area and they were the dominating mobile phylum on the seabed.

Table 9 Phyletic composition of fauna identified during visual inspection.

PHYLA	NUMBER OF EPIFAUNAL TAXA	NUMBER OF MOBILE TAXA	NUMBER OF INDIVIDUALS OF MOBILE FAUNA
Annelida	7	-	-
Arthropoda	1	18	3 713
Bryozoa	5	-	-
Chlorophyta	1	-	-
Chordata	4	28	-
Cnidaria	21	-	-
Echinodermata	-	17	12 070 (probably underestimated)
Mollusca	1	10	214
Phaeophyceae	4	-	-
Porifera	1	-	-
Rhodophyta	3	-	-
TOTAL	**48**	**73**	**15 997**

5.1 | COLONISATION

5.1.1 | TURBINE SUBSTRUCTURES

The epifouling colonisation of the substructures was overall high (approximately 80 % to 100 %) and the dominating epifouling species were *Metridium senile* and *Spirobranchus* (Figure 4 and Table 10). Blue mussels, *Mytilus* and brown algae colonised the lower intertidal depths (Figure 5).

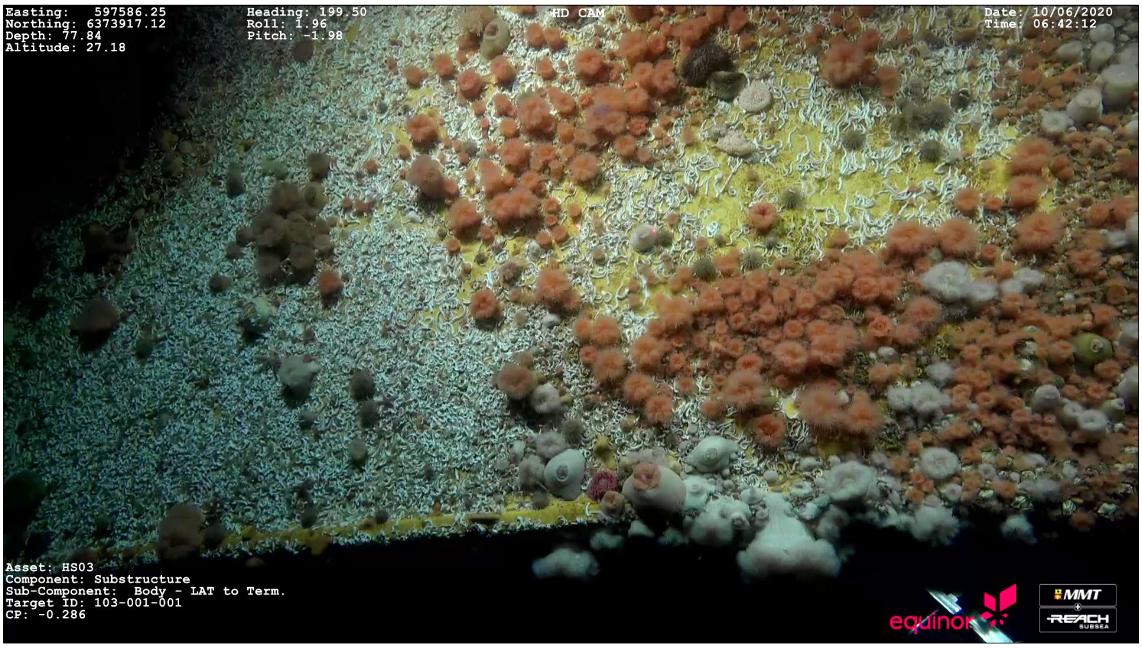


Figure 4 Spirobranchus *and* M. senile *at the bottom of HS03 Substructure.*

Figure 5 HS02 – Substructure with Mytilus *and* Laminaria *at three metres depth.*

Table 10 Estimation of epifouling colonisation on the substructures.

STRUCTURE ID	OVERALL FAUNAL COVERAGE (%)	DOMINANT SPECIES
Substructure HS01	90 – 100 %	*Metridium senile* *Spirobranchus*
Substructure HS02	95 – 100 %	*Metridium senile* *Spirobranchus*
Substructure HS03	80 – 90 %	*Metridium senile* *Spirobranchus*
Substructure HS04	80 %	*Metridium senile* *Spirobranchus*
Substructure HS05	95 %	*Metridium senile* *Spirobranchus*

Mobile taxa that were present in high abundances at the structures included Echinidea, Asteroidea and Galatheoidea. Squat lobsters were mostly present at the deeper depths. Grazers such as sea urchins, sea stars and nudibranchs were found all over the substructures (Figure 6 and Figure 7). Sea urchins and sea stars were found at all depths but were most abundant between 10 to 25 m whereas nudibranchs were more abundant below 40 m.

Figure 6 HS04 – Substructure. Grazing sea urchins at 11 m depth.

Figure 7 HS01 – Substructure. Nudibranch Aeolidia papillosa *and barnacle Balanoidea at 48 m depth.*

5.1.2| SUCTION ANCHORS

There was no substantial difference in epifouling colonisation on the Suction anchors, nor between the five turbine areas. Each Suction Anchor was assessed, with regards to faunal coverage, along the top of the structure and separately around the sides (Table 11).

Different hydroids, predominantly *Nemertesia ramosa and Ectopleura larynx*, were the dominating fauna on top of the Suction Anchors with an overall faunal colonisation of 20 % to 80 % (Figure 8). *Spirobranchus* and *Ectopleura larynx* together with patches of barnacles dominated the sides of the Suction Anchors with an overall faunal colonisation of 60 % to 90 % (Figure 9).

Mobile fauna frequently observed on the Suction anchors included different species of Galatheoidea, *Cancer pagurus*, Palaemonidae, *Lithodes maja* and nudibranchs.

Table 11 Estimation of epifouling colonisation on the Suction Anchors.

STRUCTURE ID	OVERALL FAUNAL COVERAGE (%)	DOMINANT SPECIES
HS01-SA-111		
On top	50 %	*Nemertesia ramosa*
Around the sides	90 %	*Spirobranchus*
HS01-SA-112		
On top	50 %	*Nemertesia ramosa*
Around the sides	90 %	*Spirobranchus*
HS01-SA-113		
On top	50 %	*Nemertesia ramosa* *Ectopleura larynx*
Around the sides	90 %	*Spirobranchus*
HS02-SA-121		
On top	40 %	*Ectopleura larynx*
Around the sides	80 %	*Ectopleura larynx* *Spirobranchus*
HS02-SA-122		
On top	30 %	*Ectopleura larynx*
Around the sides	90 %	*Ectopleura larynx* *Spirobranchus*
HS02-SA-123		
On top	80 %	*Nemertesia ramosa* *Ectopleura larynx*
Around the sides	90 %	*Spirobranchus*
HS03-SA-131		
On top	40 %	*Ectopleura larynx*
Around the sides	80 %	*Spirobranchus* Hydrozoa
HS03-SA-132		
On top	40 %	*Ectopleura larynx* *Metridium senile*
Around the sides	70 %	Hydrozoa *Spirobranchus*

STRUCTURE ID	OVERALL FAUNAL COVERAGE (%)	DOMINANT SPECIES
HS03-SA-133		
On top	20 %	Hydrozoa
Around the sides	90 %	Cirripedia Hydrozoa
HS04-SA-141		
On top	30 %	*Ectopleura larynx*
Around the sides	90 %	*Spirobranchus* Hydrozoa
HS04-SA-142		
On top	40 %	Hydrozoa
Around the sides	80 %	*Spirobranchus*
HS04-SA-143		
On top	40 %	Hydrozoa
Around the sides	90 %	*Spirobranchus* Hydrozoa
HS05-SA-151		
On top	40 %	*Ectopleura larynx*
Around the sides	70 %	Balanoidea *Nemertesia ramosa*
HS05-SA-152		
On top	30 %	*Nemertesia ramosa* Hydrozoa
Around the sides	60 %	*Ectopleura larynx* *Tubularia indivisa*
HS05-SA-153		
On top	70 %	*Ectopleura larynx*
Around the sides	90 %	*Spirobranchus*

Figure 8 Example image from the top of the Suction Anchor (HS03 – Suction Anchor 131).

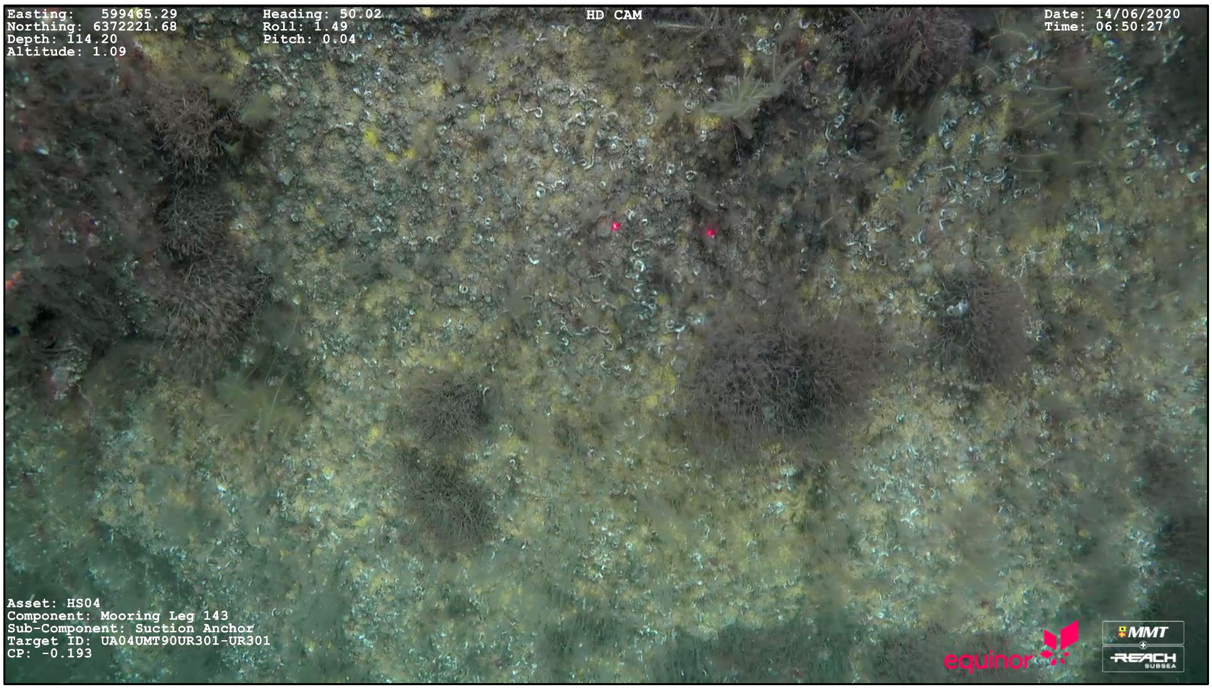


Figure 9 Example image from the side of the Suction Anchor (HS04 – Suction Anchor 143).

5.1.3| MOORING LINES

No significant difference was noted on the mooring lines between the different turbine areas. A depth zonation was distinguished on the Mooring Lines from top to bottom. The top chain was almost entirely covered with epifouling fauna and the dominating taxa were Balanoidea, *M. senile* and *E. larynx*.

The upper middle chain was similar to the top chain but epifouling decreased when the chain descended towards the seabed and the dominating species was *Spirobranchus* and the overall faunal coverage was approximately 40 % to 80 %.

The lower part of the chain, closest to and on top off the seabed surface, the epifouling fauna was dominated by a crust of *Sabellaria spinulosa* and *E. larynx* and with an overall faunal coverage of 80 % to 100 %. Continuing along the seabed, the middle chain was buried from time to time and the bottom chain was buried throughout the survey area (Table 12).

The top chain comprised an overall faunal coverage of 60 % to 100 %. The top chain of Mooring Line 111 was estimated to have an overall faunal coverage of 60 % to 95 % and Mooring Line 141 60 % to 70 %. The Mooring Lines were estimated to have 100 % coverage or close to 100 %. The composition of the middle chain was similar in all five turbine areas.

Example imagery of the colonisaiton along two of the Mooring Lines (Mooring Line 111 and Mooring Line 142) is presented in Table 13 and Table 14, from top to bottom.

Mooring Line 111 comprised abundant *M. senile* on the top chain whereas Mooring Line 142 comprised a higher density of barnacles and *E. larynx.* Mobile fauna found on and adjacent to the mooring lines was *Asterias rubens*, Galathiodea, *C. pagurus*, *L. maja*, Paguridae.

Table 12 Estimation of epifouling colonisation on the Mooring Lines. The bottom chain is excluded.

