Donegan, Fergus (Alab)

From: McManus, Catherine [redacted]
Sent: Tuesday 19 March 2024 14:45
To: Alab, Info
Cc: Booth, Yvonne
Subject: Ref AP1/2019 Request for further information

Your Ref. **AP1/2019**
Site Ref. T06/202

Dear Ms Carton,

I refer to your letter dated 14th March 2024, requesting further environmental monitoring information regarding the above appeal reference – AP1/2019.

In the following WeTransfer link you will find the following documents

https://we.tl/t-9tssbtyfxq

- Kenmare Bay Water quality monitoring reports to include Deenish sea site – 2015/2016 to 2018/2019.
- Benthic monitoring reports – 2016, 2017, 2018, 2019.

Best regards

Catherine McManus

Operations Director Farming (Ireland)
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Environmental Survey

Beneath Finfish pens

at Deenish aquaculture site (T6/202),

Kenmare Bay,

Co. Kerry

July 2016

Produced by

AQUAFACT International Services Ltd

On behalf of

Marine Harvest Ireland

Issued November 2016

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1. Introduction

This report documents the environmental conditions of the seabed at a Marine Harvest Ireland finfish (Atlantic salmon *Salmo salar*) aquaculture site (Aquaculture Licence Reference T6/202) in Kenmare Bay, Co. Kerry recorded during surveys undertaken by AQUAFACT on 20th July 2016 (see Figure 1.1). The aquaculture site is situated close to Deenish Island, County Kerry on the northern shore of Kenmare River.

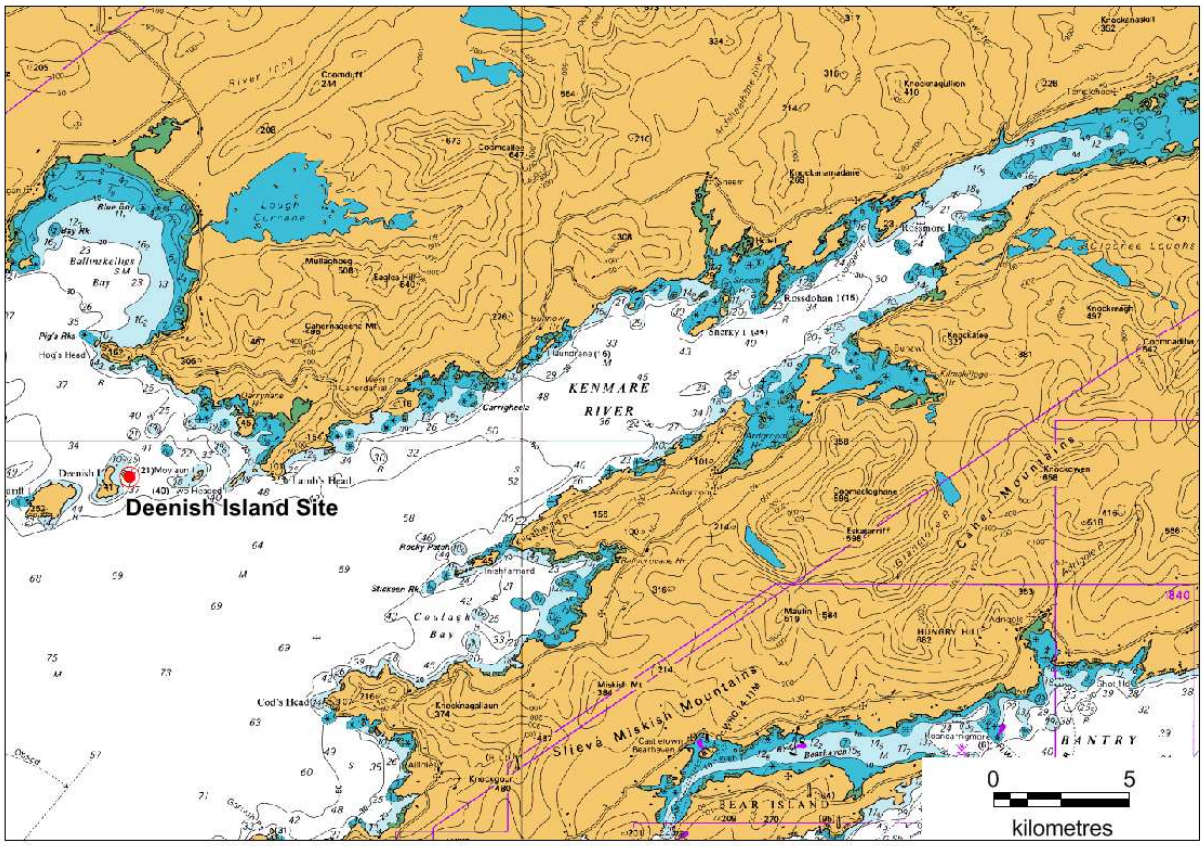

Figure 1.1: Map showing the location of the Deenish site surveyed in Kenmare Bay

1.1. Site description

Kenmare Bay, Co. Kerry, is a long and narrow, south-west facing bay. It is a deep, drowned glacial valley and the bedrock is mainly old red sandstone which forms reefs along the middle of the bay throughout

its length. Exposure to prevailing winds and swells at the mouth diminishes towards the head of the bay while numerous islands and inlets provide further areas of additional shelter.

Deenish Island is part of two Natura 2000 sites (see Figure 1.2), namely the Kenmare River cSAC (Site code: 002158) and the Deenish Island and Scariff Island SPA (Site code: 004175).

The diversity of environmental conditions, from exposed to ultra sheltered, that characterises Kenmare River cSAC results in the presence of a wide range of marine habitats including three listed on Annex I of the EU Habitats Directive, namely reefs, large shallow bay and caves. According to the cSAC site synopsis (available from www.npws.ie) Kenmare Bay is host to a high number of rare and notable marine species present (24) and some uncommon communities. The Kenmare River cSAC is the only known site in Ireland for the northern sea-fan, *Swiftia pallida* and is the only known area where this species and the southern sea-fan *Eunicella verrucosa* co-occur. Midway along the south coast of Kenmare River, a series of sea caves stretch back into the cliff, typically supporting a diversity of epifauna including encrusting sponges, ascidians and bryozoans.

Deenish Island and Scariff Island are small to medium size islands situated between 5 and 7 km west of Lamb's Head off the Co. Kerry coast and thus very exposed to the force of the Atlantic Ocean. The site is a Special Protection Area (SPA) under the E.U. Birds Directive due to its special conservation interest for seabirds including fulmar, Manx shearwater, storm petrel, lesser black-backed gull and Arctic tern. Scariff is the larger of the two islands, with very steep sides rising to a peak of 252 m with the highest cliffs located on the south side. Deenish is less rugged than Scariff, and rises to 144 m in its southern half; the northern half being lower and flatter. The vegetation is mostly grassland, with some heath occurring on the higher ground. Old fields are now overgrown with bracken and bramble. The sea areas within a 500m radius of both islands are included inside the SPA boundary to provide a 'rafting' area for shearwaters.

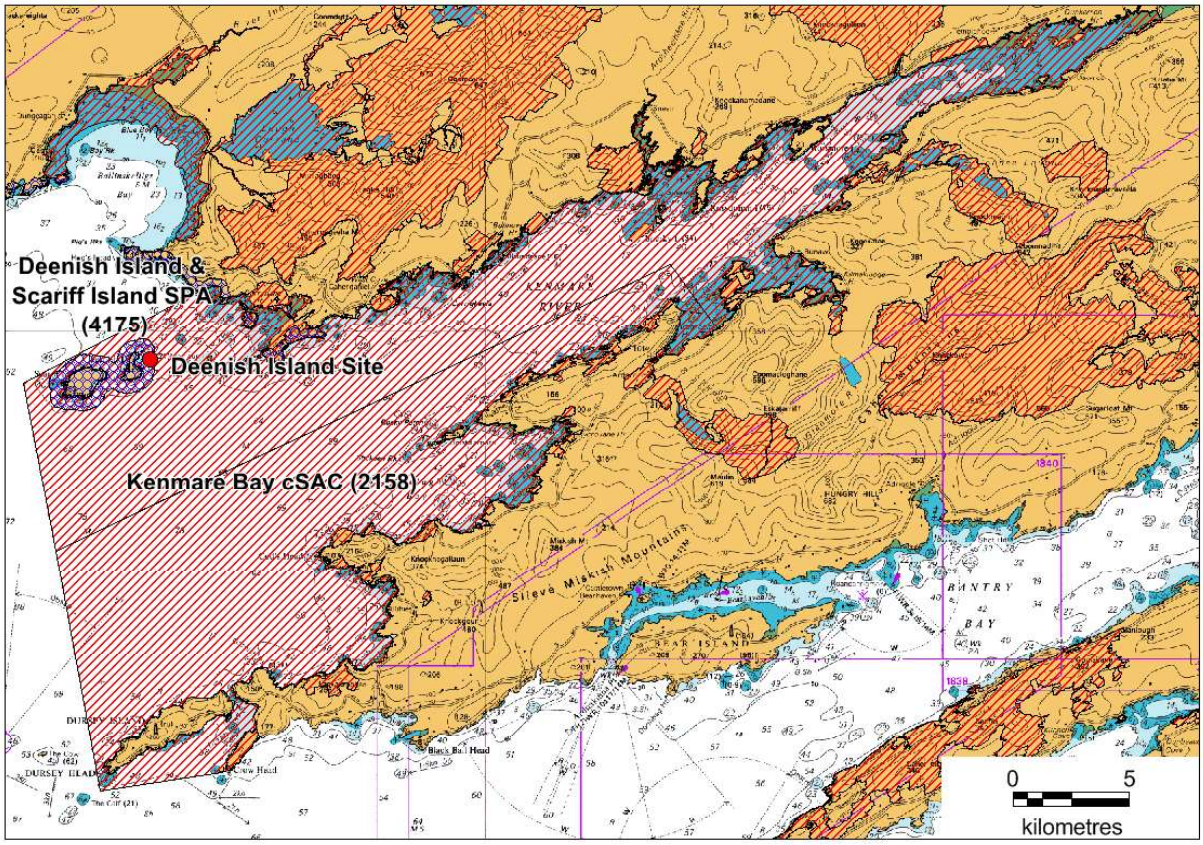

Figure 1.2: Map showing the locations of the relevant cSAC and SPA near Kenmare Bay, Co. Kerry.

1.2. Offshore finfish farms – benthic monitoring

The main objective of the survey was to assess the overall state of the environment in relation to the salmon production process. The sites were surveyed according to the revised Benthic Monitoring Guidelines laid down by the Department of Agriculture, Fisheries and Food (December 2008). The benthic monitoring requirements at a fish farm are dependent on the level of biomass held at the site and the local hydrography. Table 1.1 below sets out the level of benthic monitoring required based on tonnage produced and mean current speeds at a fish farm:

Table 1.1. Matrix of production tonnage versus current speed to determine level of benthic monitoring required

	MEAN CURRENT SPEED (CMS^{-1})		
TONNAGE	**<5**	**5-10**	**>10**
0-499	Level I	Level I	Level I
500-999	Level II	Level I	Level I
>1000	Level II	Level II	Level I

The current speed is a mean value calculated from maximum current measurements over spring and neap tidal cycles at the surface and near the bottom. The tonnage refers to the maximum biomass predicted for each site. An annual survey must be carried out at each site (production and smolt) operated by a company. A level I or level II survey may be carried out as follows:

Level I: Video/photographic and visual observations and recordings shall be made at the following stations:

- At a minimum of 2 sites directly beneath the pens
- At the edges of the pens
- Two transects at right angles to each other. Along each transect sampling stations at +/- 10m, +/- 20m, +/- 50m and + 100m from the pens
- At a control site

In addition to the above, the following samples/measurements shall be taken at the same stations as above. These will be used to calculate sediment quality parameters.

- A minimum of one Redox potential reading shall be made at each sampling station.
- A single sediment sample for Organic Carbon measurement.

Level II: In addition to the above, two replicate grab samples shall be captured at each of the sample stations for faunal analysis. The exact locations of sampling points should be agreed in advance with the Department of Agriculture Fisheries and Food (DAFF). The identification and abundance of macro-faunal invertebrates shall be estimated and tabulated. Identification of fauna to the level of species will be

required.

It is important to take note that the exact position of the individual pen structures are not permanently fixed to a single position and there is a relatively large lateral movement due to depth, wind, currents and tides. For this reason bottom stations particularly those under, at the edge and 10 m away from the pens are taken at the time of sampling but may vary relative to the overlying pen position under various environmental conditions.

2. Sampling Procedure & Processing

All survey work at the Deenish site took place on 20th July 2016. The dives were conducted at a maximum depth of 20.8 m and underwater visibility on the day was good at approximately 5m. Pen layouts at the time of survey, dive entry points and benthic transects followed by the divers are shown in Figure 2.1.

Mean current speed at the Deenish finfish aquaculture site is 30 cm sec^{-1} (Marine Harvest pers.com.). The fish biomass present in the pens at the time of survey was 1517.5 tonnes. The survey was carried out at Level 1 as per the guidance matrix displayed in Table 1.1.

Disinfection

Prior to each dive survey for each location all diving equipment, suits and boats are thoroughly disinfected utilising both a dipping and spraying protocol.