STRUCTURE ID	OVERALL FAUNAL COVERAGE (%)	DOMINANT SPECIES
HS01 Mooring Line 111		
Top chain	60 – 95 %	*Metridium senile* Balanoidea
Middle Chain	55 – 100 %	*Ectopleura larynx* *Spirobranchus* *Sabellaria spinulosa*
HS01 Mooring Line 112		
Top chain	90 %	*Spirobranchus* *Metridium senile*
Middle Chain	45 %	Hydrozoa *Sabellaria spinulosa*
HS01 Mooring Line 113		
Top chain	100 %	Biofilm *Metridium senile*
Middle Chain	50 – 90 %	Hydrozoa *Sabellaria spinulosa*
HS02 Mooring Line 121		
Top chain	100 %	*Metridium senile* Balanoidea
Middle Chain	40 – 60 %	*Ectopleura larynx* *Nemertesia ramosa* *Sabellaria spinulosa*

STRUCTURE ID	OVERALL FAUNAL COVERAGE (%)	DOMINANT SPECIES
HS02 Mooring Line 122		
Top chain	100 %	Balanoidea *Metridium senile*
Middle Chain	50 – 100 %	*Spirobranchus* Balanoidea *Sabellaria spinulosa*
HS02 Mooring Line 123		
Top chain	100 %	Balanoidea *Metridium senile*
Middle Chain	100 %	Balanoidea *Ectopleura larynx*
HS03 Mooring Line 131		
Top chain	90 – 100 %	Balanoidea *Metridium senile*
Middle Chain	40 – 100 %	*Sabellaria spinulosa* Hydrozoa
HS03 Mooring Line 132		
Top chain	100 %	Balanoidea *Spirobranchus* *Metridium senile*
Middle Chain	60 – 100 %	*Sabellaria spinulosa* Hydrozoa
HS03 Mooring Line 133		
Top chain	100 %	Balanoidea *Metridium senile* *Ectopleura larynx*
Middle Chain	60 – 100 %	Hydrozoa Balanoidea *Sabellaria spinulosa*
HS04 Mooring Line 141		
Top chain	60 – 70 %	*Metridium senile* Balanoidea *Spirobranchus*
Middle Chain	80 – 100 %	Balanoidea *Spirobranchus* *Sabellaria spinulosa*
HS04 Mooring Line 142		
Top chain	100 %	Balanoidea *Ectopleura larynx* *Metridium senile*
Middle Chain	100 %	*Sabellaria spinulosa* Hydrozoa

STRUCTURE ID	OVERALL FAUNAL COVERAGE (%)	DOMINANT SPECIES
HS04 Mooring Line 143		
Top chain	100 %	Balanoidea *Metridium senile*
Middle Chain	80 - 100 %	Balanoidea *Metridium senile* *Sabellaria spinulosa*
HS05 Mooring Line 151		
Top chain	100 %	Balanoidea *Metridium senile* *Ectopleura larynx*
Middle Chain	70 – 100 %	*Sabellaria spinulosa* Hydrozoa
HS05 Mooring Line 152		
Top chain	100 %	Balanoidea *Metridium senile* *Ectopleura larynx*
Middle Chain	80 - 100 %	*Sabellaria spinulosa* Balanoidea
HS05 Mooring Line 153		
Top chain	100 %	*Metridium senile*
Middle Chain	50 – 90 %	*Sabellaria spinulosa* Hydrozoa

Table 13 Example images of HS01 Mooring Line 111, top to bottom.

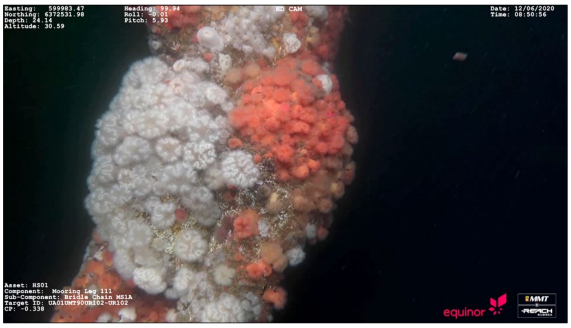
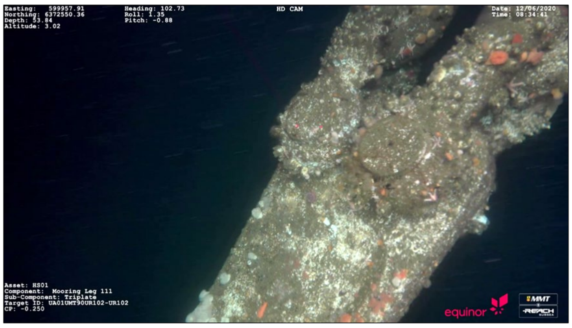
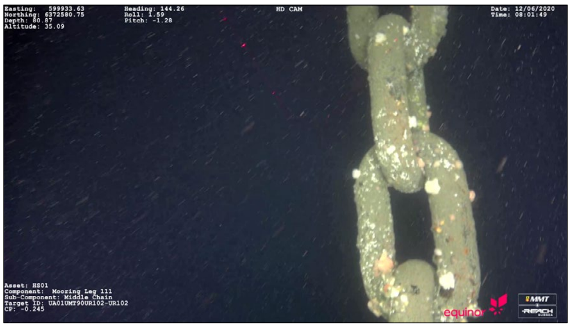
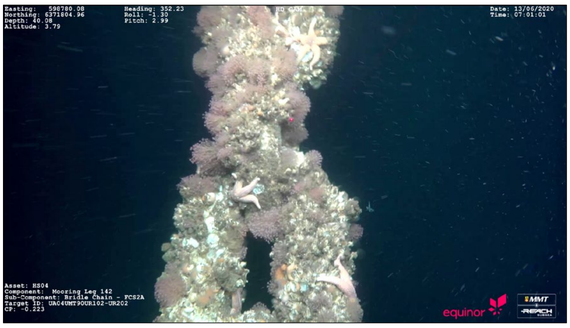
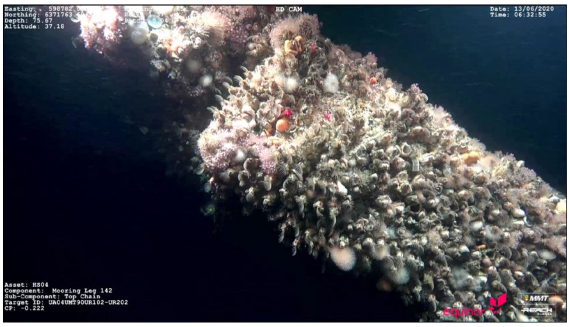
	
Top Chain, Bridle Chain	Top Chain, Triplate
	
Top Chain	Middle Chain
	
Middle Chain, off seabed	Middle Chain, on seabed

Table 14 Example images of HS04 Mooring Line 142, top to bottom.

	
Top Chain, Bridle Chain	Top Chain, Triplate
	
Top Chain	Middle Chain
	
Middle Chain, off seabed	Middle Chain, on seabed

A close up of findings of encrusting *S. spinulosa*, *Mytilus* and *E. larynx* is presented in Figure 10 to Figure 12.

Figure 10 HS04 Mooring Line 142, S. spinulosa *on Middle Chain.*

Figure 11 Bridle Chain 122 with Mytilus.

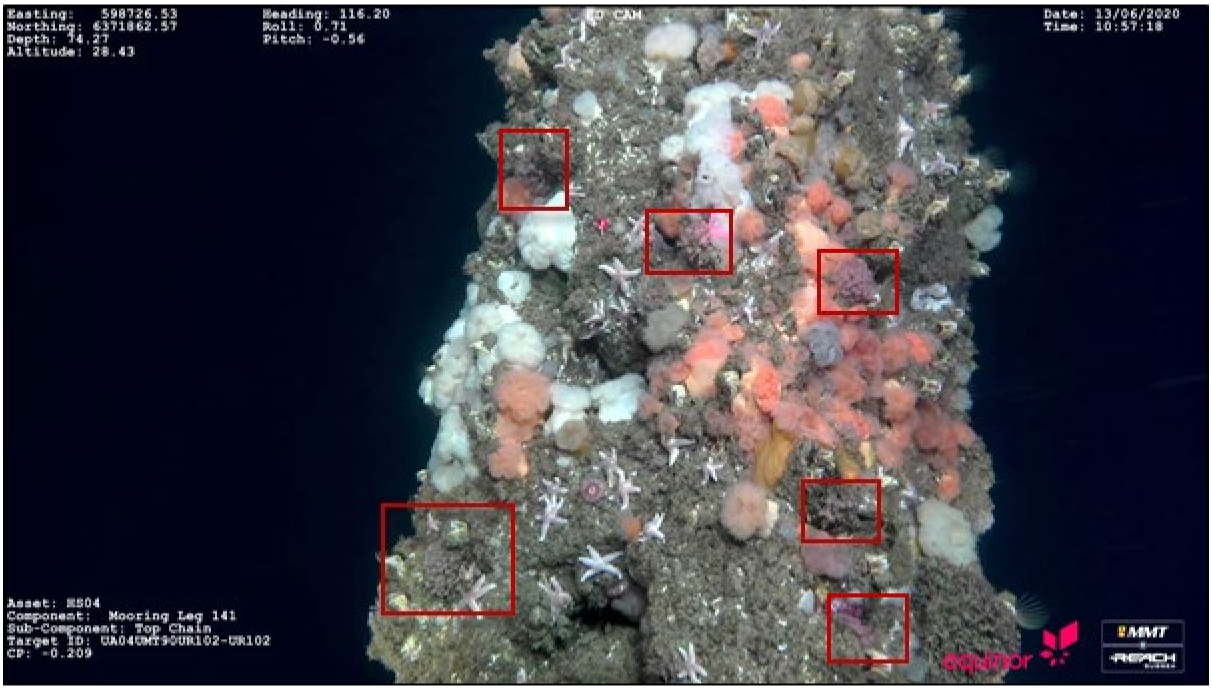


Figure 12 Top Chain 141 with E. larynx.

5.1.4| INFIELD CABLES

From the Bellmouth to Touchdown the overall dominating species was the barnacle Balanoidea which was present in high numbers along all four infield cables (Table 15).

Infield cables QA01 and QA02 comprised an overall faunal coverage of 100 % from each Bellmouth to Touch Down (Figure 13) and QA04 and QA05 comprised areas with lower faunal coverage (Figure 14). The infield cables were buried between each touchdown and no faunal colonisation was therefore present (Figure 15). A small section of infield cable QA01 was visible in connection with the Concrete Mattress (Figure 16).

Table 15 Estimation of epifouling colonisation for the infield cables.

STRUCTURE ID	OVERALL FAUNAL COVERAGE (%)	DOMINANT SPECIES
Infield Cable HS4-HS5 (QA01)		
HS04 – Bellmouth to Touch down	100 %	Balanoidea
Infield Cable	N/A	N/A
HS05 – Bellmouth to Touch down	100 %	Balanoidea
Infield Cable HS1-HS4 (QA02)		
HS01 – Bellmouth to Touch down	100 %	Balanoidea
Infield Cable	N/A	N/A
HS04 – Bellmouth to Touch down	100 %	Balanoidea *Ectopleura larynx*

STRUCTURE ID	OVERALL FAUNAL COVERAGE (%)	DOMINANT SPECIES
Infield Cable HS2-HS3 (QA04)		
HS02 – Bellmouth to Touch down	60 – 100 %	*Metridium senile* Balanoidea *Spirobranchus*
Infield Cable	N/A	N/A
HS03 – Bellmouth to Touch down	95 %	Balanoidea
Infield Cable HS3-HS5 (QA05)		
HS03 – Bellmouth to Touch down	100 %	Balanoidea
Infield Cable	N/A	N/A
HS05 – Bellmouth to Touch down	30 – 60 %	*Spirobranchus* Balanoidea *Metridium senile*

Figure 13 QA01 – HS04 Bellmouth to Buoyancy Modules at 67 metres depth, 100 % faunal coverage.

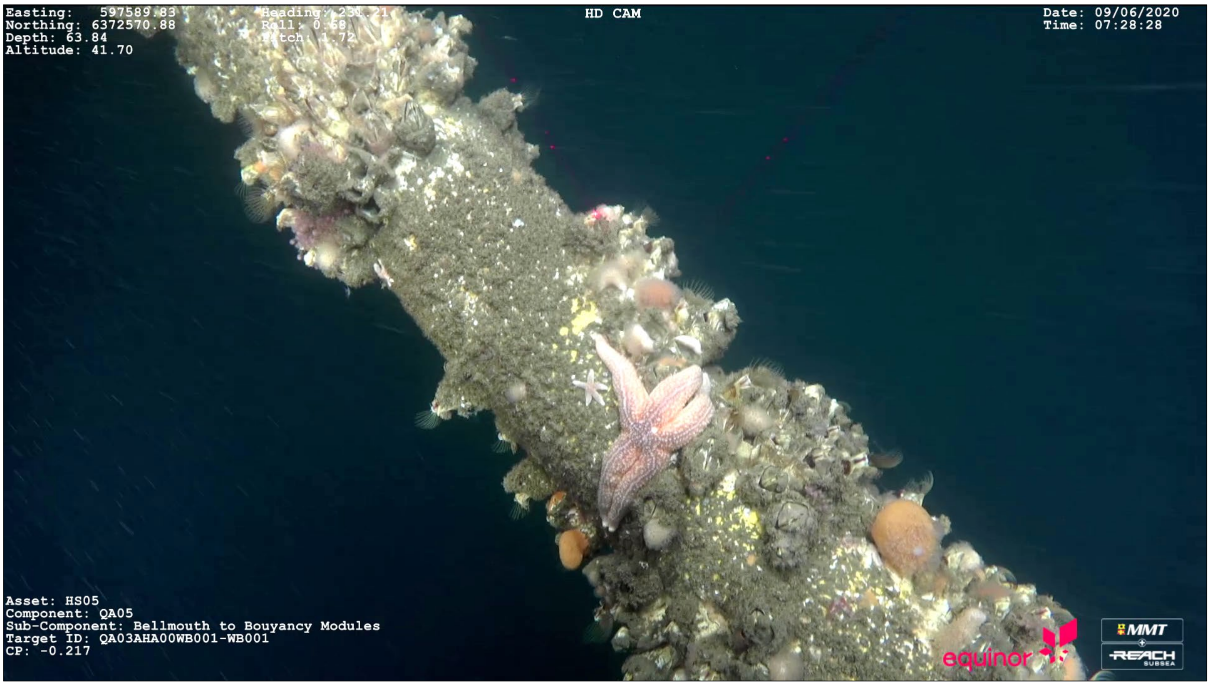


Figure 14 QA05 – HS05 Bellmouth to Buoyancy modules at 64 m depth, 50 % faunal coverage.