2.1. Dive survey

Two dive transects were laid out from the sea surface at each site using a boat equipped with a GPS mapper. Pen locations were noted as DGPS positions. The underwater survey involved direct observation, sampling and recording (through photographs and *in situ* annotations) of benthic conditions by highly experienced, qualified marine biologists and scientific divers. The notes taken *in situ* were transcribed to logs upon surfacing. In addition to standard SCUBA gear the divers were equipped with:

- A high end dSLR Nikon D200 in a Subal ND20 underwater housing fitted with a 12-24mm

lens and two INON strobes. The camera was used to photograph the epibenthos and seafloor features;

- A diver operated dSPI camera for photographing sediment profiles of the seafloor and calculate redox measurements. This unit uses a Canon EOS 450D camera with Nikkor optics;
- A compass for underwater navigation;
- Pre-labelled bags to store sediment samples for organic carbon analysis;
- Dive slates, torches and waterproof pencils for making observations/notes.

The divers photographed representative areas of the sediment and fauna and recorded observations in situ at the various stations investigated. Notes were completed immediately on surfacing and a map of the dive track was drawn up. Observations recorded during the dive included:

- Presence of bacterial mats and uneaten food;
- Presence of farm-derived litter;
- Presence of gas bubbles or anoxic areas;
- Animals visible or evidence of their presence;
- Macroalgae visible;
- Sediment characteristics, including colour and texture.

The seafloor was photographed at the following stations along two transects at the site (Figure 2.1):

A. Directly under the pens;
B. Under the edge of the pen;
C. At 10m, 20m, 50m and 100m (on T1) from the pens along the transects.

A reference station was also assessed for each pen block to give a representation of ambient benthic conditions in the area immediately surrounding the pen installations for comparison purposes. The reference station was taken at a distance greater than 150 m from the pen installations to represent the assumed 'undisturbed' condition of the seafloor surrounding the sites.

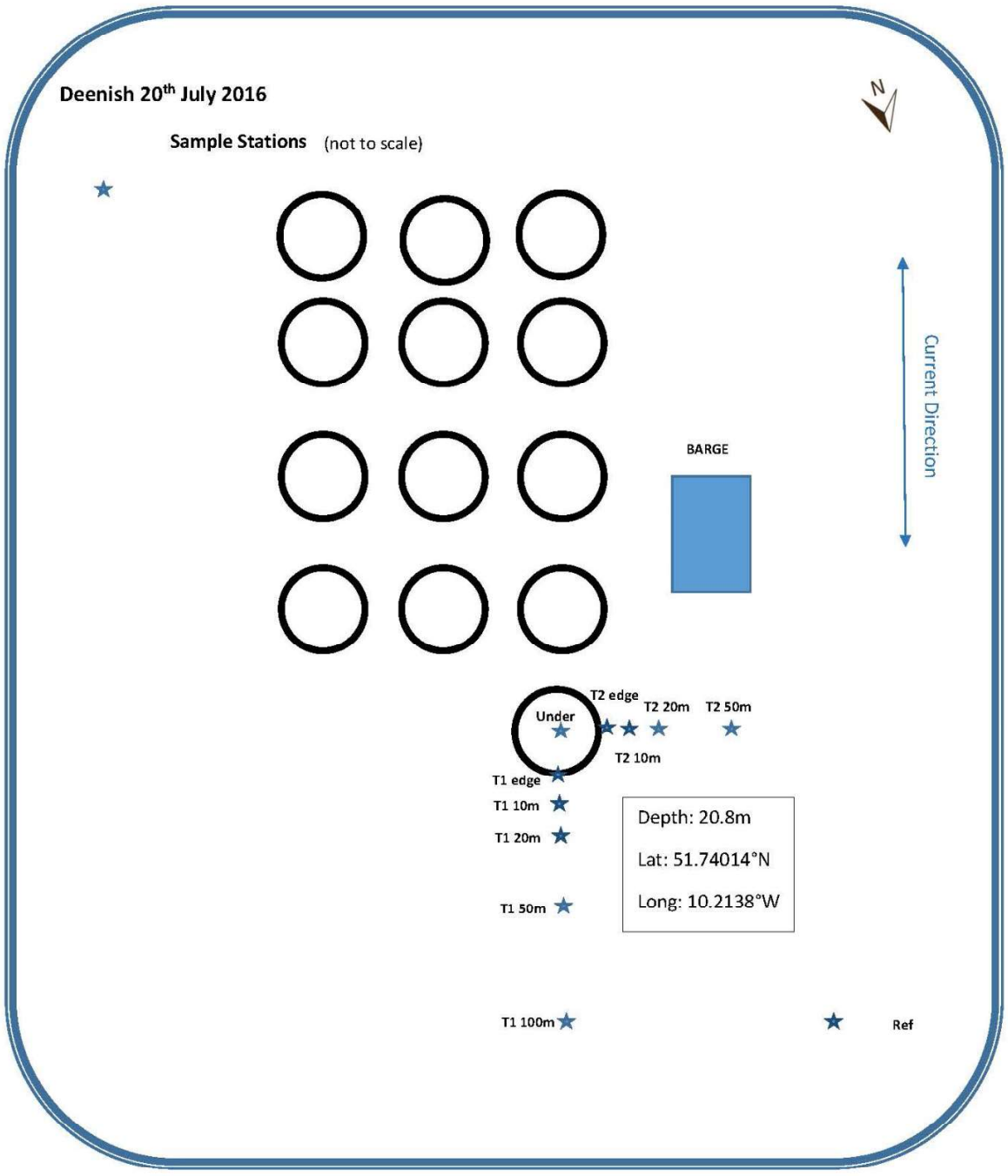

Figure 2.1: Transect seafloor station layout, Deenish finfish aquaculture site, Kenmare Bay, 20th July 2016

2.2. Sediment Profile Imagery (SPI)

Sediment profile images (SPI) obtained for each station along with ARPD depth measurements taken from the images were acquired using a diver-deployed sediment profile imaging camera system. This system is comprised of a digital SLR camera in a water-tight pressure vessel that is mounted above a prism that penetrates the upper 25 cm of sediment (see Figure 2.2). The sediment profile is viewed through a plexiglass window and the image is reflected to the camera lens via a plane mirror. Illumination is provided by an internally-mounted strobe. The prism unit is filled with distilled water – thus ambient water clarity is never a limiting factor in image quality. Upon arrival, the diver depresses the SPI unit into the seafloor and manually triggers the camera. This process is repeated at each station investigated.

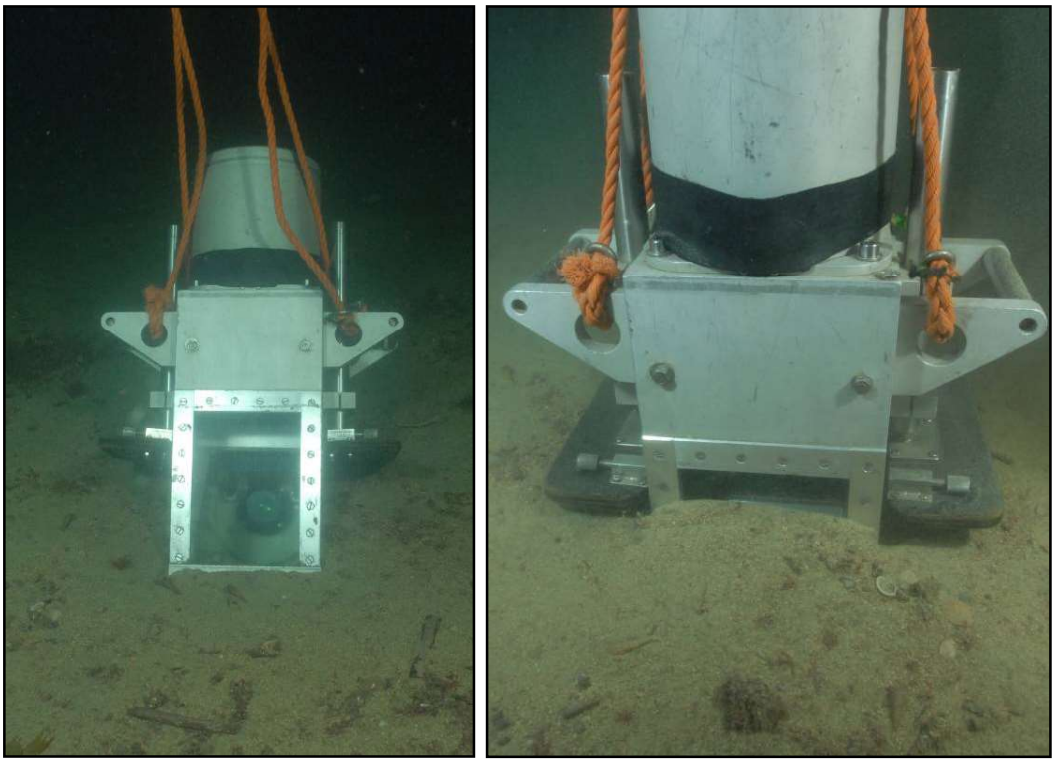

Figure 2.2: Diver operated Sediment Profile Imaging camera. The left-hand image gives a view of the camera at the sediment surface. The right-and image shows the SPI camera when inserted into the sediment

A great deal of information about benthic processes is available from sediment profile images. Measurable parameters, many of which are calculated directly by image analysis, include physical/chemical parameters (i.e. sediment type measured as grain size major mode, prism penetration

depth providing a relative indication of sediment shear strength, sediment surface relief, condition of mud clasts, redox potential discontinuity depth and degree of contrast, sediment gas voids) and biological parameters (i.e. infaunal successional stage of a well documented successional paradigm for soft marine sediments (see Pearson and Rosenberg, 1978), degree of sediment reworking, dominant faunal type, epifauna and infauna, depth of faunal activity, presence of microbial aggregations).

For the purposes of the current survey the primary feature of interest is the depth of oxygen penetration into the sediments in the vicinity of the finfish pens (this information is required to satisfy the requirements of the Benthic Monitoring Protocol (DAFF, 2008). In this case the apparent redox potential discontinuity or ARPD depth is measured. Features of particular interest that may be gleaned from SPI images taken in sediments in the vicinity of finfish pens include the presence of:

- uneaten feed pellets (and depth of this material, see Figure 2.3)
- faecal casts
- and depth of shell gravel deposits
- of gas voids in the sediment

Figure 2.3: Typical sediment profile images with examples of features relevant to aquaculture operations

2.3. Sampling for organic carbon analysis

Sediment samples for organic carbon analysis were collected at all stations. Samples were stored in pre-labelled plastic bags, kept in cold freezer boxes onboard the vessel and frozen at -20°C on return to the laboratory. Organic carbon analysis was carried out by ALS laboratories using the Loss on Ignition (LOI) technique. This method involves oven drying the sediment sample in a muffle furnace (450°C for a period of 6 hours) after which time the organic content of the sample is determined by expressing it as a percentage the weight of the sediment after ignition over the initial weight of the sediment.

3. Results

3.1. Recent Stocking History

At the time of the audit, 1517 tonnes of fish were stocked on site having been input to the site in January 2015 following a seven week fallow period.

Figure 3.12: View of pens at Deenish Island site, 20th July 2016

3.2. Seabed physical and biological characteristics

The seabed was composed of a mix of sediment types with areas of fine to medium sand with shelly sand.

3.2.1. Photographic record; Transect 1

This transect began beneath the north western most pen moored on site (see Figure 2.1) and ran for a distance of 100 m north. A total of six stations were investigated.

3.2.1.1. Under pen

The seafloor consisted medium sand and coarse shelly gravel (Figure 3.2) with a thin covering of fine sediment. Drift algae was spread over the area. There was no obvious signs of impact from the farm operations.

Figure 3.2: T1 – Under pen station, Deenish Island site, 20th July 2016

3.2.1.2. Edge of pen

The seafloor at the edge station consisted of medium sand with a high proportion of coarse shelly material and drift algae with a patchy cover of fine material. There were no signs of impact from the farm operations.

Figure 3.3: T1 – Pen edge station, Deenish Island, 20th July 2016

3.2.1.3. 10 m from pen

The seafloor at the 10m station was composed of shelly sand that was formed into small waves and troughs by the action of tidal currents. Drift algae was accumulated in the troughs. A swimming crab, *Liocarcinus depurator* was imaged in the photo (Figure 3.4).

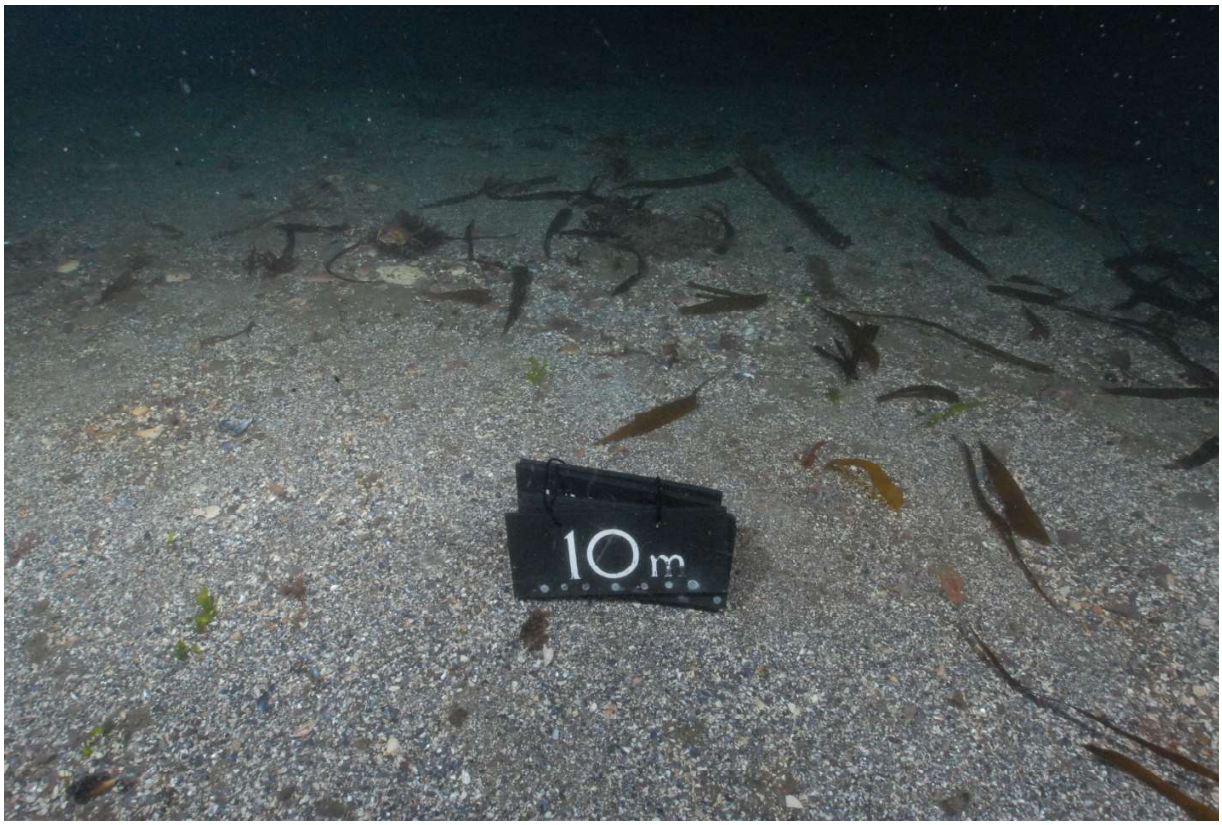

Figure 3.4: T1 – 10m, Deenish Island, 20th July 2016

3.2.1.4. 20 m from pen

There was little change in bottom conditions on moving 20 m along Transect 1 with a substrate composed of shelly sand formed into waves and troughs. Large bivalve shell and drift algae accumulated in the troughs. Anemones, *Cerianthus lloydii*, were recorded buried in the sediment. There was no obvious impact from the farming operations.

Figure 3.5: T1 – 20 m station, Deenish Island, 20th July 2016

3.2.1.5. 50 m from pen

The seafloor at the 50 m station was composed predominantly of undulating shelly sand with scattered patches of shell and algal debris in the troughs. The dominant faunal species was the burrowing anemone *C. lloydii*. Red algae (*e.g. Cryptopleura ramosa, Rhodymenia* sp*., Phycodris rubens*) were also noted attached to pebble and the larger shell fragments (Figure 3.6). There were no obvious signs of impact from the farming operations.

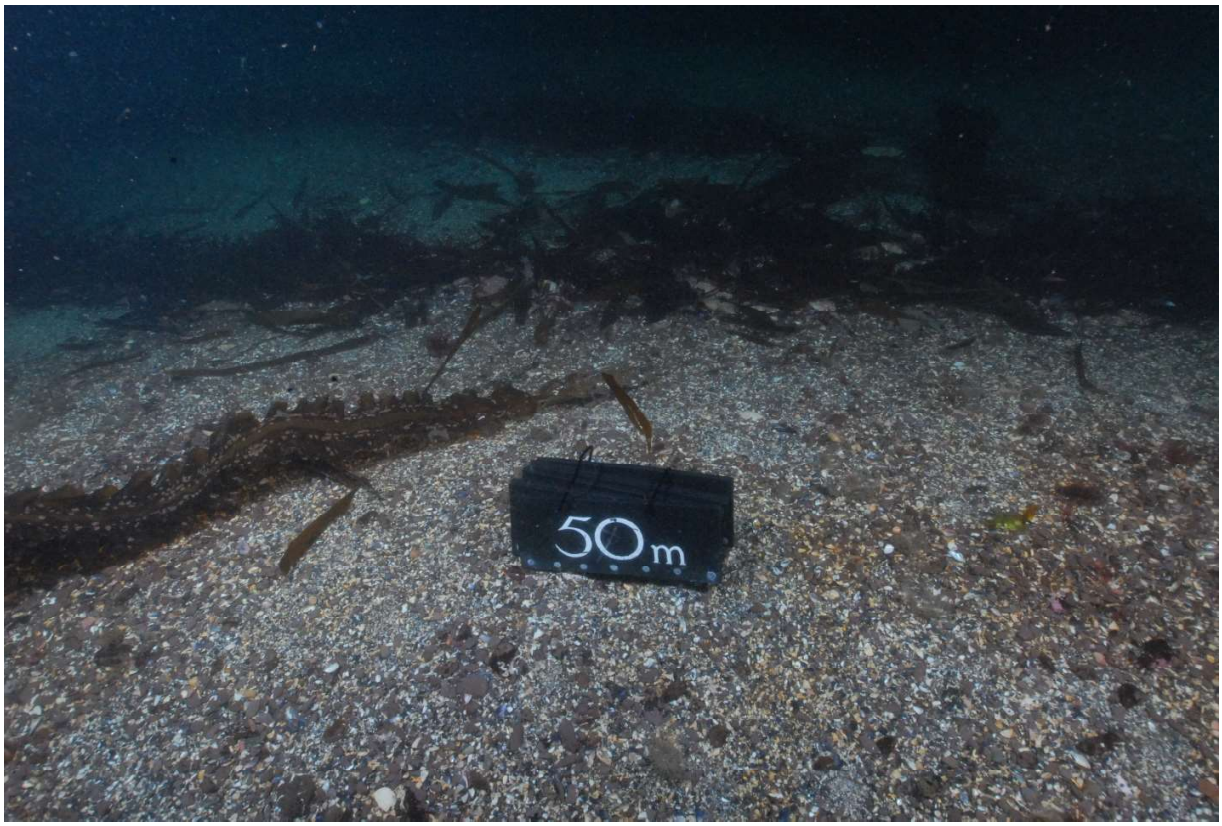

Figure 3.6: T1 – 50 m station, Deenish Island, 20th July 2016

3.2.1.6. 100 m from Pen

This station was dominated by sand, gravel and bivalve shell forming small crests and troughs created by prevalent hydrodynamic conditions. The site was dominated by red algae attached to pebble and shell accumulated in the troughs and occasional anemones *C. lloydii*. There were no apparent signs of impact from the nearby finfish rearing operation.

Figure 3.7: T1 – 100 m station, Deenish Island, 20th July 2016

3.2.2. Sediment Profile Imagery – Transect 1

Figure 3.8 presents sediment profile images taken at the six stations visited on Transect 1 of the Deenish site. Substrate composition ranged from fine and medium sand at the under pen station to a coarser shelly gravelly sand at the outer end of the transect. The seafloor at this site is probably relatively mobile due to winter surges.

The images display a single image and the maximum and minimum apparent redox potential discontinuity (ARPD) depths measured at each station. Each image is 15.5cm × 25cm. ARPD depths ranged from a minimum of 0.0 cm (T1 20m & 50m) to a maximum of greater than 5.7 cm (T1 Edge).

Due to the coarse nature of the seafloor the SPI camera achieved relatively low penetrations. The ARPD ranged from 2.3 cm at the under station to 7.9 cm at the 100 m station.

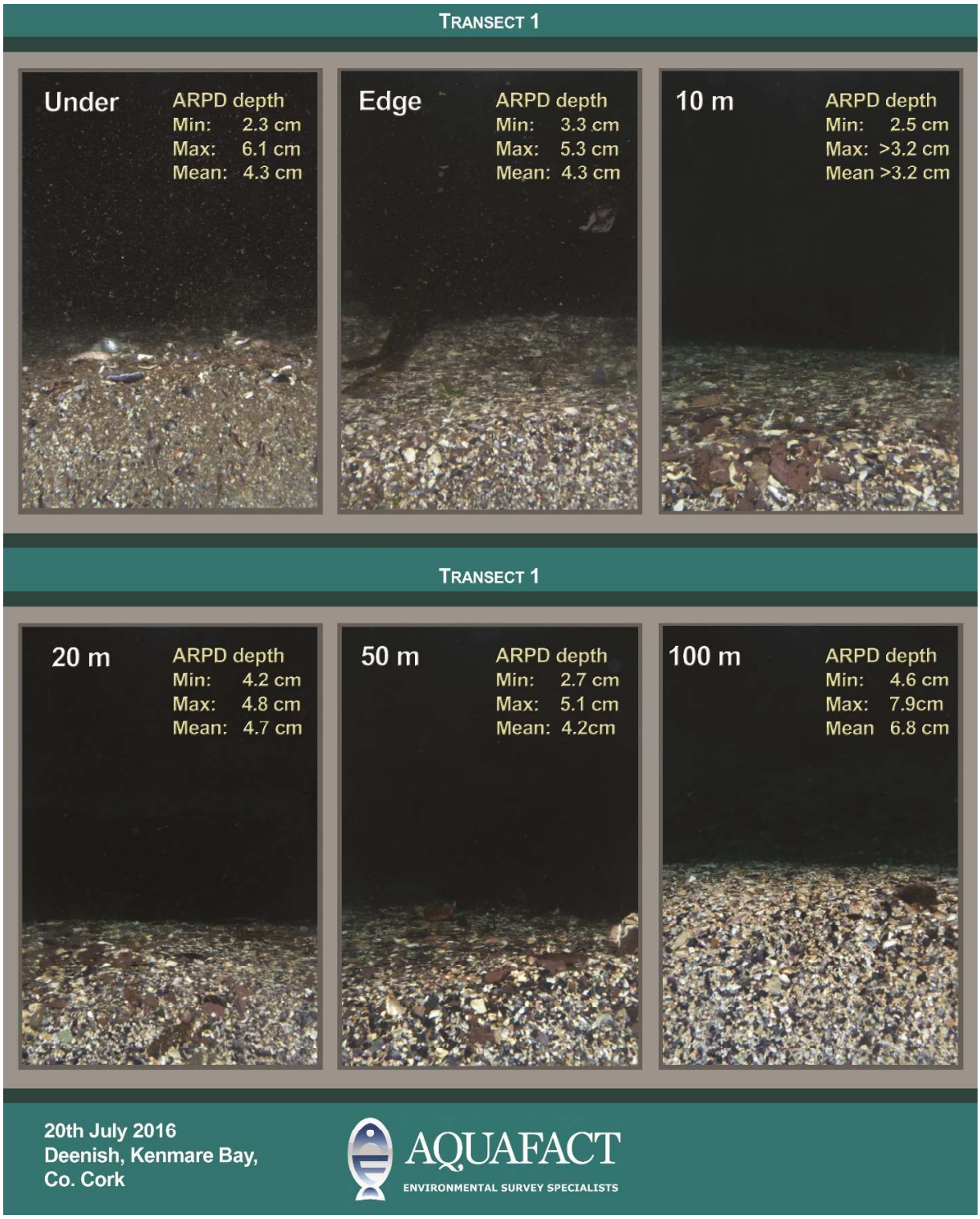

Figure 3.8: Representative photographs of the seafloor taken along Transect 1 by Sediment Profile Imagery (SPI)

3.2.3. Photographic Record; Transect 2

This transect began beneath the same pen as Transect 1 and ran for a distance of 50m west. A total of five stations were investigated on Transect 2 with an additional (Reference) station investigated just *c.* 180 m north of the pen edge (See Figure 2.1).

3.2.3.1. Under pen

The seafloor consisted of troughs and ridges of medium sand and coarse shelly gravel with a patchy layer detrital soft material and drift algae. The burrowing anemone *Cerianthus lloydii* was occasionally recorded (Figure 3.9). There was no signs of impact from the farm operations overhead.