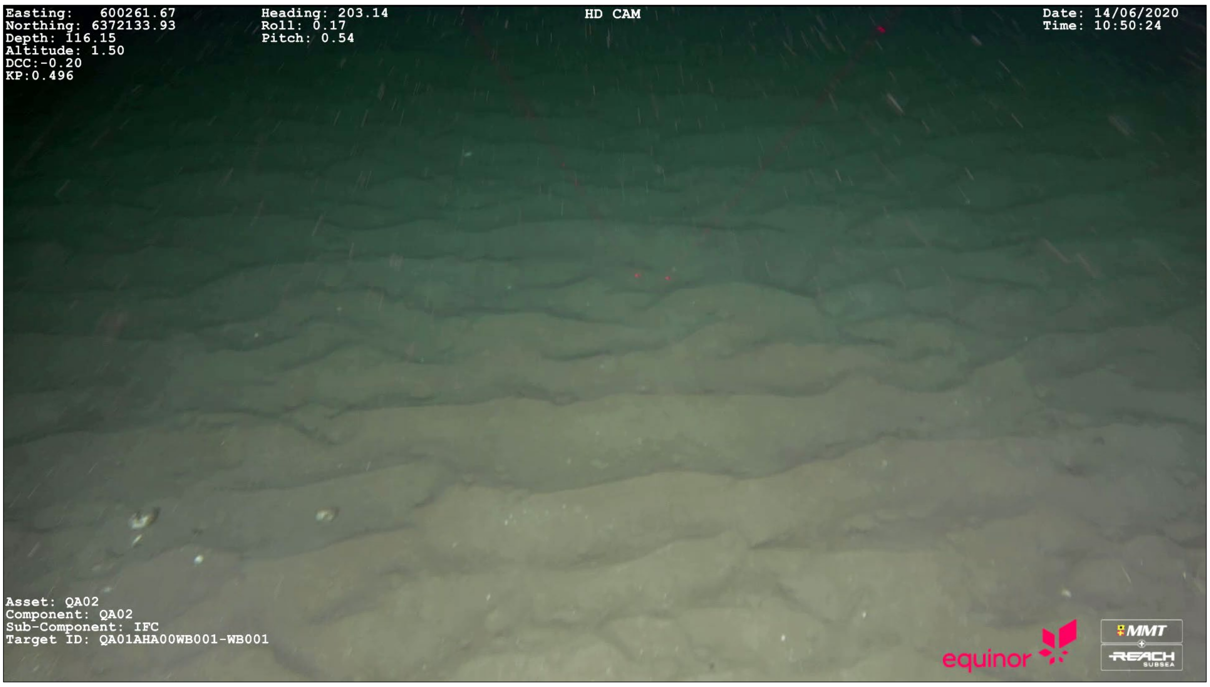


Figure 15 Infield Cable QA02. Example image of a buried cable and rippled sands.

Figure 16 Infield Cable QA01 – Small section of the cable visible with encrusting S. spinulosa.

5.1.5| CONCRETE MATRESS

The concrete mattress located on top of QA01 was predominantly buried and overall faunal coverage was 40 %. The dominating species was *S. spinulosa* and *E. larynx* (Table 16).

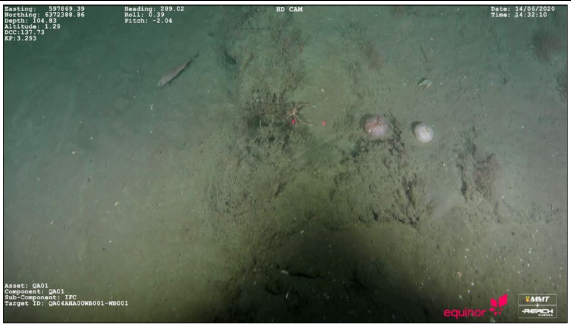
Other epifouling fauna present included other hydroids such as *N. ramosa*, *Tubularia indivisa*, and *Urticina*. Mobile fauna found on the structure included Asteroidea, Galatheoidea, Paguridae, *L. maja* and *C. pagurus*.

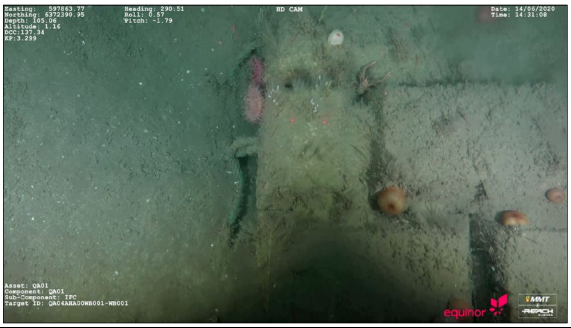
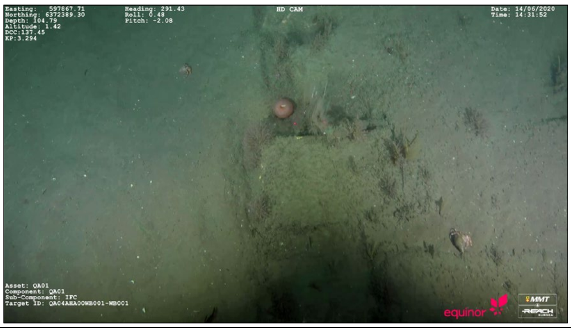
One individual of Pleuronectiformes, *Homarus sp*. and *Molva molva* was present on the concrete mattress (Table 17).

Table 16 Estimation of epifouling colonisation for the Concrete mattress.

STRUCTURE ID	OVERALL FAUNAL COVERAGE (%)	DOMINANT SPECIES
Concrete Mattress	40 %	*Sabellaria spinulosa* *Ectopleura larynx*

Table 17 Concrete Mattress.



5.2| ZONATION ON SUBSTRUCTURES

The five substructures (HS01 to HS05) were assessed in terms of depth zonation and with regard to faunal composition.

The priority structures HS01, HS02 and HS04 were investigated at a slower speed and on three sides (12 o'clock, 4 o'clock and 8 o'clock) while non priority structures HS03 and HS05 were investigated simultaneously as NES Ops investigation. The coverage of the dominating taxa and overall faunal colonisation of the substructures and at different zonation depths are presented in Table 18.

The overall species composition was similar at all five turbines with *Spirobranchus* and *M. senile* being the dominant species at all depths except for the lower intertidal zone (0 – 10 m) where *Mytilus* and different species of brown algae, Phaeophyceae, mainly *Laminaria* dominated.

The estimated vertical zonation for all five substructures is illustrated in Figure 17 to Figure 21. The top is represented at the sea surface staring at 0 m extending to a depth of 77 m representing the bottom of the structure.

Five different faunal zones were identified at HS02 to HS05 and four layers at HS01. HS01 was dominated by *M. senile* (50 %) and *Spirobranchus* (50 %) from approximately 30 m to 77 m.

At substructure HS03, a change in dominating species occurred at approximately 45 m where *Spirobranchus* was noted to dominate completely. This was also noted for substructures HS02, HS04 and HS05 at 60 m down to 77 m.

At substructure HS01 to HS03, *Mytilus* and *Laminaria* were the dominating taxa from 0 m to approximately 4 m and at HS04 and HS05 it was *Mytilus* and different species of Phaeophyceae.

From approximately 4 m to 15 m differed between the five substructures. Substructure HS01 was colonised by biofilm and Phaeophyceae, HS02 by *M. senile* and *Laminaria,* HS03 by *Laminaria* and Phaeophyceae, HS04 by *M. senile*, *Spirobranchus* and biofilm, and HS05 was dominated by *M. senile*, Biofilm and Phaeophyceae.

Table 18 Vertical zonation on the substructures.

STRUCTURE ID	ZONATION	SPECIES	COVERAGE (%)	OVERALL FAUNAL COLONISATION (%)
HS01 12 o'clock	0 – 4 m	Phaeophyceae *Alaria* *Laminaria* *Mytilus*	20 % 10 % 20 % 50 %	100 %
	4 – 13 m	Phaeophyceae Biofilm	10 % 90 %	90 %
	13 – 30 m	*Metridium senile* Biofilm *Spirobranchus*	30 % 40 % 30 %	70 %
	30 – 77 m	*Metridium senile* *Spirobranchus*	50 % 50 %	100 %
	Under structure	*Metridium senile* *Spirobranchus* *Ascidia mentula*	75 % 15 % 10 %	100 %
HS01 4 o'clock	0 – 6 m	N/A	N/A	N/A
	6 – 14 m	Phaeophyceae Biofilm	50 % 50 %	90 %
	14 – 25 m	Biofilm *Spirobranchus*	75 % 25 %	90 %
	25 – 60 m	*Metridium senile* *Spirobranchus*	45 % 55%	90 %
	60 – 77 m	*Spirobranchus* *Metridium senile*	50 % 50 %	100 %
	Under structure	*Spirobranchus* *Metridium senile*	50 % 50 %	100 %
HS01 8 o'clock	0 – 5 m	*Mytilus* *Laminaria* *Ulva* Phaeophyceae	60 % 15 % 5 % 20 %	90 %
	5 – 10 m	Biofilm Phaeophyceae	50 % 50 %	80 %
	10 – 20 m	Biofilm *Spirobranchus* *Metridium senile*	50 % 25 % 25 %	70 %
	20 – 30 m	*Spirobranchus* Biofilm *Metridium senile*	80 % 10 % 10 %	90 %
	30 – 35 m	*Spirobranchus* Biofilm *Alcyonium digitatum* *Metridium senile*	40 % 30 % 10 % 20 %	90 %
	35 – 60 m	*Metridium senile* *Spirobranchus*	40 % 60 %	90 %
	60 – 77 m	*Metridium senile* *Spirobranchus*	60 % 40 %	70 %
	Under structure	*Spirobranchus*	60 %	70 %

STRUCTURE ID	ZONATION	SPECIES	COVERAGE (%)	OVERALL FAUNAL COLONISATION (%)
		Metridium senile *Alcyonium digitatum*	30 % 10 %	
HS02 **12 o'clock**	0 – 3 m	*Mytilus* *Laminaria*	70 % 30 %	100 %
	3 – 10 m	Phaeophyceae *Laminaria* *Metridium senile*	10 % 10 % 80 %	90 %
	10 – 30 m	*Metridium senile* *Spirobranchus*	90 % 10 %	90 %
	30 – 60 m	*Metridium senile* *Spirobranchus*	60 % 40 %	90 %
	60 – 77 m	*Spirobranchus* *Metridium senile*	70 % 30 %	100 %
	Under structure	*Metridium senile* *Spirobranchus* Balanoidea	90 % 5 % 5 %	100 %
HS02 **4 o'clock**	0 – 5 m	*Mytilus* *Laminaria* Biofilm	70 % 20 % 10 %	100 %
	5 – 10 m	*Laminaria* Phaeophyceae Biofilm	40 % 40 % 20 %	90 %
	10 – 15 m	Phaeophyceae Biofilm *Metridium senile* *Spirobranchus*	20 % 40 % 30 % 10 %	90 %
	15 – 25 m	*Spirobranchus* *Metridium senile* Biofilm	50 % 25 % 25 %	90 %
	25 – 45 m	*Metridium senile* *Spirobranchus*	80 % 20 %	90 %
	45 – 65 m	*Metridium senile* *Spirobranchus*	60 % 40 %	100 %
	65 – 77 m	*Spirobranchus* *Metridium senile*	70 % 30 %	100 %
	Under structure	*Spirobranchus* *Metridium senile*	60 % 40 %	100%
HS02 **8 o'clock**	0 – 5 m	*Mytilus* *Laminaria*	80 % 20 %	100 %
	5 – 10 m	*Metridium senile* *Laminaria*	80 % 20 %	100 %
	10 – 20 m	*Metridium senile* *Spirobranchus*	90 % 10 %	90 %
	20 – 35 m	*Metridium senile* *Spirobranchus*	75 % 25 %	90 %
	35 – 70 m	*Spirobranchus* *Metridium senile*	50 % 50 %	100 %

STRUCTURE ID	ZONATION	SPECIES	COVERAGE (%)	OVERALL FAUNAL COLONISATION (%)
	70 – 77 m	*Spirobranchus* *Metridium senile*	70 % 30 %	100 %
	Under structure	*Metridium senile* *Spirobranchus* Balanoidea	45 % 50 % 5 %	100 %
HS03	0 – 3 m	*Mytilus* *Laminaria*	80 % 20 %	100 %
	3 – 9 m	*Laminaria* *Ulva* Phaeophyceae	50 % 10 % 40 %	100 %
	9 – 15 m	*Metridium senile* Phaeophyceae	80 % 20 %	80 %
	15 – 45 m	*Metridium senile* *Spirobranchus*	75 % 25 %	85 %
	45 –77 m	*Spirobranchus* *Metridium senile*	70 % 30 %	80 %
HS04 **12 o'clock**	0 – 4 m	*Mytilus* Phaeophyceae	70 % 30 %	100 %
	4 – 15 m	*Metridium senile* *Spirobranchus* Biofilm	50 % 30 % 20 %	80 %
	15 – 25 m	Biofilm *Metridium senile* *Spirobranchus*	50 % 40 % 10 %	90 %
	25 – 60 m	*Metridium senile* *Spirobranchus*	50 % 50 %	100 %
	60 – 77 m	*Spirobranchus* *Metridium senile*	70 % 30 %	100 %
	Under structure	*Metridium senile* *Spirobranchus* *Urticina*	60 % 30 % 10 %	100 %
HS04 **4 o'clock**	0 – 5 m	*Mytilus* *Laminaria*	70 % 30 %	80 %
	5 – 15 m	Biofilm Phaeophyceae *Laminaria* *Ulva*	80 % 10 % 5 % 5 %	80 %
	15 – 25 m	Biofilm *Spirobranchus*	70 % 30 %	80 %
	25 – 60 m	*Spirobranchus* *Metridium senile*	50 % 50 %	80 %
	70 – 77 m	*Spirobranchus* *Metridium senile*	80 % 20 %	90 %
	Under structure	*Metridium senile* *Spirobranchus*	80 % 20 %	100 %
HS04	0 – 4 m	*Mytilus* Phaeophyceae	80 % 20 %	90 %