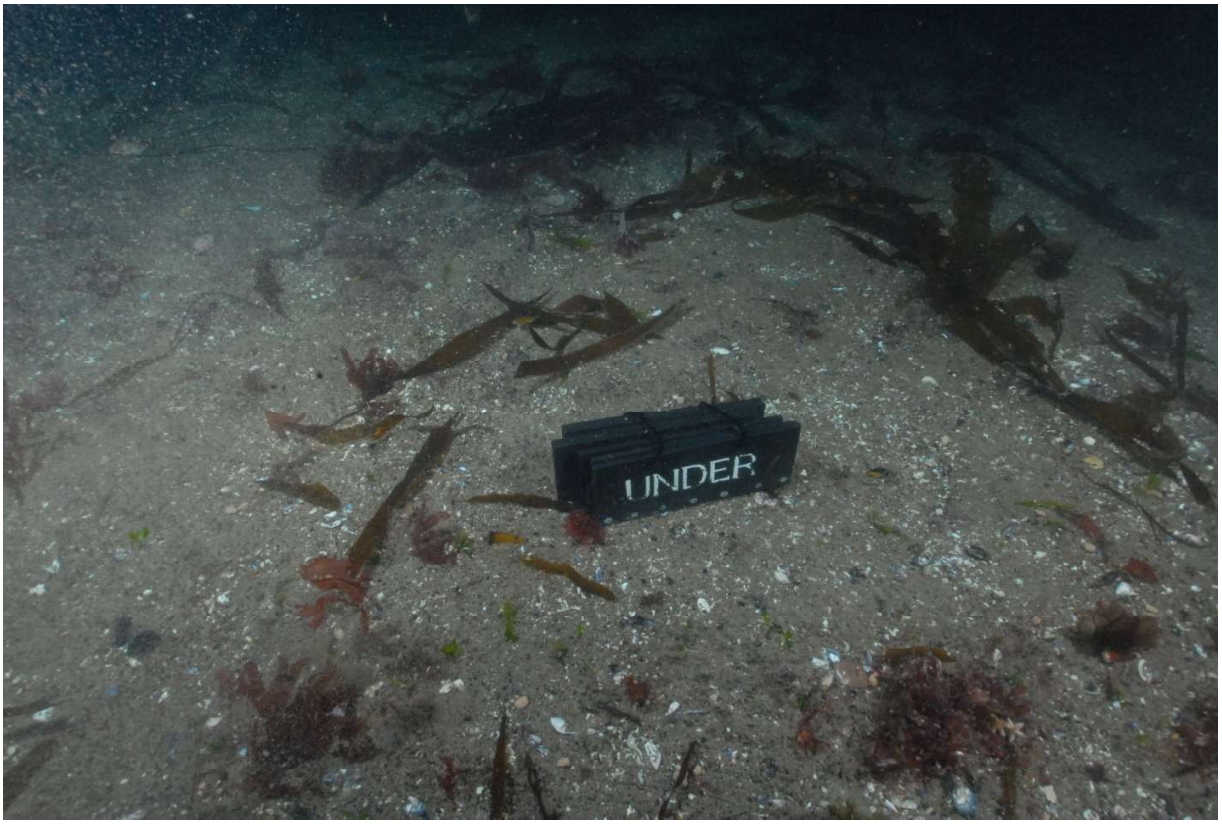

Figure 3.9: T2 – Under pen station, Deenish Island, 20th July 2016

3.2.3.2. Edge of pen

The seafloor substrate consisted of shelly gravel and medium sand, shell and occasional pebble and small stones with a light cover of drift algae. The burrowing anemone *C. lloydii* was occasionally recorded and one is noted beside the tags in the photograph taken at this station (Figure 3.10).

Figure 3.10: T2 – Pen edge station, Deenish Island, 20th July 2016

3.2.3.3. 10 m from pen

The seafloor consisted of shelly sand with occasional pebble. The anemones *C. lloydii* were occasionally recorded. There was no signs of impact from the farm operations.

Figure 3.11: T2 – 10 m station, Deenish Island, 20th July 2016

3.2.3.4. 20 m from pen

The seafloor at the 20 m station consisted of coarse to medium sand and shell gravel with scattered empty bivalve shell. The biotic community was characterised by the presence of burrowing anemone *Cerianthus lloydii* and some red algae. There were no obvious signs that indicated the presence of the nearby finfish farm.

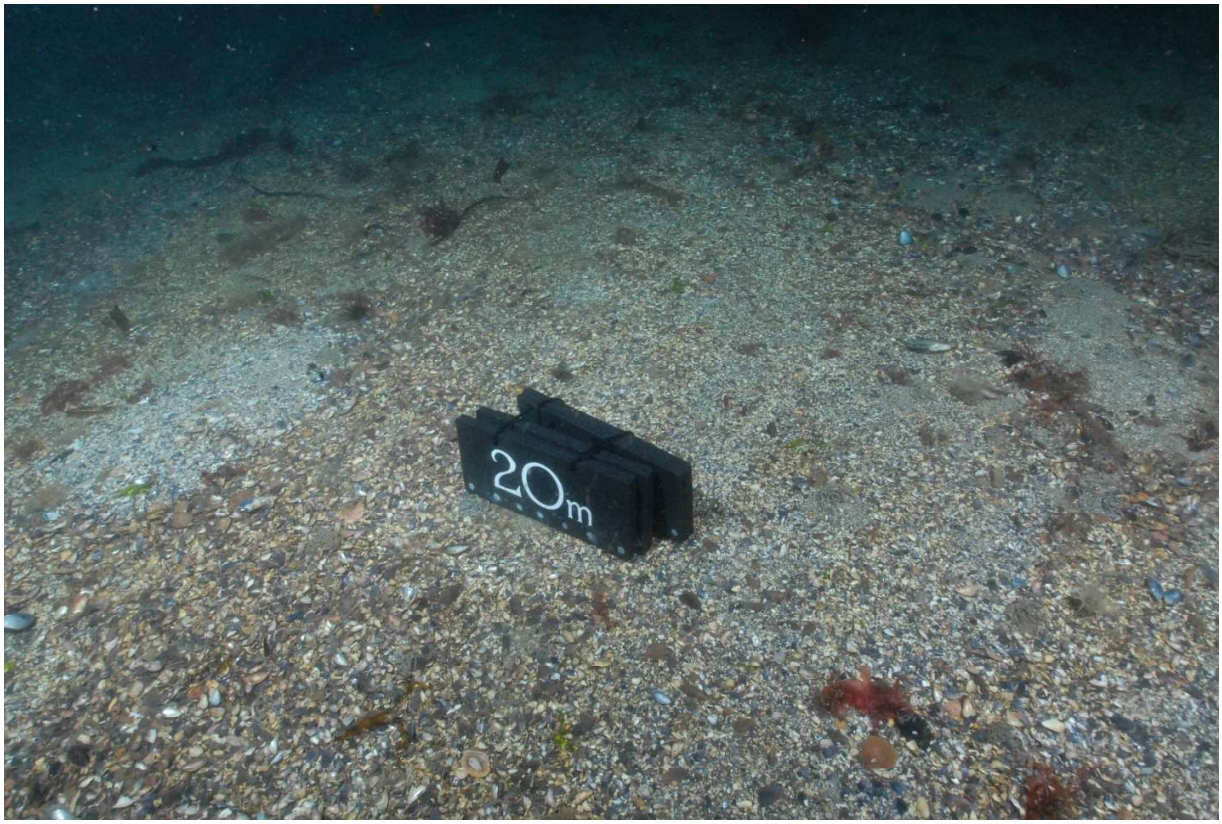

Figure 3.12: T2 – 20 m station, Deenish Island, 20th July 2016

3.2.3.5. 50 m from pen

The seafloor at this station consisted of shelly gravel and medium sand overlaid by empty bivalve shell. Red algae and occasional *C. lloydii* (Figure 3.13) were present. There was no obvious impact from the farming operations.

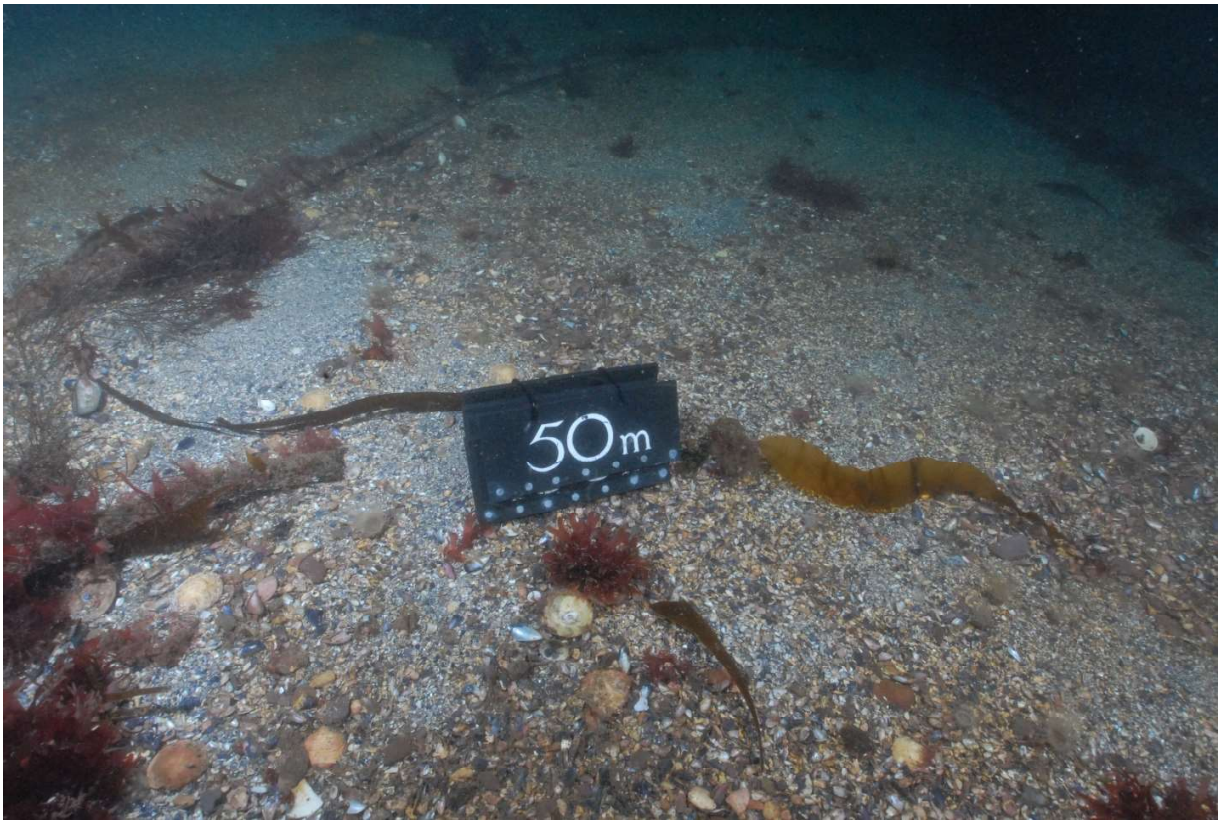

Figure 3.13: T2 – 50 m station, Deenish Island, 20th July 2016

3.2.3.6. Reference station

The seafloor at the reference station consisted of a substrate composed of sand, stones, empty shell and shell gravel forming broad shallow sand waves with attached foliose and encrusting red algal species with large drift algae (*Laminaria saccharina*) moving over the bottom. The benthic faunal community was dominated by the anemone *C. lloydii* (Figure 3.14)

Figure 3.14: Reference station, Deenish Island, 20th July 2016

3.2.4. Sediment Profile Imagery – Transect 2 & Reference

Figure 3.15 presents sediment profile images taken at the five stations visited on Transect 2 of the Deenish site and the reference station on 12th June 2015. The figure displays a single image and the maximum and minimum apparent redox potential discontinuity (ARPD) depths measured at each station. Each image is 15.5 cm × 25 cm.

Sediment type varied from fine/medium sands under and close to the pen compared with higher proportions of gravel and shell with increasing distance from the pen. Due to the hard and compact nature of the substratum SPI penetration was low and, consequently, ARPD depths were difficult to ascertain. Nonetheless, and based on prism penetration, the oxidised sediment layer at the site was regarded to be relatively deep, estimated to range from a minimum of 0.5 cm ns to 7.3 cm recorded at the under pen location. ARPD depths at the Reference station ranged from 7.3 cm to 8.3 cm.

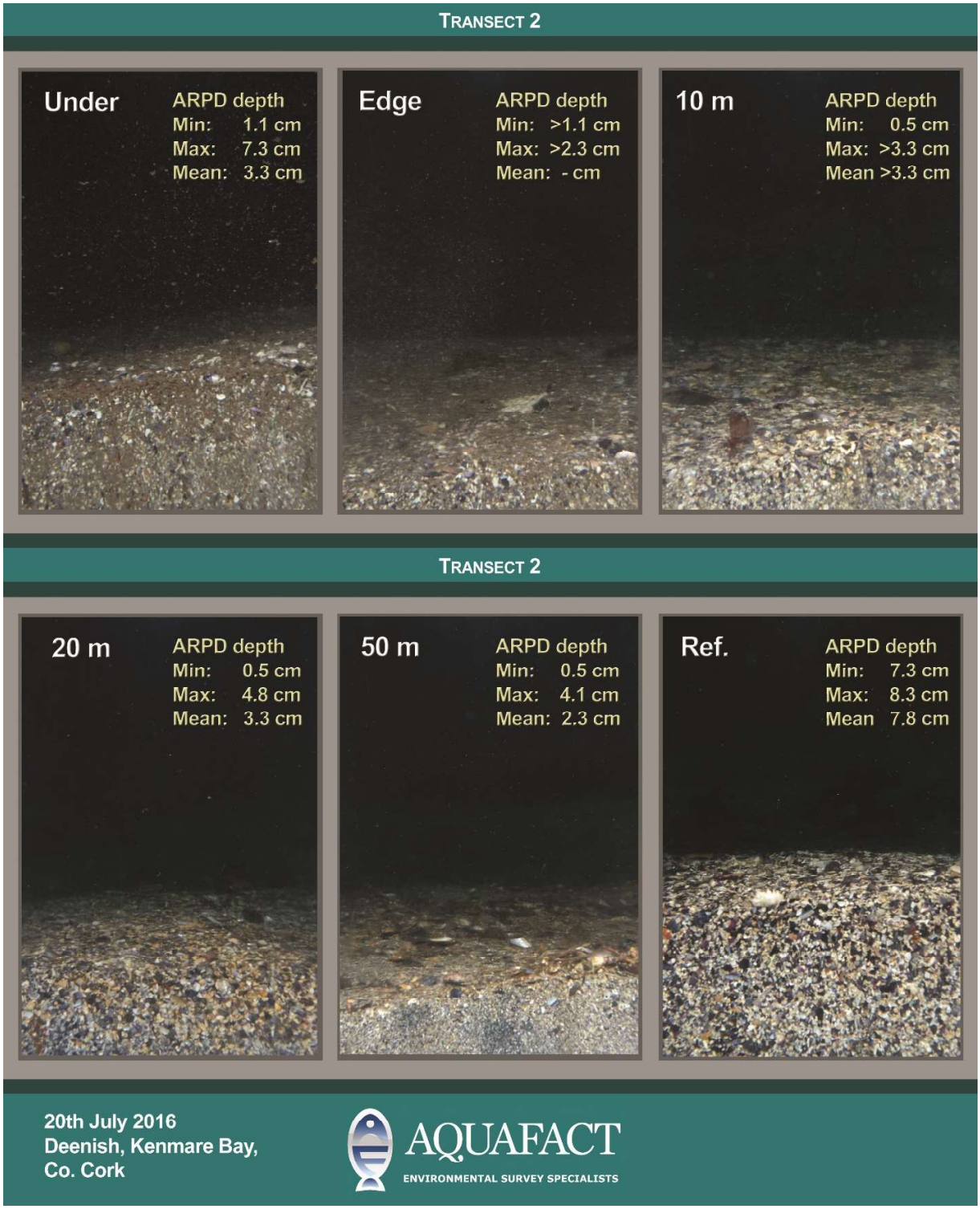

Figure 3.15: Representative photographs of the seafloor taken along Transect 2 by Sediment Profile Imagery

3.2.5. Transect Species List

Table 3.1 shows a list of species observed during the dives at the Deenish fish farm site on this and previous occasions.