STRUCTURE ID	ZONATION	SPECIES	COVERAGE (%)	OVERALL FAUNAL COLONISATION (%)
8 o'clock	4 – 9 m	Biofilm *Metridium senile* Phaeophyceae	70 % 15 % 15 %	80 %
	9 – 25 m	Biofilm *Metridium senile*	50 % 50 %	80 %
	25 – 60 m	*Metridium senile* *Spirobranchus*	40 % 60 %	70 %
	60 – 77 m	*Spirobranchus* *Metridium senile*	50 % 50 %	90 %
	Under structure	*Metridium senile* *Spirobranchus*	80 % 20 %	90 %
HS05	0 – 5 m	*Mytilus* Phaeophyceae *Laminaria*	70 % 25 % 5 %	90 %
	5 – 15 m	*Metridium senile* Biofilm Phaeophyceae	40 % 40 % 20 %	70 %
	15 – 25 m	*Metridum senile* Biofilm	50 % 50 %	80 %
	25 – 60 m	*Metridium senile* *Spirobranchus*	75 % 25 %	100 %
	60 – 77 m	*Spirobranchus* *Metridium senile*	70 % 30 %	90 %

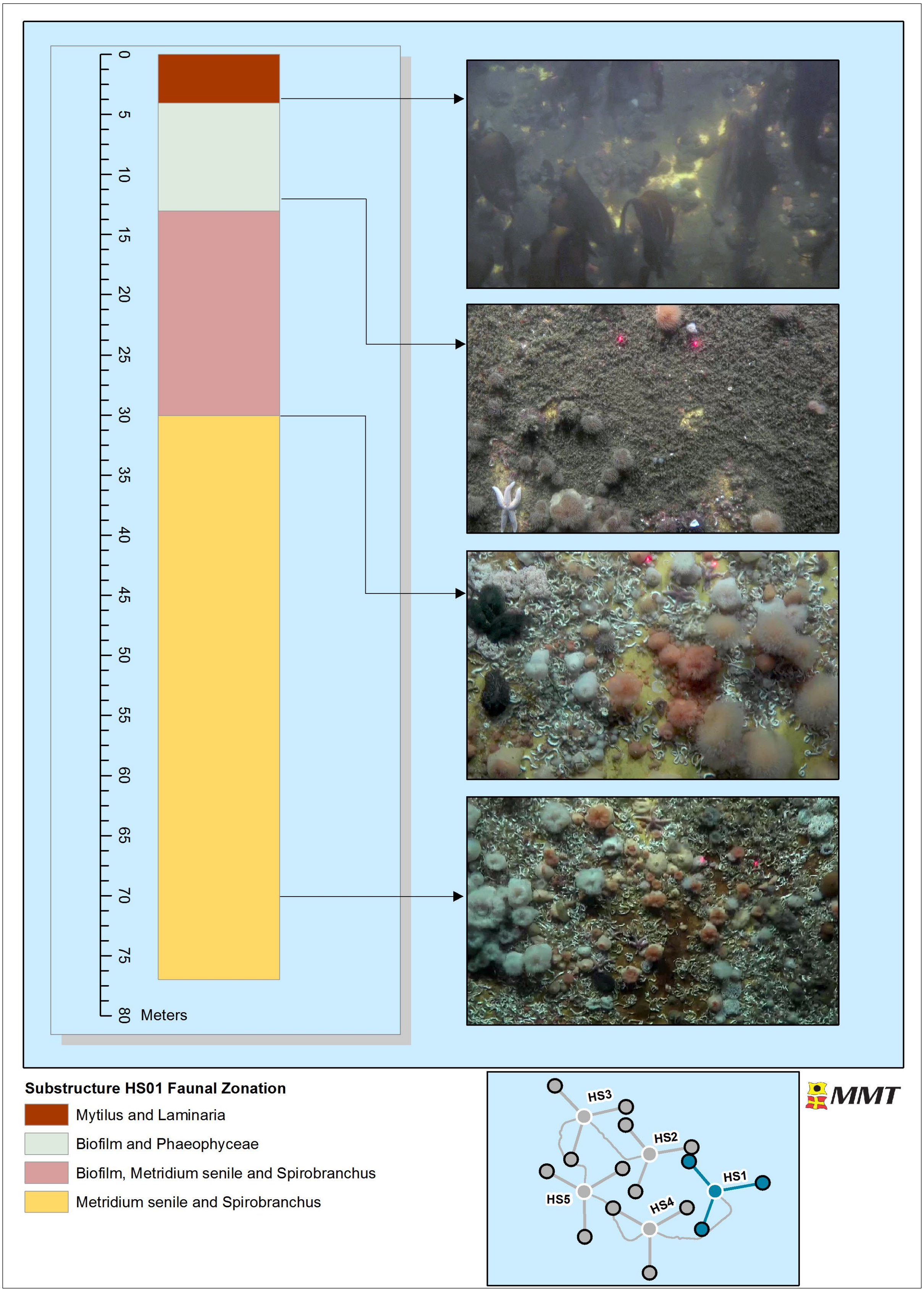


Figure 17 Illustration of faunal zonation at substructure HS01.

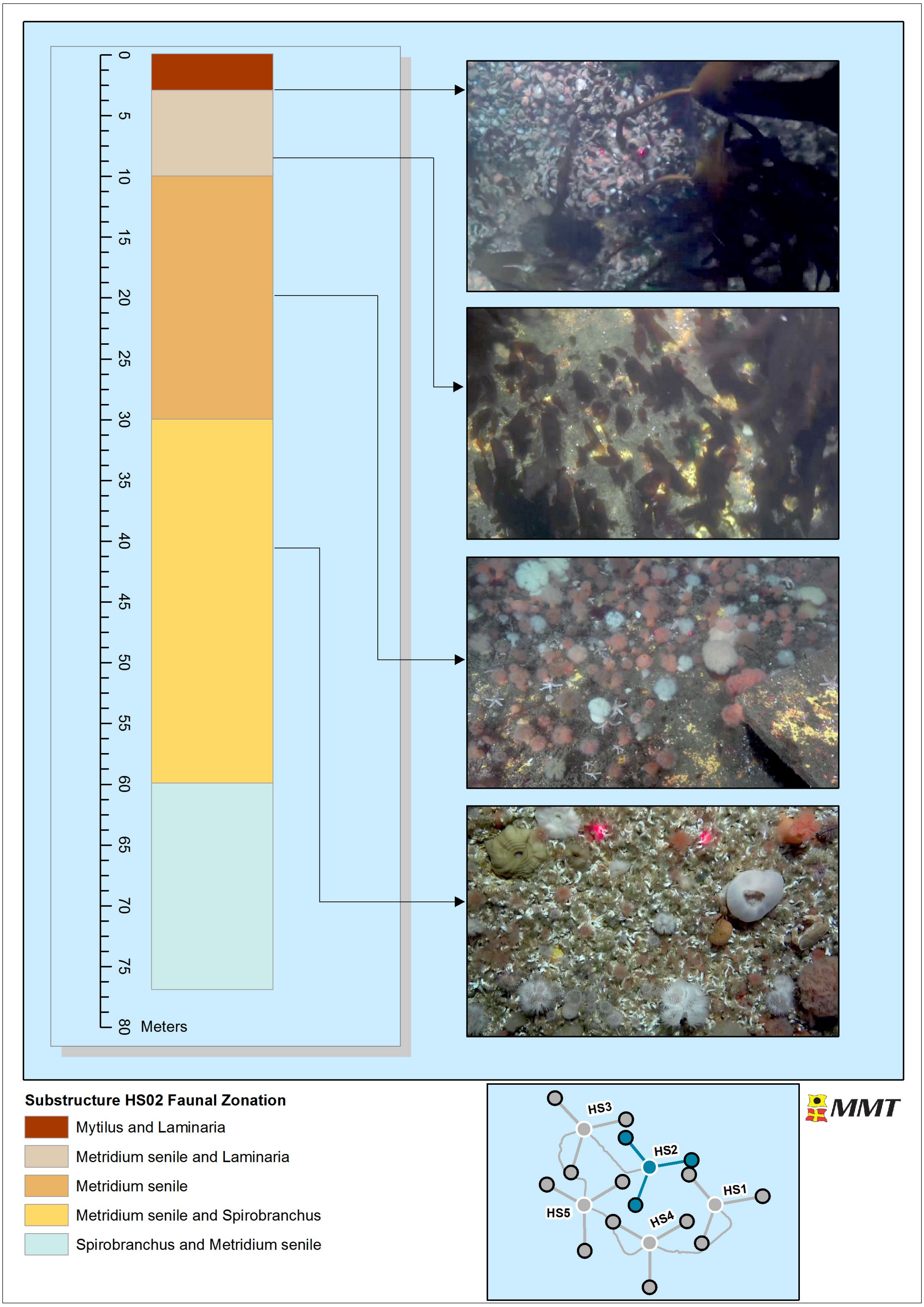


Figure 18 Illustration of faunal zonation depth at substructure HS02.

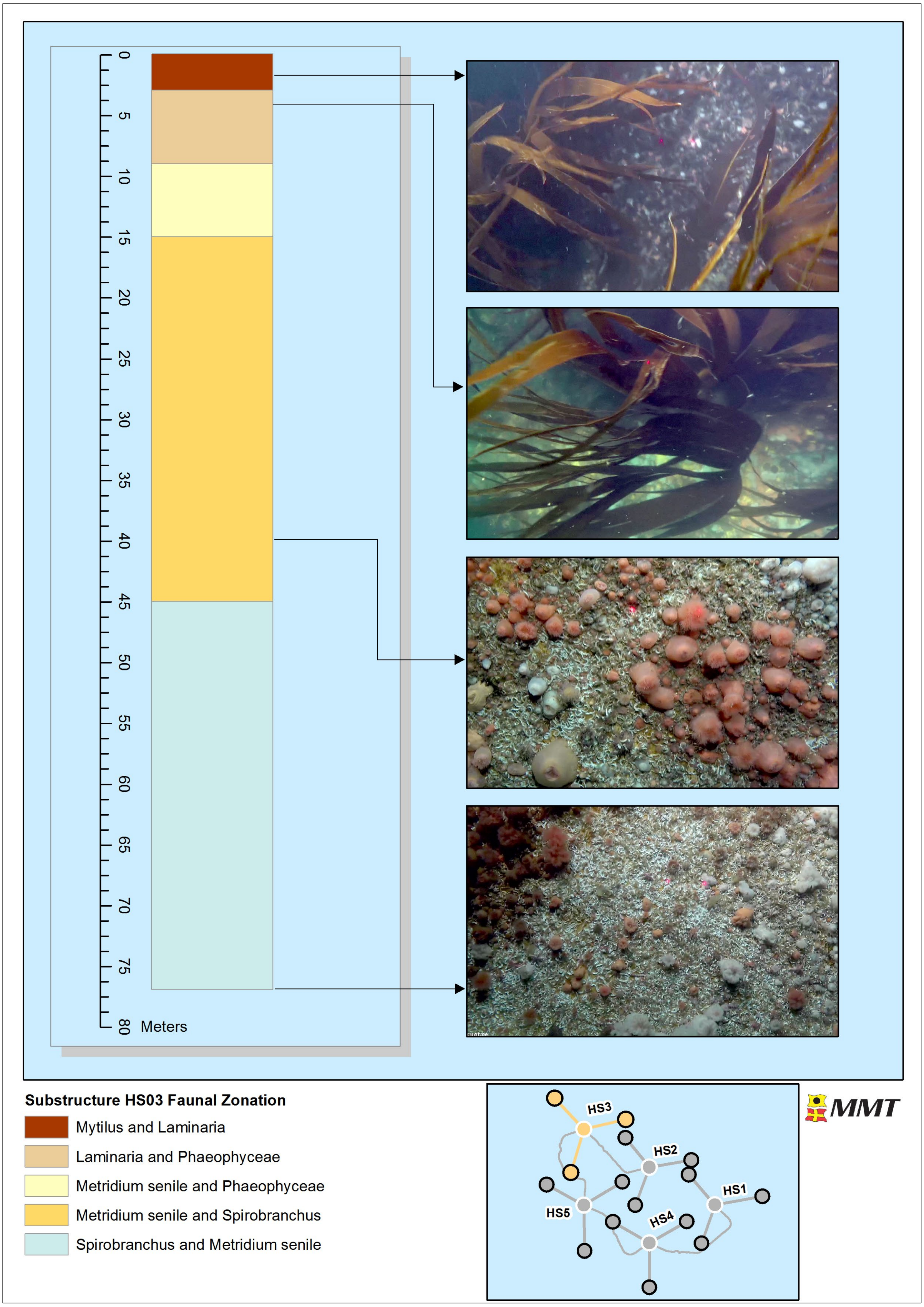


Figure 19 Illustration of faunal zonation depth at substructure HS03.

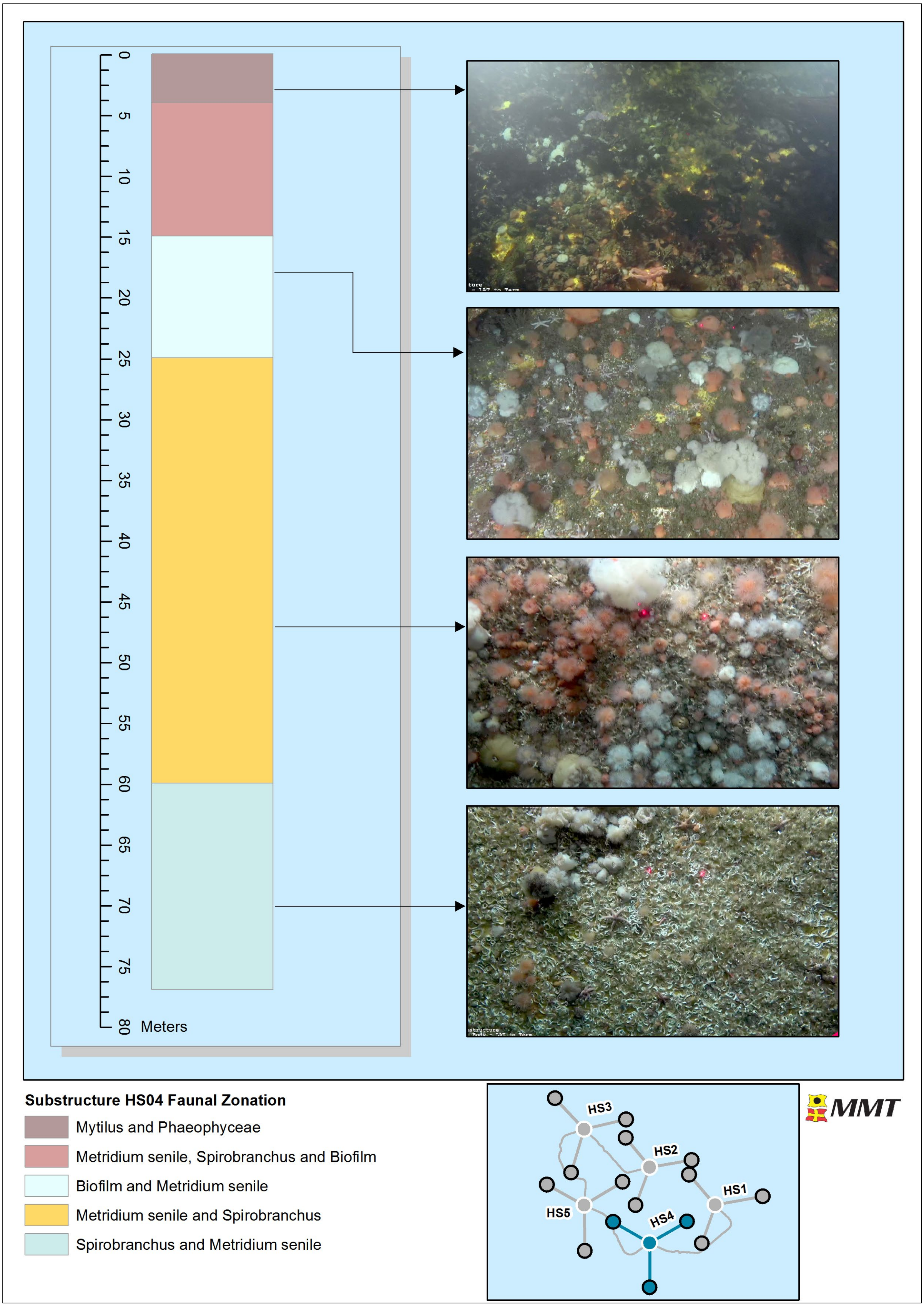


Figure 20 Illustration of faunal zonation depth at substructure HS04.

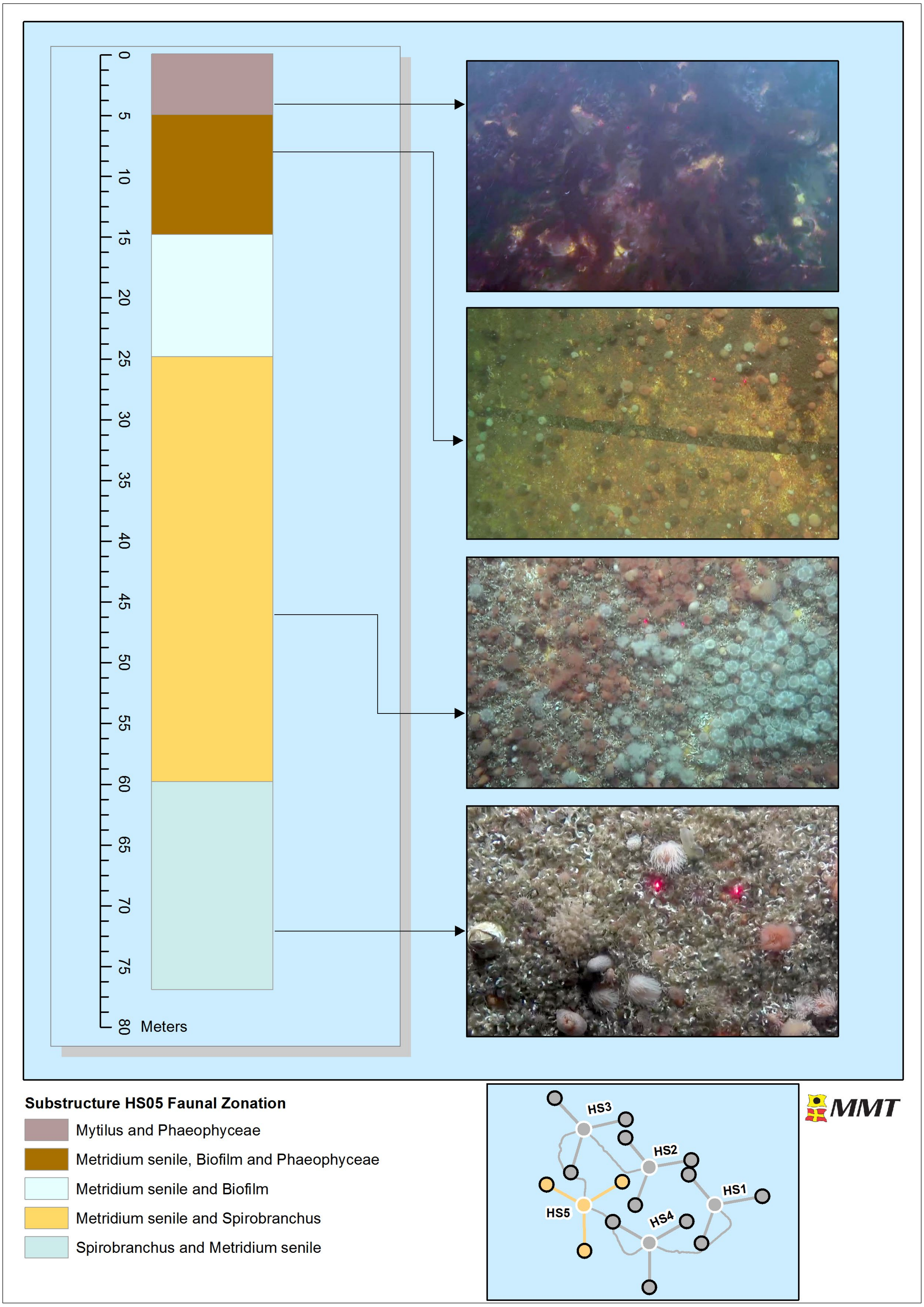


Figure 21 Illustration of faunal zonation depth at substructure HS05.

5.3| COMPARISON ON MARINE GROWTH

Data, from the 2018 inspection campaign, provided by REACH Subsea was compared to the current 2020 campaign. Structures and subcomponents not reported on during the 2018 campaign have been excluded in this comparison, which includes all cables and H-links.

TURBINE SUBSTRUCTURE HS01

An overall increase in hard marine growth coverage for HS01, especially for Mooring Line 111, was noted during the current survey in comparison with the findings of 2018. The coverage of soft marine growth has also increased (Figure 22 and Figure 23).

The thickness of hard marine growth has generally decreased, however, where the thickness has increased it has increased distinctly. Soft marine growth has partially increased and partially decreased in thickness (Figure 24 and Figure 25).

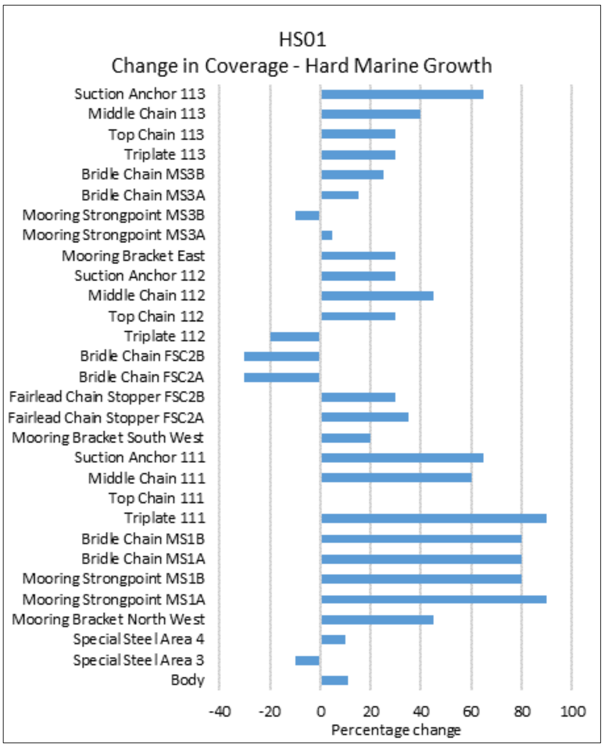


Figure 22 Change in coverage of hard marine growth for HS01.

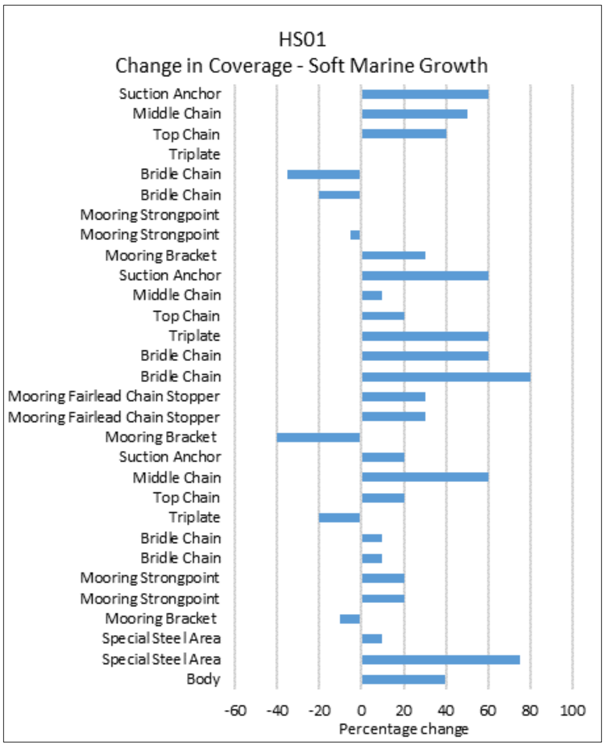


Figure 23 Change in coverage of soft marine growth for HS01.

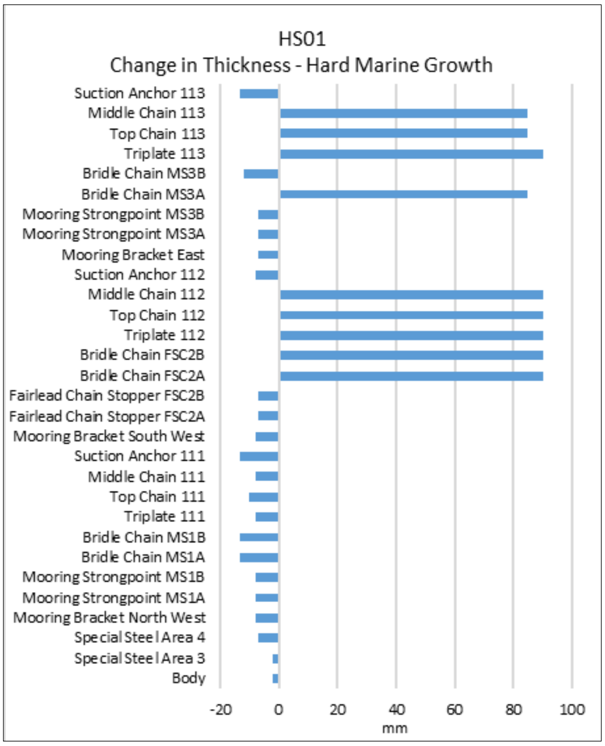


Figure 24 Change in thickness of hard marine growth for HS01.

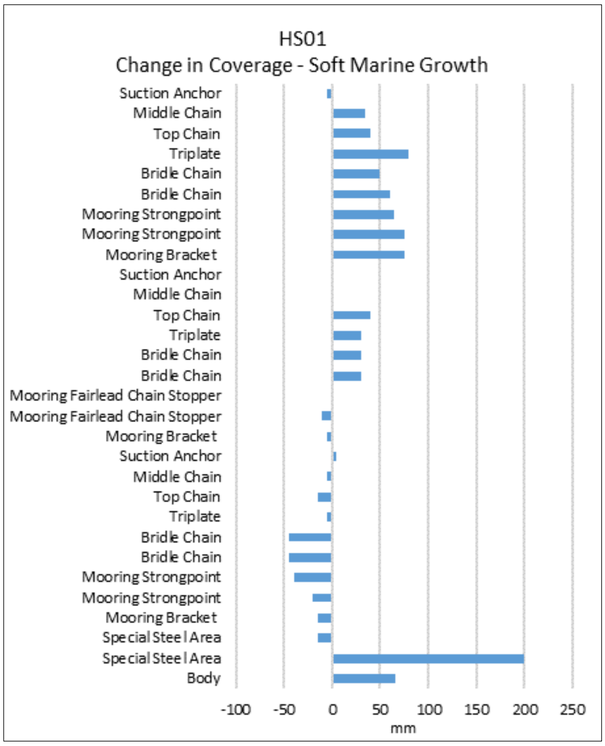


Figure 25 Change in thickness of soft marine growth for HS01.

TURBINE SUBSTRUCTURE HS02

Hard and soft marine growth at turbine HS02 have both generally increased, with the most noticeable increase in hard marine growth having occurred at Mooring Lines 121 and 123 (Figure 26 and Figure 27).