Table 3.1: Species noted during dives on the seabed beneath the Deenish pens

Group	Species	Common Name
(Cnidaria) Hexacorallia	*Cerianthus lloydii*	Tube anemone
(Annelida) Polychaeta	*Pomatoceros* sp. *Lanice conchilega* *Chaetopterus variopedatus*	Tube worm The sand mason Parchment tube worm
(Mollusca) Bivalvia	*Pecten maximus* Faceliniidae Aeolidiida Nudibranch	King scallop Sea slugs Sea slugs Sea slugs
(Arthropoda) Decapoda	Paguridae	Hermit crab
Echinodermata	*Luidia ciliaris* *Asterias rubens* *Marthasterias sp* *Ophiura* sp. Amphiuridae sp.	Seven armed starfish Common starfish Starfish Brittlestar Brittlestar
(Chordata) Osteiichthyes	*Pomatoschistus* sp. *Trisopterus minutus* *Labrus bergylta*	Gobies Poor Cod Ballan Wrasse
Rhodophyta	*Delesseria sanguinea* *Phycodrys rubens* *Cryptopleura ramose* *Calliblepharis ciliata* *Lythophyllum* sp.	Sea beech Sea oak
Ochrophyta	*Alaria esculenta*	Edible kelp

3.2.6. Organic Carbon Analysis & ARPD Depths

Table 3.3 shows the organic carbon results from the Deenish stations. Organic carbon levels ranged from 2.03% (T2 50m) to 8.4% (T1 Under). Table 3.7 shows in tabular form the ARPD depths from the SPI images from Deenish (see Sections 3.1.4 and 3.1.7).

Table 3.2: Organic carbon results for Deenish (% values, Loss on Ignition at 450°C).

T1	**Under**	**Edge**	**10m**	**20m**	**50m**	**100m**
LOI %	8.4	6.34	4.34	3.37	2.94	3.02
T2	**Under**	**Edge**	**10m**	**20m**	**50m**	**REF**
LOI %	-	7.89	4.31	3.06	2.03	2.99

Table 3.3: ARPD Depths for Deenish, Kenmare Bay, 20th July 2016

Station		**Transect 1**	**Transect 2**
Under	Range (cm)	2.3 – 6.1	1.1 – 7.3
	Mean (cm)	4.3	3.3
Edge	Range (cm)	3.3 – 5.3	>1.1 - >2.3
	Mean (cm)	4.3	N/A
10m	Range (cm)	2.5 - >3.2	0.5 - >3.3
	Mean (cm)	N/A	N/A
20m	Range (cm)	4..2 – 4.8	0.5 – 4.8
	Mean (cm)	4.7	3.3
50m	Range (cm)	2.7 – 5.1	0.5 – 4.1
	Mean (cm)	4.2	2.3
100m	Range (cm)	4.6 – 7.8	
	Mean (cm)	6.8	
Reference	Range (cm)		7.3 – 8.3.
	Mean (cm)		7.8

4. Discussion

The extent to which an overlying fish farm impacts the seafloor is largely dependent on:

- the feeding regime at that farm, i.e. the amount of food that eventually ends up on the seafloor;
- the degree of current movement at the site in question; and
- the depth of water at that site.

These factors combine to form either erosional or depositional locations where organic material is either dispersed or it accumulates, and subsequently affects the receiving environment (*i.e.* the seafloor). The type of biotic community living at a particular site will also play a role in determining bottom conditions there. The influence of feeding activities of populations of starfish, polychaete worms, anemones, crabs and finfish at the Deenish site largely determine the level of impact of overlying farm operations on the benthos there.

Faunal feeding activity can remove large amounts of waste organic material from the seabed beneath a farm facility – with groups of mobile fauna capable of consuming large quantities of material. The fallowing schedule at a site also has a large bearing on benthic impact – most notably the length of time pens have been on site since the last fallow period. The presence of opportunistic deposit feeders such as *Capitella* sp., most notably at the under pen and pen edge stations will tend to help keep the benthic organics in a state of equilibrium at the fish farm sites. Sedimentary organic carbon levels in general are relatively higher at the under and edge of pen conditions at the Deenish site.

Mobile epibenthic scavengers such as starfish, fish and crabs also help in reducing the amount of waste material on the seafloor. This potential speed of the removal of waste was demonstrated in a previous study where photographic evidence was collected showing that epibenthic macrofauna were capable of removing, in less than 7 days, fish feed pellets spread at a density of 3.4 kg dry weight per m^2 on the sediment under a marine fish farm (Smith *et al.*, 1997).

Based on the benthic photographic records taken during the current survey, little habitat degradation is

obvious beyond the edge station on both transects at the Deenish site. Results from previous years surveys of the seafloor beneath the Deenish Island pen blocks indicated little change year on year on and showed few obvious signs of impact outside the areas of the seafloor immediately underneath the fish pens.

5. Conclusion

Benthic audit surveys were carried out at the Deenish fish farm site operated by Marine Harvest Ireland on 20th July 2016. The Deenish survey followed the DCMNR Level I monitoring protocols. In the present surveys beneath the pen blocks there no obvious signs of impact from the farming operation on the benthos other than elevated organic carbon levels at the under and edge stations with associated fine sediment layer over the coarse shelly sand recorded at the majority of the site.

6. References

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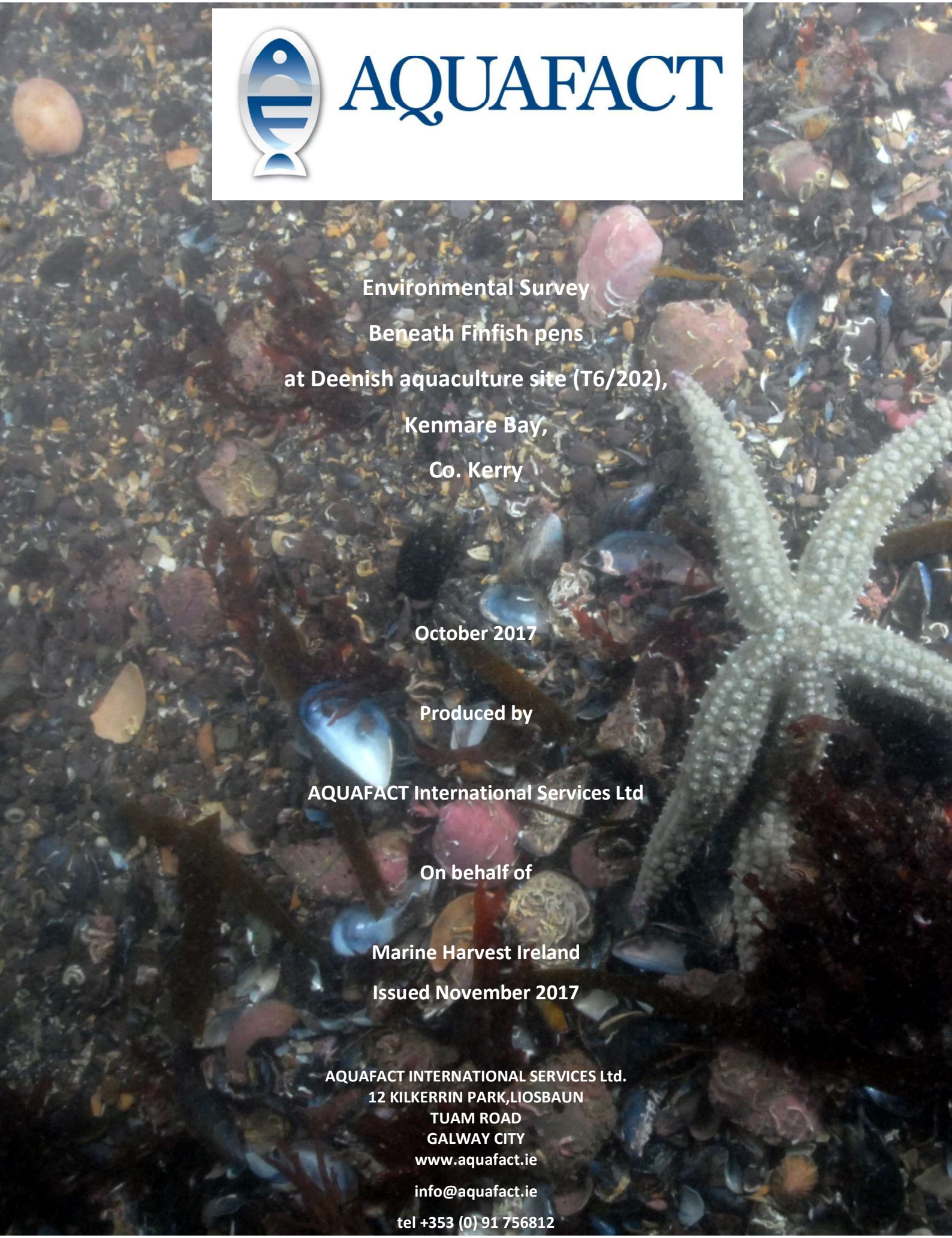

Environmental Survey
Beneath Finfish pens
at Deenish aquaculture site (T6/202),
Kenmare Bay,
Co. Kerry

October 2017

Produced by

AQUAFACT International Services Ltd

On behalf of

Marine Harvest Ireland

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1. Introduction

This report documents the environmental conditions of the seabed at a Marine Harvest Ireland finfish (Atlantic salmon *Salmo salar*) aquaculture site (Aquaculture Licence Reference T6/202) in Kenmare Bay, Co. Kerry recorded during surveys undertaken by AQUAFACT on 26th October 2017 (see Figure 1.1). The aquaculture site is situated close to Deenish Island, County Kerry on the northern shore of Kenmare River.

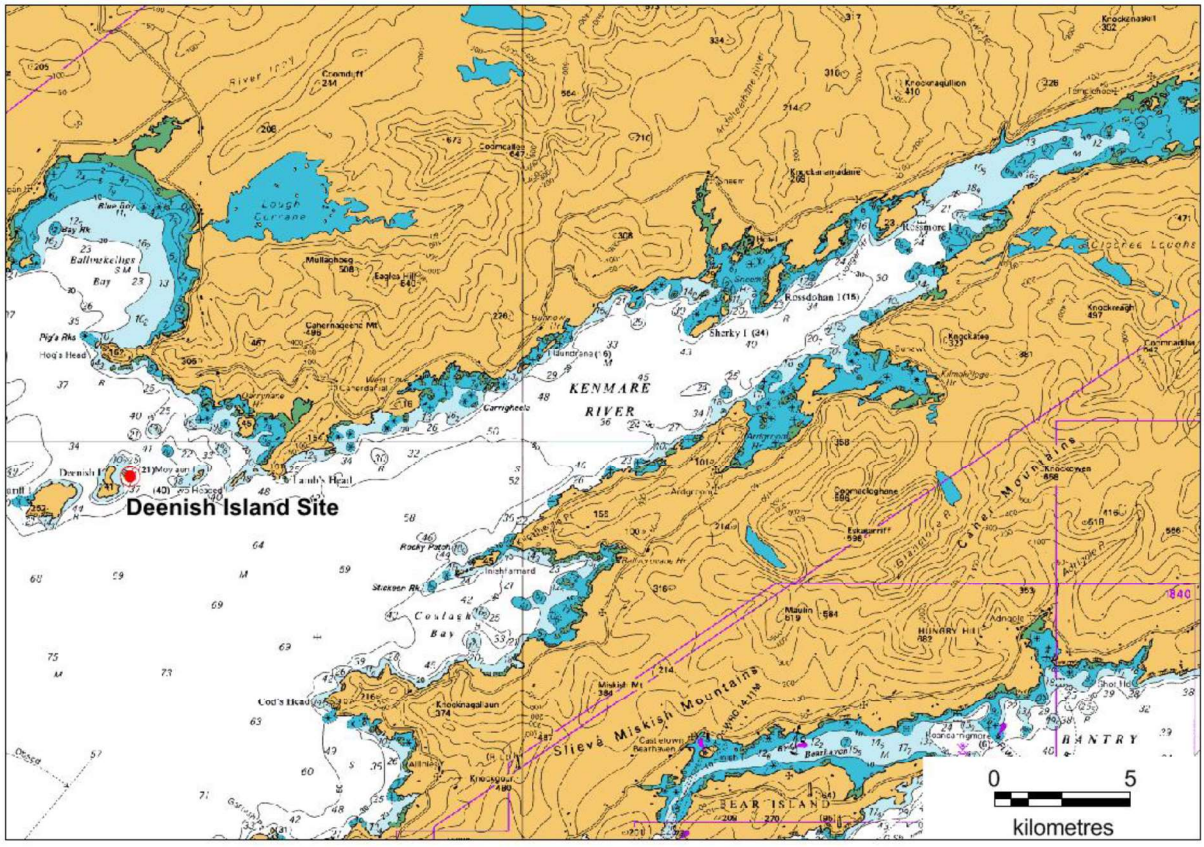

Figure 1.1: Map showing the location of the Deenish site surveyed in Kenmare Bay

1.1. Site description

Kenmare Bay, Co. Kerry, is a long and narrow, south-west facing bay. It is a deep, drowned glacial valley and the bedrock is mainly old red sandstone which forms reefs along the middle of the bay throughout

its length. Exposure to prevailing winds and swells at the mouth diminishes towards the head of the bay while numerous islands and inlets provide further areas of additional shelter.