The thickness of hard marine growth had an overall decrease and the thickness of soft marine growth decreased or remained unchanged for all structures but the Main Body which had an increase in thickness. (Figure 28 and Figure 29).

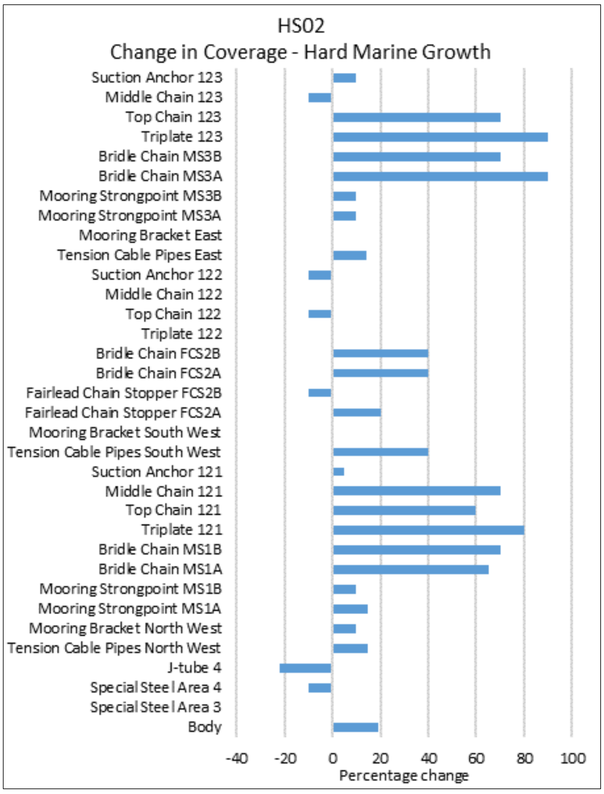


Figure 26 Change in coverage of hard marine growth for HS02.

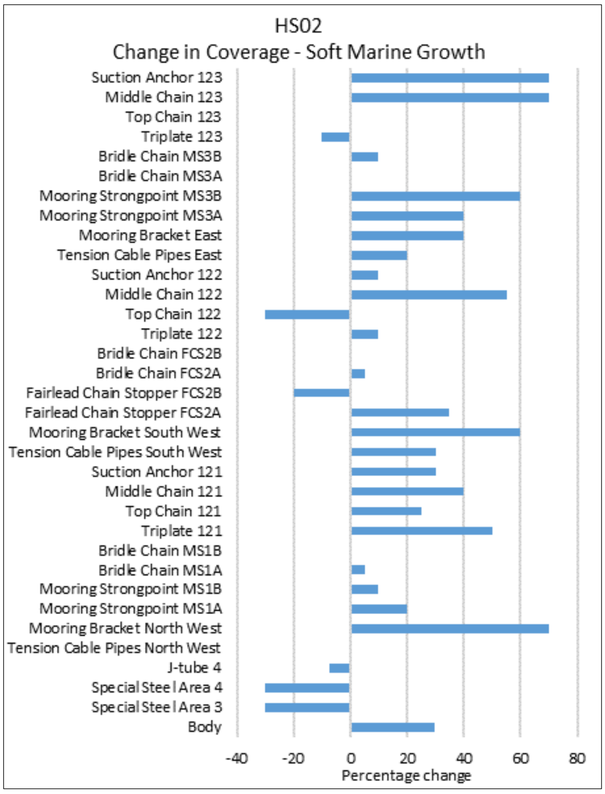


Figure 27 Change in coverage of soft marine growth for HS02.

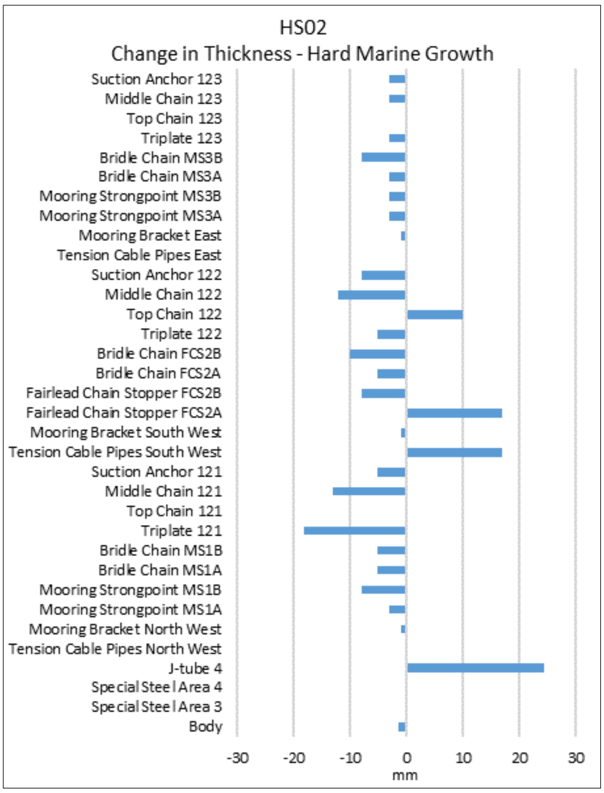


Figure 28 Change in thickness of hard marine growth for HS02.

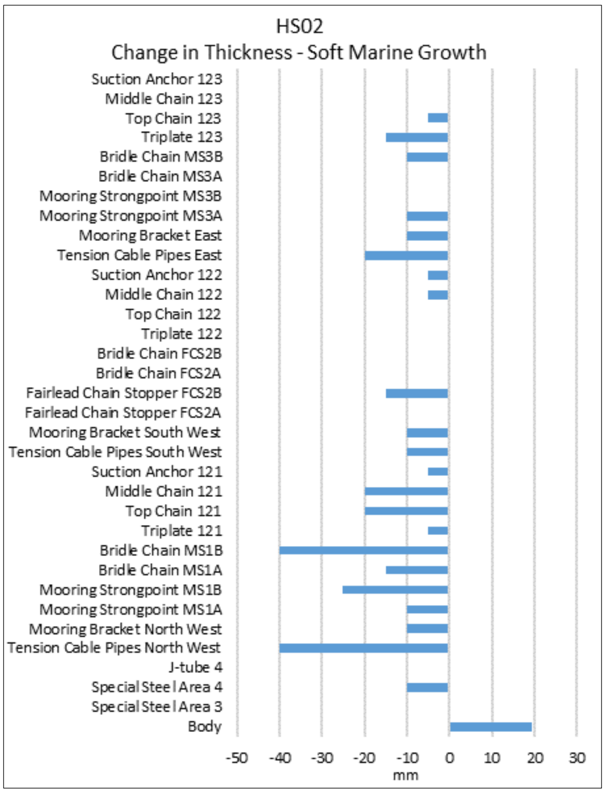


Figure 29 Change in thickness of soft marine growth for HS02.

TURBINE SUBSTRUCTURE HS03

At Turbine HS03, both hard and soft marine growth show an overall increase with regards to coverage for HS03 (Figure 30 and Figure 31).

The thickness of hard marine growth has decreased or remained unchanged for all structures but for Top Chain 133 and Mooring Strong Point MS3A. Soft marine growth has decreased in thickness overall with the exception of the Main Body and some of the structures attached to it (Figure 32 and Figure 33).

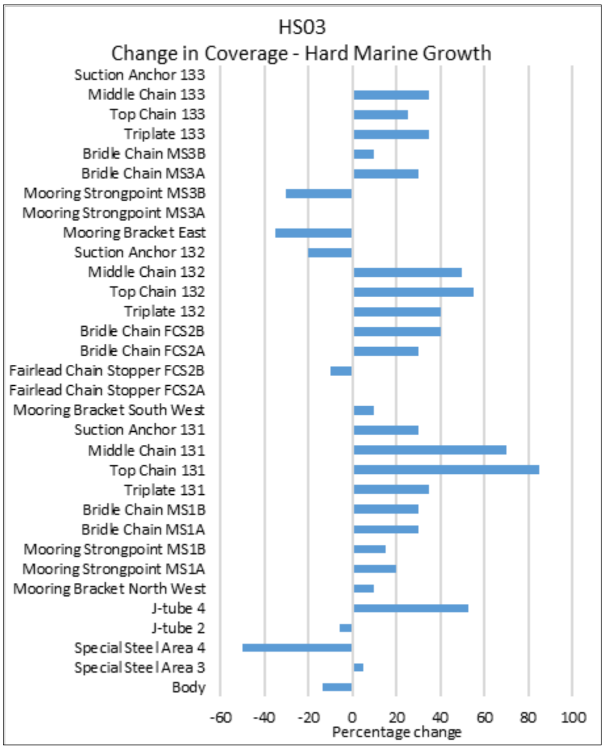


Figure 30 Change in coverage of hard marine growth for HS03.

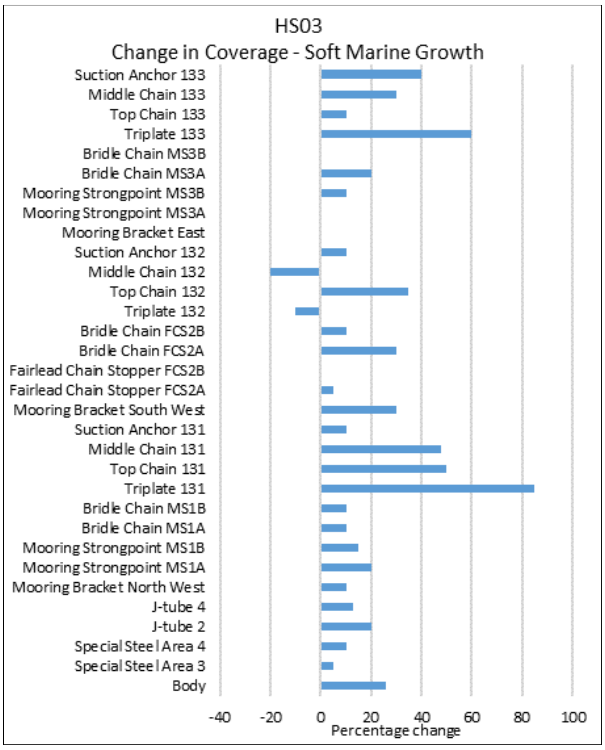


Figure 31 Change in coverage of soft marine growth for HS03.

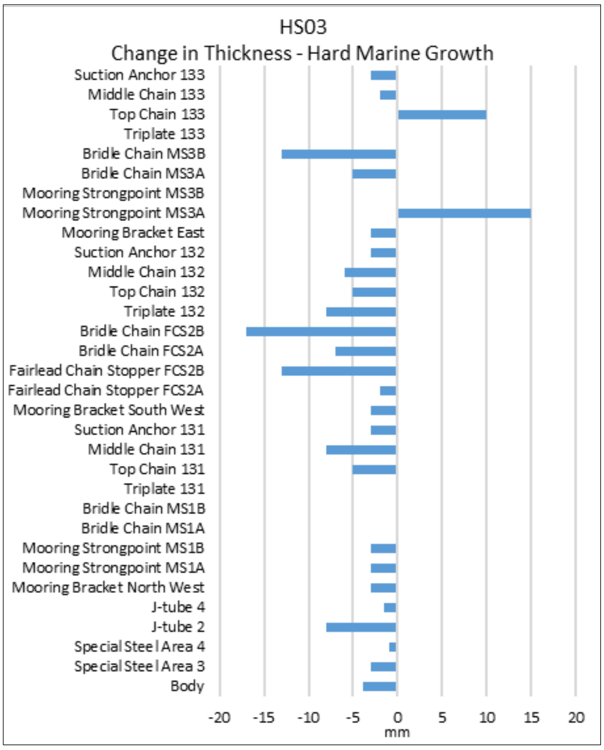


Figure 32 Change in thickness of hard marine growth for HS03.

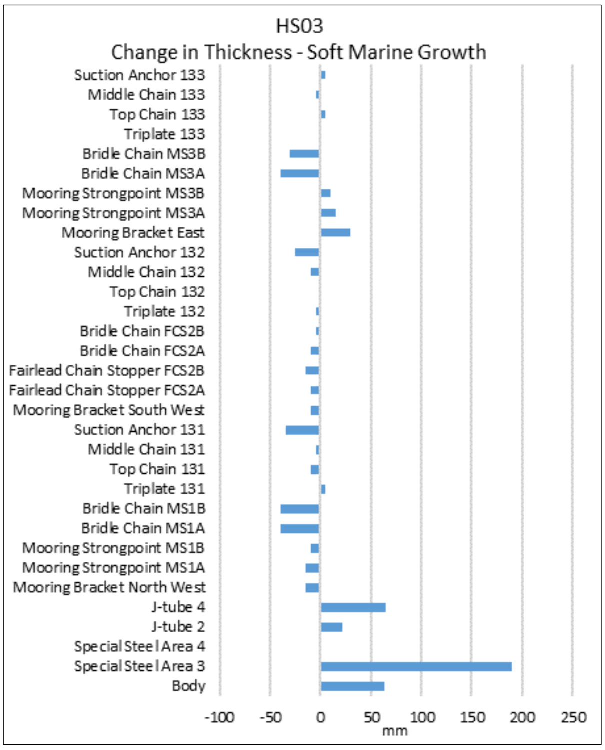


Figure 33 Change in thickness of soft marine growth for HS03.

TURBINE SUBSTRUCTURE HS04

Both hard and soft marine growth has overall increased with regards to coverage for HS04 (Figure 34 and Figure 35).

The thickness of marine growth has overall decreased for both hard and soft marine growth. However, thickness has increased markedly at Bridle Chains and Mooring Strongpoints MS3A and MS3B for both hard and soft marine growth, as well as J-tube 4 and Special Steel Areas 3 and 4 for soft marine growth (Figure 36 and Figure 37).