Deenish Island is part of two Natura 2000 sites (see Figure 1.2), namely the Kenmare River cSAC (Site code: 002158) and the Deenish Island and Scariff Island SPA (Site code: 004175).

The diversity of environmental conditions, from exposed to ultra sheltered, that characterises Kenmare River cSAC results in the presence of a wide range of marine habitats including three listed on Annex I of the EU Habitats Directive, namely reefs, large shallow bay and caves. According to the cSAC site synopsis (available from www.npws.ie) Kenmare Bay is host to a high number of rare and notable marine species present (24) and some uncommon communities. The Kenmare River cSAC is the only known site in Ireland for the northern sea-fan, *Swiftia pallida* and is the only known area where this species and the southern sea-fan *Eunicella verrucosa* co-occur. Midway along the south coast of Kenmare River, a series of sea caves stretch back into the cliff, typically supporting a diversity of epifauna including encrusting sponges, ascidians and bryozoans.

Deenish Island and Scariff Island are small to medium size islands situated between 5 and 7 km west of Lamb's Head off the Co. Kerry coast and thus very exposed to the force of the Atlantic Ocean. The site is a Special Protection Area (SPA) under the E.U. Birds Directive due to its special conservation interest for seabirds including fulmar, Manx shearwater, storm petrel, lesser black-backed gull and Arctic tern. Scariff is the larger of the two islands, with very steep sides rising to a peak of 252 m with the highest cliffs located on the south side. Deenish is less rugged than Scariff, and rises to 144 m in its southern half; the northern half being lower and flatter. The vegetation is mostly grassland, with some heath occurring on the higher ground. Old fields are now overgrown with bracken and bramble. The sea areas within a 500m radius of both islands are included inside the SPA boundary to provide a 'rafting' area for shearwaters.

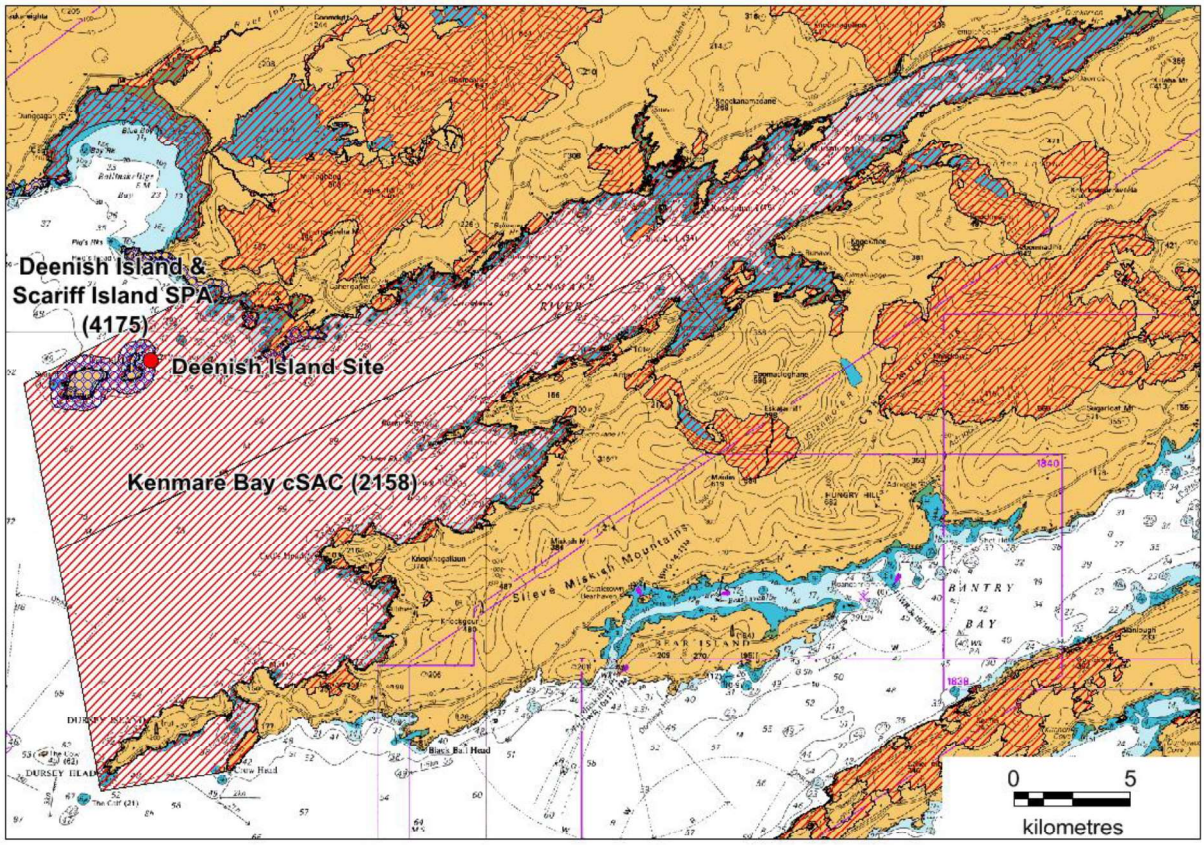

Figure 1.2: Map showing the locations of the relevant cSAC and SPA near Kenmare Bay, Co. Kerry.

1.2. Offshore finfish farms – benthic monitoring

The main objective of the survey was to assess the overall state of the environment in relation to the salmon production process. The sites were surveyed according to the revised Benthic Monitoring Guidelines laid down by the Department of Agriculture, Fisheries and Food (December 2008). The benthic monitoring requirements at a fish farm are dependent on the level of biomass held at the site and the local hydrography. Table 1.1 below sets out the level of benthic monitoring required based on tonnage produced and mean current speeds at a fish farm:

Table 1.1. Matrix of production tonnage versus current speed to determine level of benthic monitoring required

	MEAN CURRENT SPEED (CMS^{-1})		
TONNAGE	**<5**	**5-10**	**>10**
0-499	Level I	Level I	Level I
500-999	Level II	Level I	Level I
>1000	Level II	Level II	Level I

The current speed is a mean value calculated from maximum current measurements over spring and neap tidal cycles at the surface and near the bottom. The tonnage refers to the maximum biomass predicted for each site. An annual survey must be carried out at each site (production and smolt) operated by a company. A level I or level II survey may be carried out as follows:

Level I: Video/photographic and visual observations and recordings shall be made at the following stations:

- At a minimum of 2 sites directly beneath the pens
- At the edges of the pens
- Two transects at right angles to each other. Along each transect sampling stations at +/- 10m, +/- 20m, +/- 50m and + 100m from the pens
- At a control site

In addition to the above, the following samples/measurements shall be taken at the same stations as above. These will be used to calculate sediment quality parameters.

- A minimum of one Redox potential reading shall be made at each sampling station.
- A single sediment sample for Organic Carbon measurement.

Level II: In addition to the above, two replicate grab samples shall be captured at each of the sample stations for faunal analysis. The exact locations of sampling points should be agreed in advance with the Department of Agriculture Fisheries and Food (DAFF). The identification and abundance of macro-faunal invertebrates shall be estimated and tabulated. Identification of fauna to the level of species will be

required.

It is important to take note that the exact position of the individual pen structures are not permanently fixed to a single position and there is a relatively large lateral movement due to depth, wind, currents and tides. For this reason, bottom stations particularly those under, at the edge and 10 m away from the pens are taken at the time of sampling but may vary relative to the overlying pen position under various environmental conditions.

2. Sampling Procedure & Processing

All survey work at the Deenish site took place on 26th October 2017. The dives were conducted at a maximum depth of 20.8 m and underwater visibility on the day was good at approximately 5m. Pen layouts at the time of survey, dive entry points and benthic transects followed by the divers are shown in Figure 2.1.

Mean current speed at the Deenish finfish aquaculture site is 30 cm sec^{-1} (Marine Harvest pers.com.). The fish biomass present in the pens at the time of survey was 558 tonnes. The survey was carried out at Level 1 as per the guidance matrix displayed in Table 1.1.

Disinfection

Prior to each dive survey for each location all diving equipment, suits and boats are thoroughly disinfected utilising both a dipping and spraying protocol.

2.1. Dive survey

Two dive transects were laid out from the sea surface at each site using a boat equipped with a GPS mapper. Pen locations were noted as DGPS positions. The underwater survey involved direct observation, sampling and recording (through photographs and *in situ* annotations) of benthic conditions by highly experienced, qualified marine biologists and scientific divers. The notes taken *in situ* were transcribed to logs upon surfacing. In addition to standard SCUBA gear the divers were equipped with:

- A high-end dSLR Nikon D200 in a Subal ND20 underwater housing fitted with a 12-24mm

lens and two INON strobes. The camera was used to photograph the epibenthos and seafloor features;

- A diver-operated dSPI camera for photographing sediment profiles of the seafloor and calculate redox measurements. This unit uses a Canon EOS 450D camera with Nikkor optics;
- A compass for underwater navigation;
- Pre-labelled bags to store sediment samples for organic carbon analysis;
- Dive slates, torches and waterproof pencils for making observations/notes.

The divers photographed representative areas of the sediment and fauna and recorded observations in situ at the various stations investigated. Notes were completed immediately on surfacing and a map of the dive track was drawn up. Observations recorded during the dive included:

- Presence of bacterial mats and uneaten food;
- Presence of farm-derived litter;
- Presence of gas bubbles or anoxic areas;
- Animals visible or evidence of their presence;
- Macroalgae visible;
- Sediment characteristics, including colour and texture.

The seafloor was photographed at the following stations along two transects at the site (**Error! Reference source not found.**):

A. Directly under the pens;
B. Under the edge of the pen;
C. At 10m, 20m, 50m and 100m (on T1) from the pens along the transects.

A reference station was also assessed for each pen block to give a representation of ambient benthic conditions in the area immediately surrounding the pen installations for comparison purposes. The reference station was taken at a distance greater than 150 m from the pen installations to represent the assumed 'undisturbed' condition of the seafloor surrounding the sites.

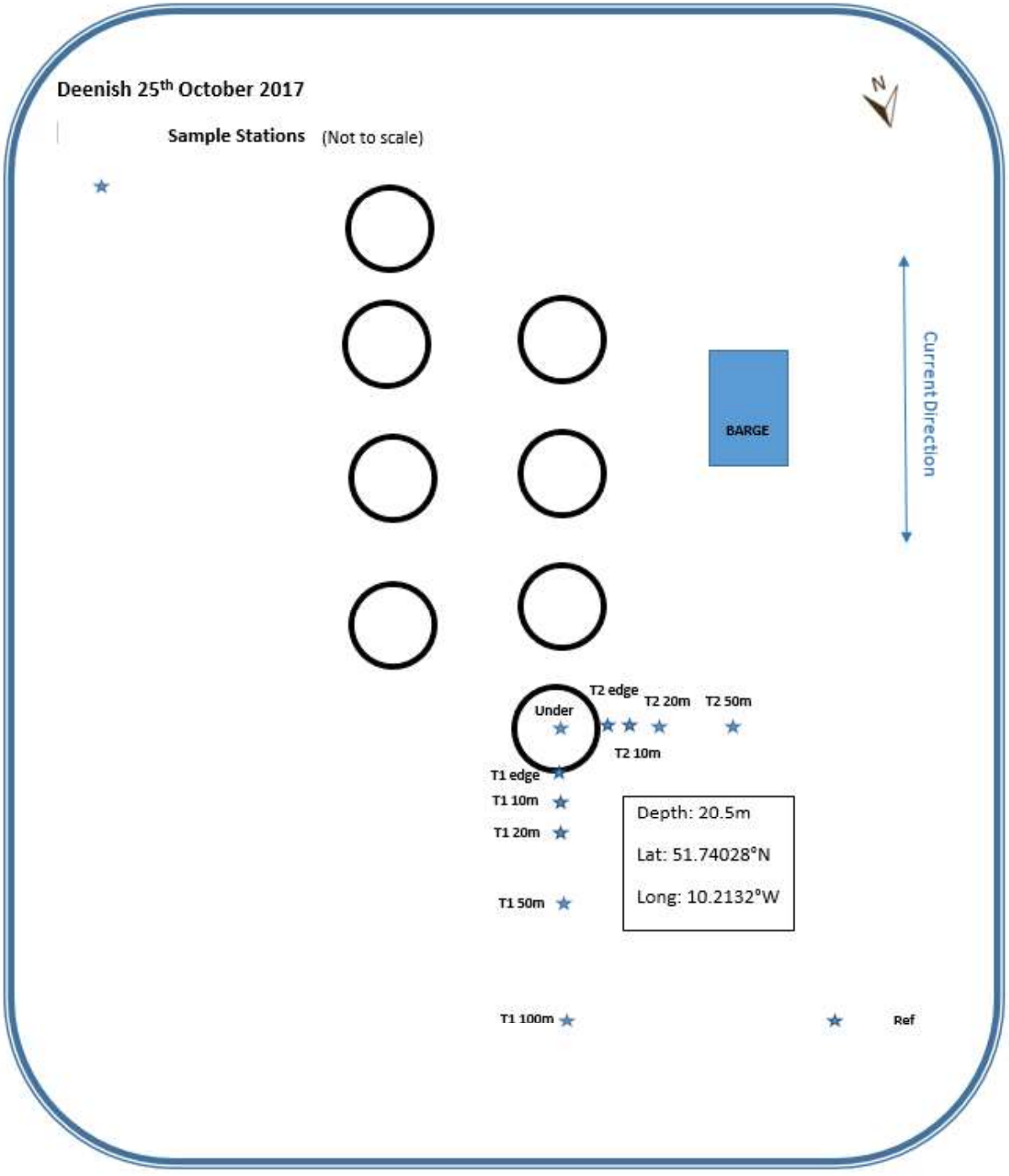

Figure 2.1: Transect seafloor station layout, Deenish finfish aquaculture site, Kenmare Bay, 25th October 2017