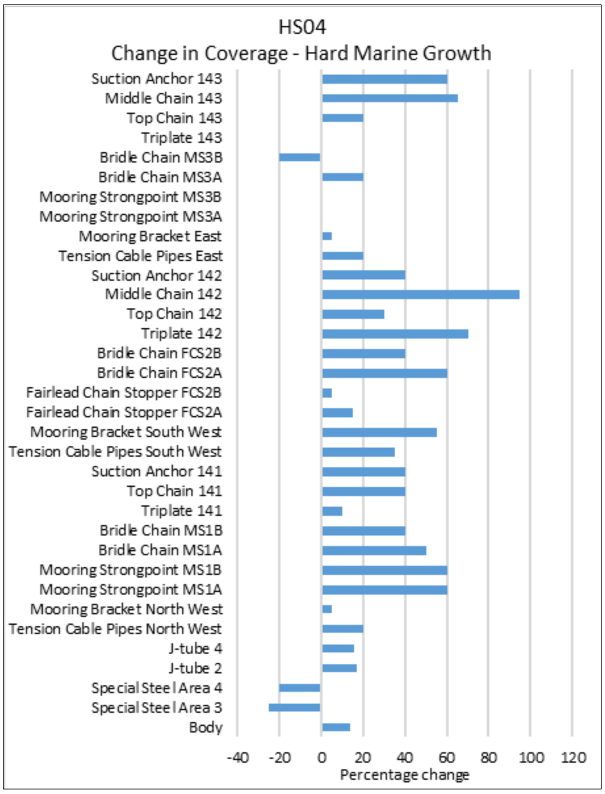


Figure 34 Change in coverage of hard marine growth for HS04.

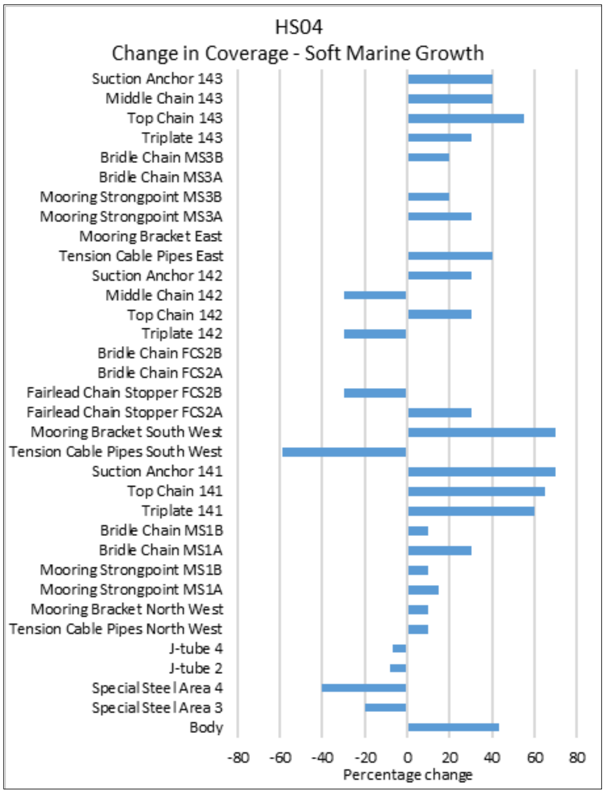


Figure 35 Change in coverage of soft marine growth for HS04.

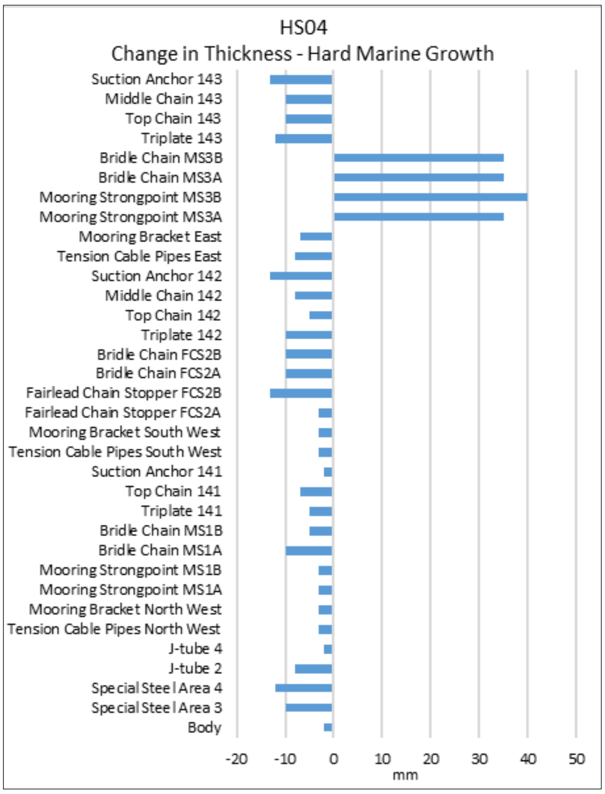


Figure 36 Change in thickness of hard marine growth for HS04.

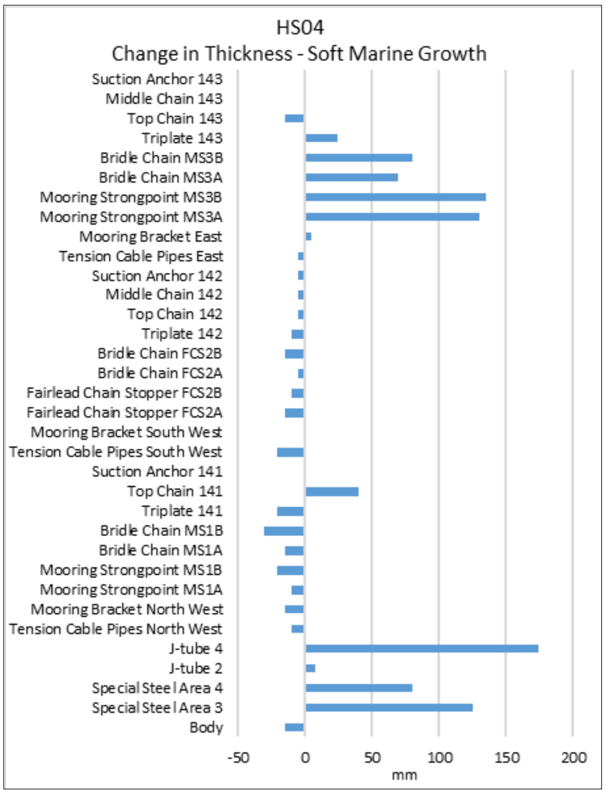


Figure 37 Change in thickness of soft marine growth for HS04.

TURBINE SUBSTRUCTURE HS05

Coverage of hard marine growth at turbine HS05 has increased distinctly, with the only decrease observed at J-tube 2 and Top Chain 152. The change in soft growth coverage was variable (Figure 38 and Figure 39).

The thickness of hard marine growth has increased at all structures but for of the structures along Mooring Line 151. Soft marine growth has had an overall decrease in thickness with the exception of a few structures attached to the Main Body (Figure 40 and Figure 41).

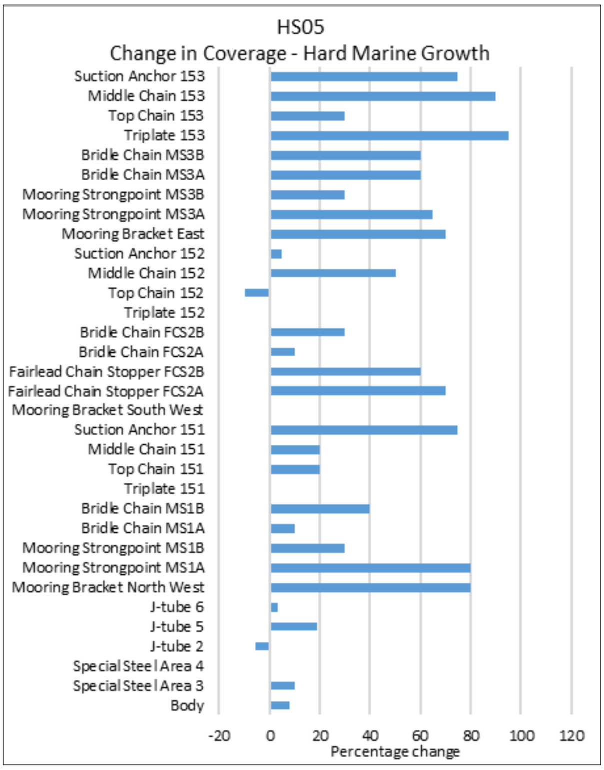


Figure 38 Change in coverage of hard marine growth for HS05.

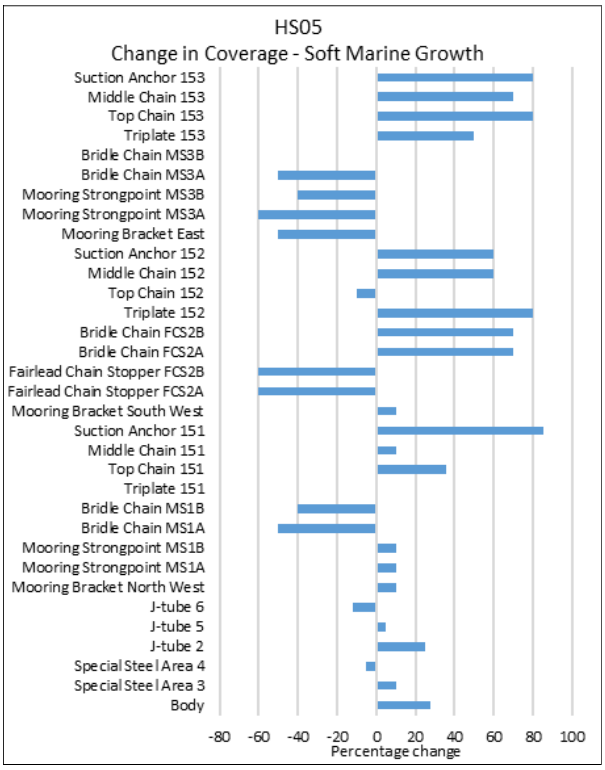


Figure 39 Change in coverage of soft marine growth for HS05.

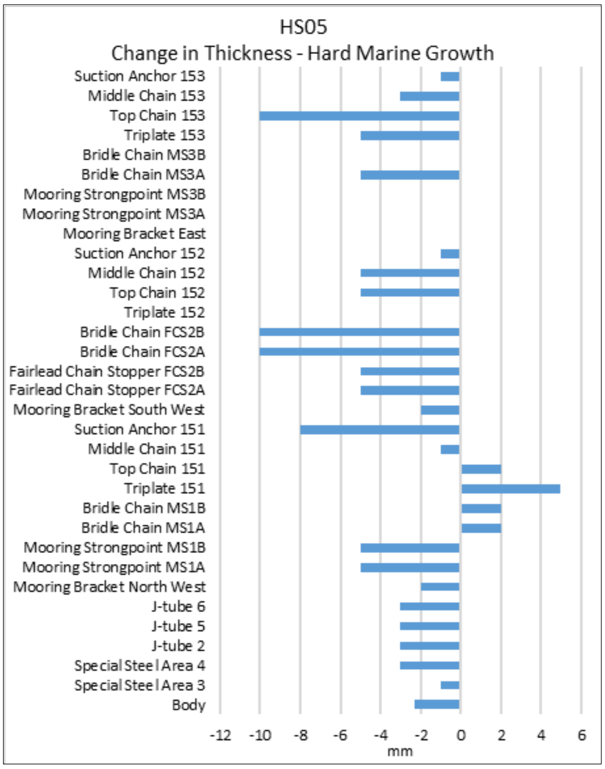


Figure 40 Change in thickness of hard marine growth for HS05.

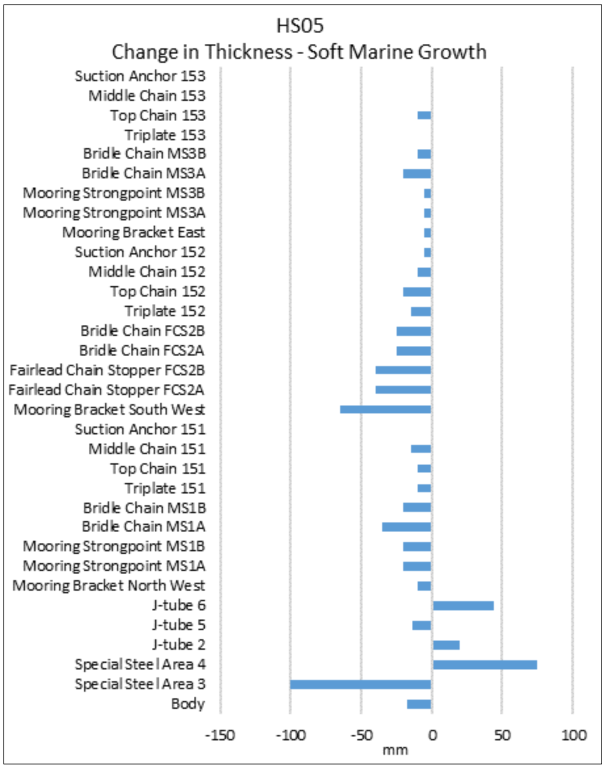


Figure 41 Change in thickness of soft marine growth for HS05.

6| CONCLUSIONS AND DISCUSSIONS

IDENTIFIED SPECIES AND NON-INDIGENOUS SPECIES

The preliminary phyletic composition of the survey area identified a total of 11 phyla and a total of 121 different taxa and 48 epifouling taxa.

Species characterisation during visual inspection gave a good overall image over the survey area and the higher phyletic community composition. The species detail level was limited when fauna was small and/or the environmental conditions were poor.

The noted biofouling classified as Biofilm, within this report, most likely consist of different species of hydroids, microorganisms and marine snow particles depending on the water depth.