2.2. Sediment Profile Imagery (SPI)

Sediment profile images (SPI) obtained for each station along with ARPD depth measurements taken from the images were acquired using a diver-deployed sediment profile imaging camera system. This system is comprised of a digital SLR camera in a water-tight pressure vessel that is mounted above a prism that penetrates the upper 25 cm of sediment (see Figure 2.2). The sediment profile is viewed through a plexiglass window and the image is reflected to the camera lens via a plane mirror. Illumination is provided by an internally-mounted strobe. The prism unit is filled with distilled water – thus ambient water clarity is never a limiting factor in image quality. Upon arrival, the diver depresses the SPI unit into the seafloor and manually triggers the camera. This process is repeated at each station investigated.

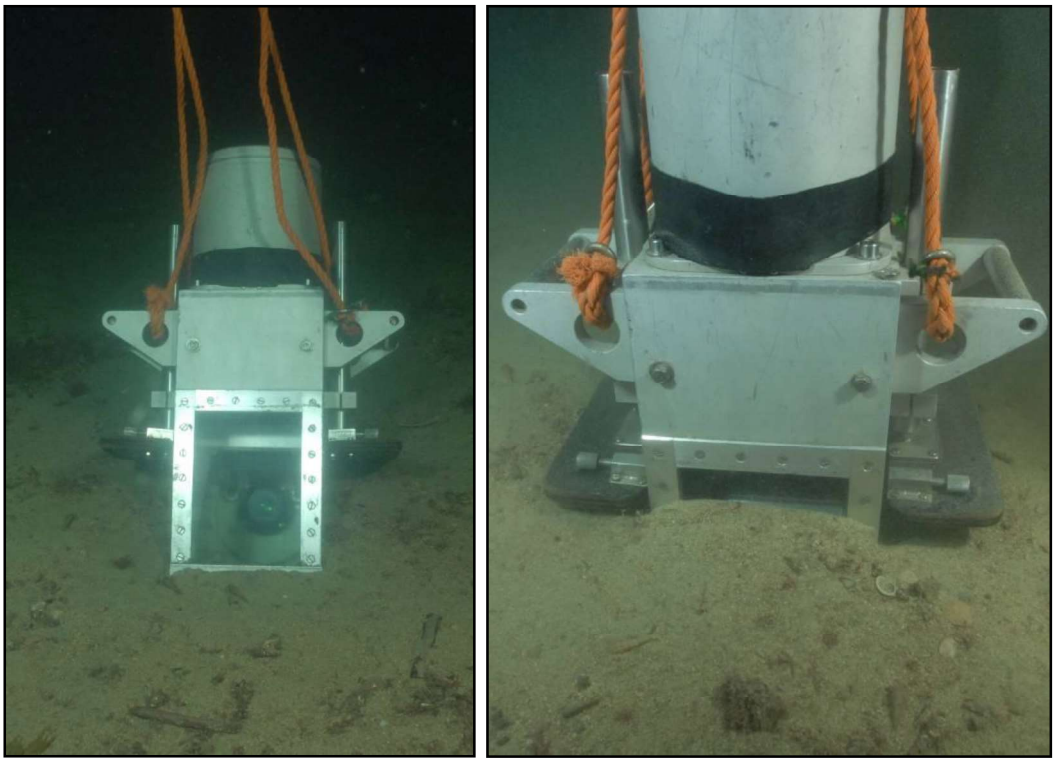

Figure 2.2: Diver operated Sediment Profile Imaging camera. The left-hand image gives a view of the camera at the sediment surface. The right-and image shows the SPI camera when inserted into the sediment

A great deal of information about benthic processes is available from sediment profile images. Measurable parameters, many of which are calculated directly by image analysis, include physical/chemical parameters (i.e. sediment type measured as grain size major mode, prism penetration

depth providing a relative indication of sediment shear strength, sediment surface relief, condition of mud clasts, redox potential discontinuity depth and degree of contrast, sediment gas voids) and biological parameters (i.e. infaunal successional stage of a well documented successional paradigm for soft marine sediments (see Pearson and Rosenberg, 1978), degree of sediment reworking, dominant faunal type, epifauna and infauna, depth of faunal activity, presence of microbial aggregations).

For the purposes of the current survey, the primary feature of interest is the depth of oxygen penetration into the sediments in the vicinity of the finfish pens (this information is required to satisfy the requirements of the Benthic Monitoring Protocol (DAFF, 2008). In this case, the apparent redox potential discontinuity or ARPD depth is measured. Features of particular interest that may be gleaned from SPI images taken in sediments in the vicinity of finfish pens include the presence of:

- uneaten feed pellets (and depth of this material, see Figure 2.3)
- faecal casts
- and depth of shell gravel deposits
- of gas voids in the sediment

Figure 2.3: Typical sediment profile images with examples of features relevant to aquaculture operations

2.3. Sampling for organic carbon analysis

Sediment samples for organic carbon analysis were collected at all stations. Samples were stored in pre-labelled plastic bags, kept in cold freezer boxes onboard the vessel and frozen at -20°C on return to the laboratory. Organic carbon analysis was carried out by ALS laboratories using the Loss on Ignition (LOI) technique. This method involves oven drying the sediment sample in a muffle furnace (450°C for a period of 6 hours) after which time the organic content of the sample is determined by expressing it as a percentage the weight of the sediment after ignition over the initial weight of the sediment.

3. Results

3.1. Recent Stocking History

At the time of the audit, 558 tonnes of fish were stocked on site having been input to the site in March 2017 following a 10 week week fallow period.

Figure 3.12: View of pens at Deenish Island site.

3.2. Seabed physical and biological characteristics

The seabed was mainly composed of coarse sand with a shell gravel constituent, the majority of which was composed of the shell of the edible mussel *Mytilus edulis* amongst other species.

3.2.1. Photographic record; Transect 1

This transect began beneath the northeastern most pen moored on site (see Figure 2.1) and ran for a distance of 100 m north. A total of six stations were investigated.

3.2.1.1. Under pen

The seafloor located directly beneath the pens was characterised by a gravel and shell covering mainly made up of the shell of the edible mussel *M. edulis*. Drift brown and red algae was common on the seabed. The anemone, *Cerianthus lloydii*, was noted as common. There were no direct impacts from the aquaculture operations observed at the time of the survey.

Figure 3.2: T1 – Under pen station, Deenish Island site, 25th October 2017

3.2.1.2. Edge of pen

The station located to the edge of the pen along Transect 1, was characterised by an undulating seafloor created by the prevailing tidal current of the area. The burrowing anemone, *C. lloydii* was present in the sediment. There were no immediate signs of impact from the adjacent aquaculture activities observed at this station, and in general the sediment appeared to be well oxygenated and in a stable condition.

Figure 3.3: T1 – Pen edge station, Deenish Island, 25th October 2017

3.2.1.3. 10 m from pen

The conditions observed 10 m along Transect 1 were very similar to the conditions observed at the edge station of the same transect. The sediment was composed of a coarse gravel with a high percentage of shell fragments, most of which was derived from the edible mussel *M. edulis*. Brown drift algae and phytodetrital debris was accumulated in the troughs of the sediment waves. There were no signs of farm derived material, and in general the benthic environment appeared to be in good condition.

Figure 3.4: T1 – 10m, Deenish Island, 25th October 2017

3.2.1.4. 20 m from pen

The station located 20 m along Transect 1 was characterised by a coarse gravel seafloor with a percentage of shell fragment, most of which originated from the edible mussel *M. edulis*. The seafloor had an undulating appearance that had been formed by the prevailing tidal current, which has formed a series of shallow peaks and troughs. Some drift brown algae had accumulated in the troughs (Figure 3.5) and the burrowing anemone *C. lloydii* was buried in the sediment waves. There were no visible signs of any anthropogenic influence.

Figure 3.5: T1 – 20 m station, Deenish Island, 25th October 2017

3.2.1.5. 50 m from pen

The seafloor at the 50 m station along Transect 1 was similar to the previous station although with coarser material accumulated in the sand troughs along with some drift algae. There were no obvious signs of impact from the aquaculture activities and the seafloor had an oxygenated appearance.

Figure 3.6: T1 – 50 m station, Deenish Island, 25th October 2017

3.2.1.6. 100 m from Pen

The conditions observed towards the end of Transect 1 at the 100 m station were markedly different from the previous stations in that the general size of the pebble and shell gravel sediment was larger with more intact shell fragments. Red algae were present on the seafloor along with drift brown algae and other phytodetrital material. There were no obvious signs of impact from the aquaculture activities and in general the benthic environment appeared to be in good health (Figure 3.7).

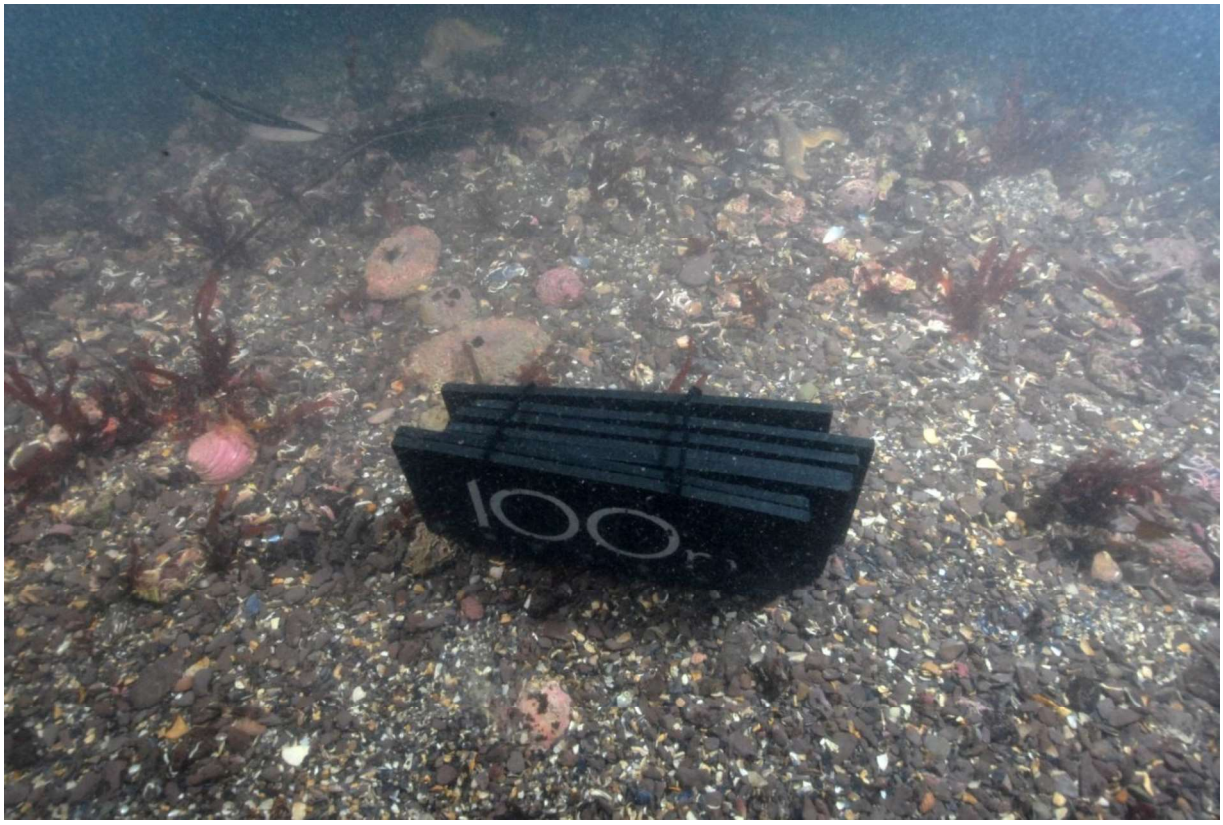

Figure 3.7: T1 – 100 m station, Deenish Island, 25th October 2017

3.2.2. Sediment Profile Imagery – Transect 1

Figure 3.8 presents sediment profile images taken at the six stations visited on Transect 1 of the Deenish site. The substrate of the site was composed of fine and medium grained sand with shell gravel at the under pen station which gradually gave way to a coarser shelly gravelly sand with intact shell at the outer end of the transect. The energy levels experienced by the seafloor in this area is more than likely quite high particularly during winter storms.