The group Asteroidea was highly abundant and the majority of recorded individuals most likely belong to the species *A. rubens*. Individuals from the group Echinidea could be either *Psammechinus miliaris* and/or *Strongylocentrotus droebachiensis*. Squat lobsters were grouped in the super family Galatheoidea or when it was possible, the genus *Munida*.

No invasive or non-indigenous species were identified during the 2020 survey. However, it should be noted that the use of a WROV without any physical sampling limits the ability to identify smaller species and positively identified certain filamentous species of red and brown algae. For instance, the red algae *Dasysiphonia japonica* is an invasive and established species in Scotland, as well as the Japanese skeleton shrimp *Caprella mutica* (Scottish Natural Heritage, 2017).

Historically, invasive or non-indigenous species have been identified on man-made structures in the North Sea. Generally, species that have already been reported from the North Sea and are known to be early colonisers, are also known to take advantage of the newly added hard substrates (De Mesel, 2015).

The non-native American lobster, *Homarus americanus,* has been reported from the North Sea and around the British islands (Stebbing, 2012). Therefore, it cannot with certainty be determined whether any of the individuals observed during the current survey belong to that species.

Species *H. gammarus* and *H. americanus* are differentiated morphologically by the absence or presence of spines on the rostrum. One or more spines on the ventral surface of the rostrum are found at *H. americanus* and are absent from *H. gammarus* (Figure 42). This characteristic is difficult to distinguish without a physical specimen to examine in detail.

The barnacles observed on the structures were difficult to identify to species level and are grouped in the superfamily Balanoidea. Two possible species have been considered, *Balanus crenatus* and *Chirona hameri*. External experts were consulted and considered *B. crenatus* as the probable species but *C. hameri* cannot be excluded without a physical sample.

Figure 42 Homarus sp. *on the Concrete Mattress.*

The epifouling fauna identified during current survey were all species naturally occurring in Scottish waters and around the North Sea. The community structure, with its high abundances of *M. senile*, is however different when comparing the structures to what is generally observed on rocky intertidal habitats. *M. senile*, *Spirobranchus*, *M. edulis* and barnacles are predominant species normally observed on artificial structures in UK waters and seem to take advantage of newly installed surfaces (Bessel, 2008).

The seabed within the survey area comprises sand and gravel substrates with mega ripples and occasional boulder fields classified as mixed sediments, based on the 2013 survey (MMT, 2013). The areas with coarser sediment comprised aggregations of *S. spinulosa*, and were associated with a higher abundance of crustaceans, poriferans, sessile cnidarians, hydrozoans and fish.

Areas with high abundance of *S. spinulosa* provided reef-like structures that were elevated from the seabed. The report identified a higher abundance of anemones, hydrozoans, arthropods, echinoderms and flatfishes (MMT, 2013). The Mooring lines and Suction Anchors on the seabed surface have thus provided additional opportunity for settling and colonisation by *S. spinulosa* (Figure 43).

As the species occurs naturally in the area, the facilitated establishment created by the structures for *S. spinulosa* should not have a negative impact on the ecosystem. *S. spinulosa* habitats are often associated with high faunal biodiversity which create feeding grounds for different species of fish. After installation of the wind park no trawling occurs in the area which could also benefit commercial fish species.

A possible young colony of the deep water coral *Desmophyllum pertusum*, previously *Lophelia pertusa* was identified at QA02 – HS01 Buoyancy Modules (Figure 44). The deep water coral *D. pertusum* has not previously been recorded in this area although colonies have been observed on offshore structures in the North Sea (Roberts, 2002; Bergmark, 2014).

Cold water coral reefs occur naturally on the continental shelf in western Scotland in water depths between 130 m to 2000 m (Marine Scotland, 2016). However, a physical sample is required to confirm the species observed during this survey.

Simulations of larval dispersal of *D. pertusum* from offshore structures in the North Sea demonstrate that there is potential for larvae to settle in the survey area (Henry, 2018).

Figure 43 Dense encrusting S. spinulosa on a mooring line.

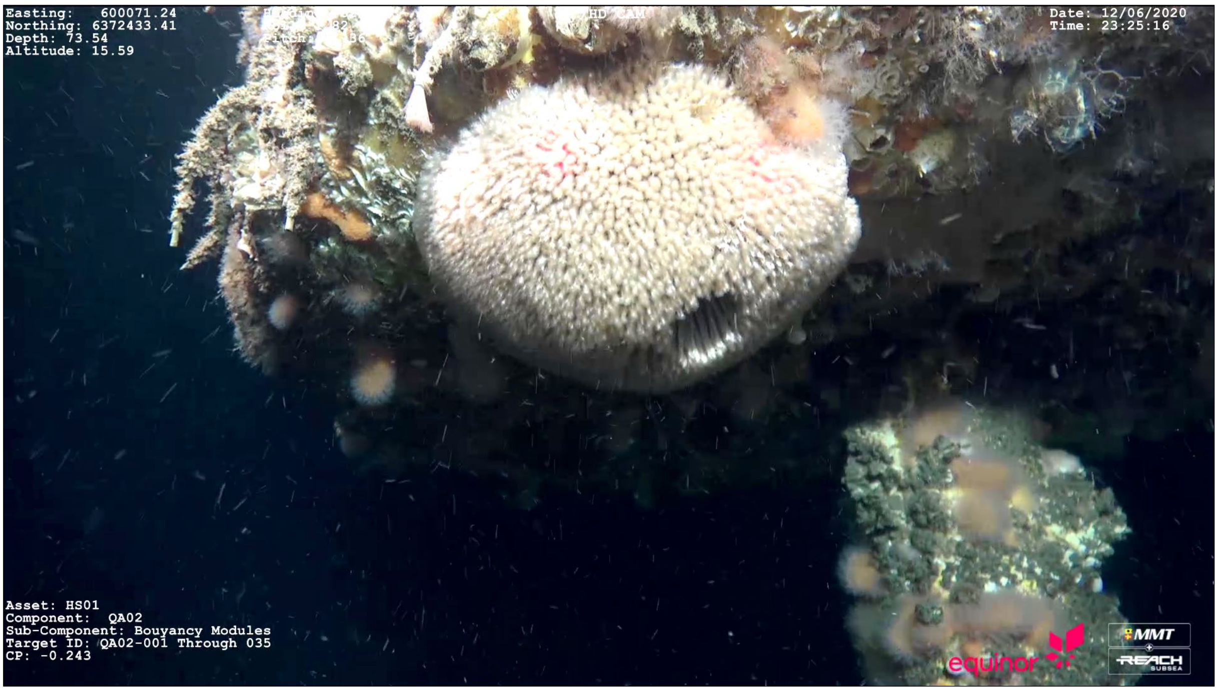


Figure 44 QA02 – HS01 Buoyancy Modules. Possible young colony of D. pertusum.

Species observed on the seabed in close proximity of the structures included different crustaceans (the brown crab *C. pagurus*, the Norway king crab *L. maja*, different species of squat lobsters (*Munida* and other species from the family Galatheoidea), and few individuals of the lobster *Homarus spp.)*.

Demersal fish including different species of flatfish Pleuronectiformes, Haddock *Melanogrammus aeglefinus,* and Ling *M. molva* were also found in high abundances around the structures. Squids, octopuses and rays were also observed.

Four mobile taxa featured on the Scottish Biodiversity List and as Priority Marine Features were identified in close proximity of the structures; Cod *Gadus morhua*, Ling *M. molva*, sand eel *Ammodytes* spp. and Whiting *Merlangius merlangus*.

EPIFOULING COLONISATION AND DOMINANT SPECIES

The overall epifaunal colonisation was assessed to almost 100 % on the different structures with some minor localized variations noted.

A study conducted in Belgium looked at the short- and long-term dynamics of the epifouling colonisation at two Offshore Wind Farms focusing on early colonisers and their succession stages (Rumes, 2013). Sampling started shortly after the completions of the installation and was performed yearly on a ten-year period for the turbines and yearly on a nine-year period for the monopiles.

The study further described an increase in biomass from epifouling fauna from an Offshore Wind Farm in Belgium due to the number of hard substrate associated species found on the structures. No samples were taken during current survey and therefore biomass was not included in the scope.

The high abundance of *M. senile*, within the current survey, is consistent with studies describing for offshore structures in the North Sea (Whomersley, 2003; Kerckhof F. R., 2012; De Mesel, 2015; Kerckhof, Rumes, & Degraer, 2019). Species of the amphipod *Jassa spp.* have been identified as one of the dominating species on offshore structures in the North Sea together with anemones and hydroids (Lindeboom, 2011; Krone, 2013), but was not observed during the current survey. Amphipods are small crustaceans and are challenging to identify without a physical sample. The brown layer observed on the blue mussels could be *Jassa* tubes (Figure 5), but a physical sample is required to confirm this.

The epifouling colonisation differed between the different structures with regards to species diversity. The painted substructures lacked the diversity generally found on the uncoated Mooring Lines. The tube building worm *Spirobranchus* dominated the painted substructures while Balanoidea together with hydroids dominated the uncoated structures. Uncoated structures have been found to comprise more diverse communities than steel monopiles (Kerckhof F. R., 2012).

The Concrete Mattress, inspected during the current survey, was partial covered with sediment and is likely to be completely buried in the future. The structure provided a hard substrate for epifouling taxa including Hydroids and *S. spinulosa*. Several mobile taxa inhabited the structure including squat lobsters, lobster, flatfishes and ling. Should the structure remain exposed it could continue to provide a suitable habitat for commercially important species.

Epifouling colonisation observed during the survey showed overall similarities with colonisation of other artificial structures in the North Sea regarding early colonisers and epifouling structure.

ZONATION

A clear vertical zonation has been described by various studies regarding wind turbines in the North Sea (mostly Belgian waters). The zones have been defined and delineated as four sections; splash zone (5 - 3 m above surface), higher intertidal zone (3 - 0 m above surface), low intertidal zone (0 - 7 m below surface) and deep subtidal zone (7 - 30 m below surface) (De Mesel, 2015).

A depth zonation similar to other wind turbines in the North Sea was noticeable within the current survey area. Safety restrictions from the turbines made it impossible to get close enough to get an estimation of the epifouling above the surface.

The low intertidal zone was dominated by *Mytilus* which was in line previous studies. The deep subtidal zone extended from 10 m to 15 metres below the surface and continued down to the bottom.

Between the low intertidal zone and deep intertidal zone there was a high presence of biofilm and less epifouling species, which could be due to grazing fauna that were occasionally numerous.

Four depth zonation's were observed at Substructure HS01 and five on Substructures HS02 to HS05. Substructure HS01 lacked the deepest *Spirobranchus* dominated zonation found at the other four Substructures. The difference is likely due to local circumstances and faunal spread. The differences were not large enough to indicate that currents or the distance to shore would affect the zonation and growth of epifaunal species.

A zonation was also observed along the Mooring Lines where different epifouling fauna dominated different depths. A different species community was identified on the Mooring Lines compared to the substructures. The top and upper middle sections of the Mooring Lines were dominated by *M. senile* and Balanoidea. The middle chain comprised, overall, a lower faunal colonisation.

SUCCESSION

A study performed by (Kerckhof, Rumes, & Degraer, 2019) in Belgian waters in the North Sea described three succession stages based of superabundant epifouling species on two different wind turbine foundation types (monopiles and gravity based foundations).

The first stage, year one and two, started with pioneer (opportunistic) species and the second stage, from around year three and six, comprised a species rich intermediate stage. The species included several types of suspension feeders (bivalves, hydrozoans and polychaetes). The third and final stage, year six and onwards was called the Climax stage which was dominated by *M. senile*.

The succession stages of offshore installations in the northern North Sea showed that tubeworms and hydroids were the first to colonise the structures. The second colonisers were *M. senile* and *Alcyonium digitatum* which out-competed the early colonisers by over-growing. Blue mussel *Mytilus* was present in the mussel zone throughout the survey time. Without predators they seem to withstand other competitors (Whomersley, 2003).

The same trend can be observed within the current survey and would indicate that the park is in the species rich intermediate stage moving towards a more *M. senile* dominating stage with less biodiversity.

As in previous studies in the North Sea (De Mesel, 2015; Whomersley, 2003) a zonation was established in just a few years after the installation of the structures. Echinoderms were present in high abundance and are considered an important grazer that affects the epifouling community (Witman, 1985) and could keep the epifouling colonisation growth supressed.

COMPARISON ON MARINE GROWTH

Coverage of both hard and soft marine growth is assessed to have increased from 2018 to 2020. The change in thickness is more variable compared to coverage but most structures and substructures have had a decrease in thickness of both hard and soft marine growth. However, drastic increases in thickness was noted for several substructures on multiple turbines.

This drastic increase, as well as the observed decrease, could be natural or due to variable measuring techniques relying on the qualitative assessment conducted in 2018. It should also be noted that no lasers were utilised during the 2018 survey which could be a contributing factor to the skewness in thickness.

7| RESERVATIONS AND RECOMMENDATIONS

For future inspections and assessments, a still camera, mounted on the WROV acquiring imagery would aid in higher resolution of diversity as well as offer the possibility of quantitate assessments and subsequent comparisons to be conducted.

To confirm the presence or absence of invasive and non-indigenous species on the structures a physical sample is recommended for future surveys as a compliment to the images.

Early colonisation and succession could in future monitoring be studied by adding clean sample surfaces in the survey area and following succession stages at regular intervals.

It is worth noting that the assessments and conclusions are based on one survey and that additional surveys would provide a better understanding of the biofouling and successions stages. From maintenance perspectives the potential negative effects of biofoulings are associated with accelerated corrosion rates and changes in hydrodynamic properties. A higher resolution of species composition, via stills imagery and scrapings, would facilitate a better understanding of the early settlers and zonation patterns.

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APPENDIX A| SPECIES LIST

APPENDIX B| FIELD PROTOCOLS