The images display a single image and the maximum and minimum apparent redox potential discontinuity (ARPD) depths measured at each station. Each image is 15.5cm × 25cm. ARPD depths ranged from a minimum of 1.2 cm (T1 20m) to a maximum of greater than 3.9 cm (T1 Under).

Due to the relatively coarse nature of the seafloor, the SPI camera achieved relatively low penetrations.

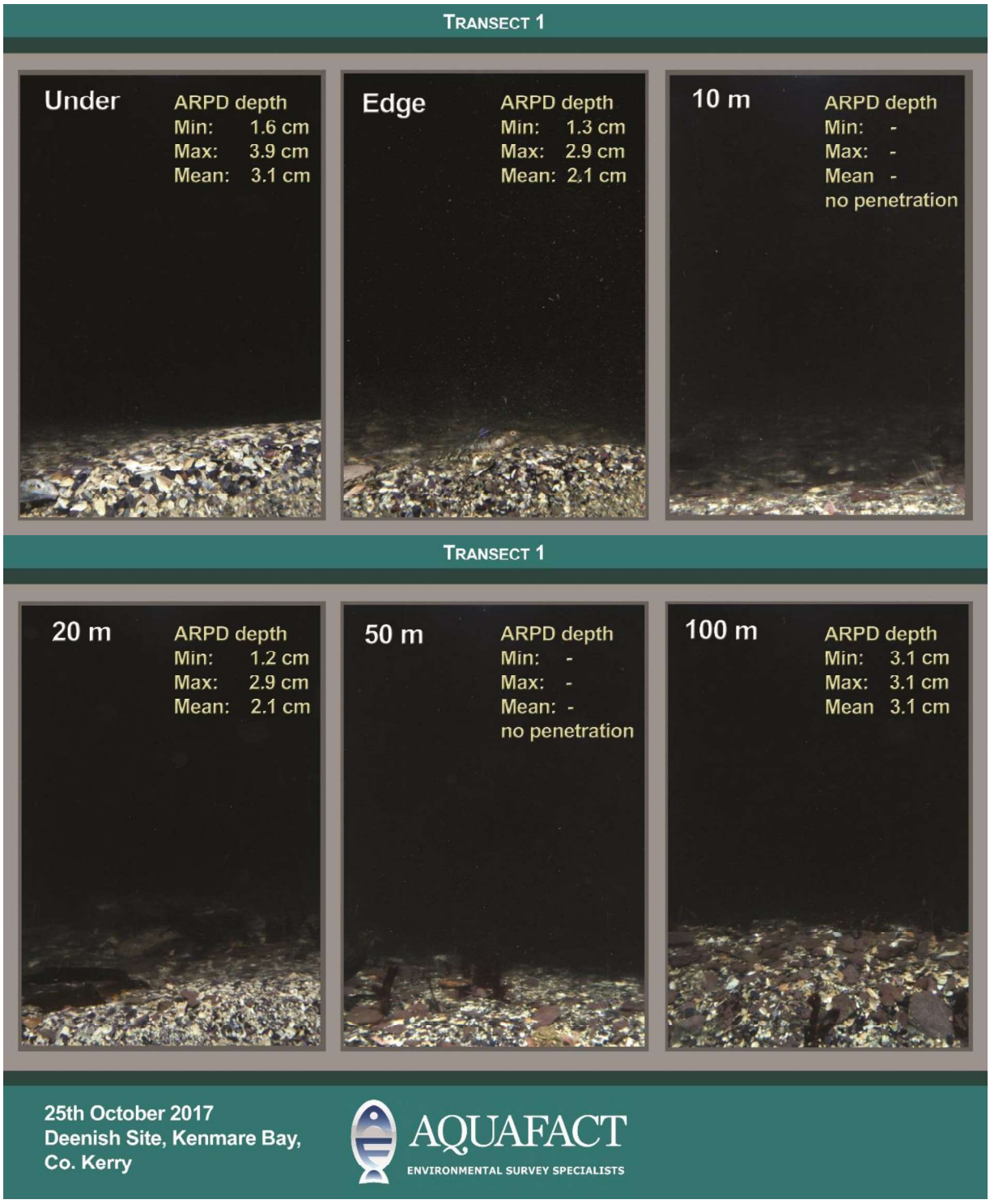

Figure 3.8: Representative photographs of the seafloor taken along Transect 1 by Sediment Profile Imagery (SPI)

3.2.3. Photographic Record; Transect 2

This transect began beneath the same pen as Transect 1 and ran for a distance of 50m west. A total of five stations were investigated on Transect 2 with an additional (Reference) station investigated just *c.* 150 m north of the pen edge (See Figure 2.1).

3.2.3.1. Under pen

The under pen conditions recorded at the beginning of Transect 2 were very similar to those observed at the Under station at the beginning of Transect 1. The sediment is mainly composed of shell fragment and forms an undulating profile of peaks and troughs influenced by the prevailing tidal current of the area. There were no immediate signs of waste material from the adjacent aquaculture activity.

Figure 3.9: T2 – Under pen station, Deenish Island, 25th October 2017

3.2.3.2. Edge of pen

The Edge of pen station along Transect 2 was characterised by a course grained sand with a considerable percentage of shell fragment. Drift algae and phytodetrital material had accumulated in the trough of the sand waves along with whole shells of the edible mussel *M. edulis*. No signs of impact from the overhead pens were appreciable, and the benthic environment appeared to be in good health.

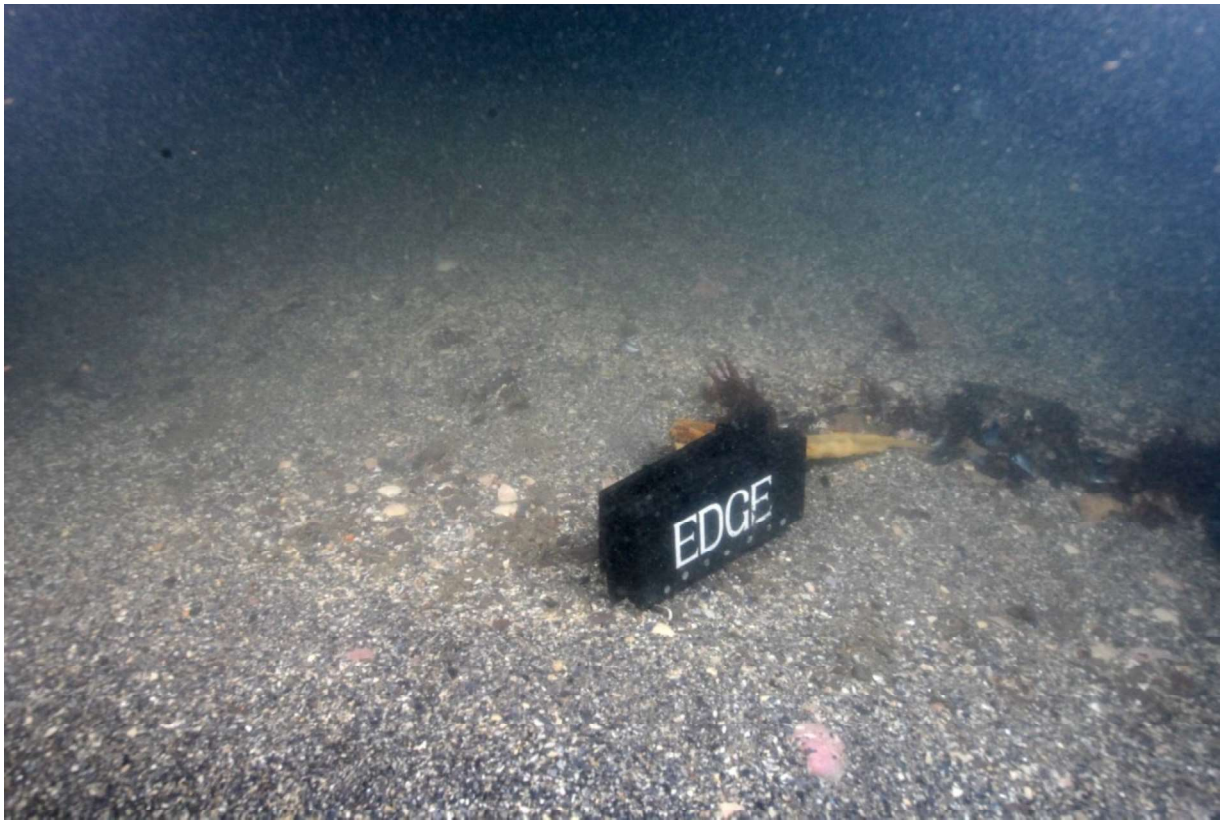

Figure 3.10: T2 – Pen edge station, Deenish Island, 25th October 2017

3.2.3.3. 10 m from pen

Moving to the 10 m station along Transect 2 the sediment changed from medium grained sand to a coarser sand with a larger percentage of intact clam shells scattered along the seabed. Clumps of drift algae and phytodetrital material were also present. The anemone, *C. lloydii*, was common buried in the sand. There were no observations of waste material from the adjacent aquaculture site visible on the seabed. In general, the benthic environment of the area seemed to be in good condition.

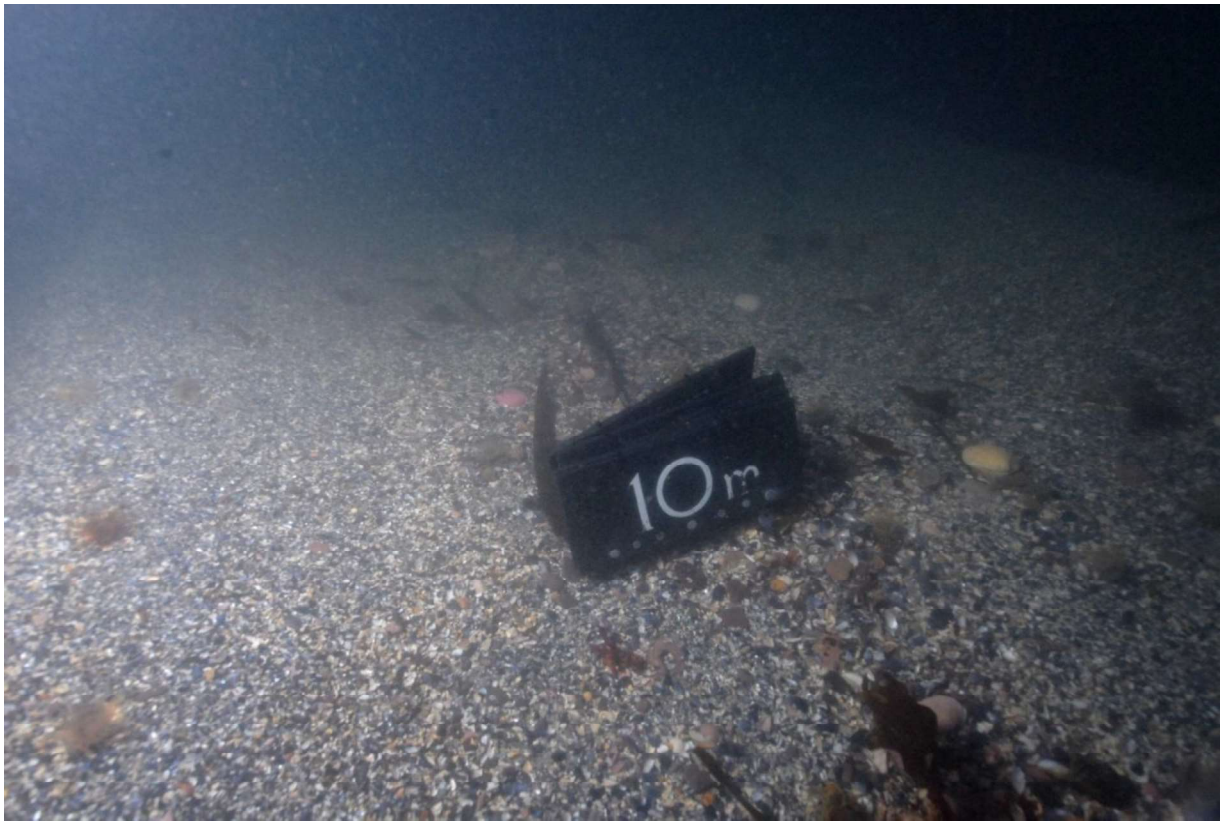

Figure 3.11: T2 – 10 m station, Deenish Island, 25th October 2017

3.2.3.4. 20 m from pen

The seafloor located 20 m along Transect 2 was characterised by a medium grained sand sediment with a mixture of larger stones and intact shells throughout. The profile of the seafloor was wavy in appearance due to the prevailing tidal current creating peaks and troughs. The anemone, *C. lloydii*, was common buried in the sand. There were no signs of impact from the adjacent finfish farm and the benthic environment appeared to be relatively unaltered.

Figure 3.12: T2 – 20 m station, Deenish Island, 25th October 2017

3.2.3.5. 50 m from pen

The seafloor 50 m along Transect 2 was characterised by a seafloor where the sediment was more uniform than previous stations with fewer large empty shell fragments. The anemone, *C. lloydii*, was not as frequent as in the previous stations but a number of individuals were noted.

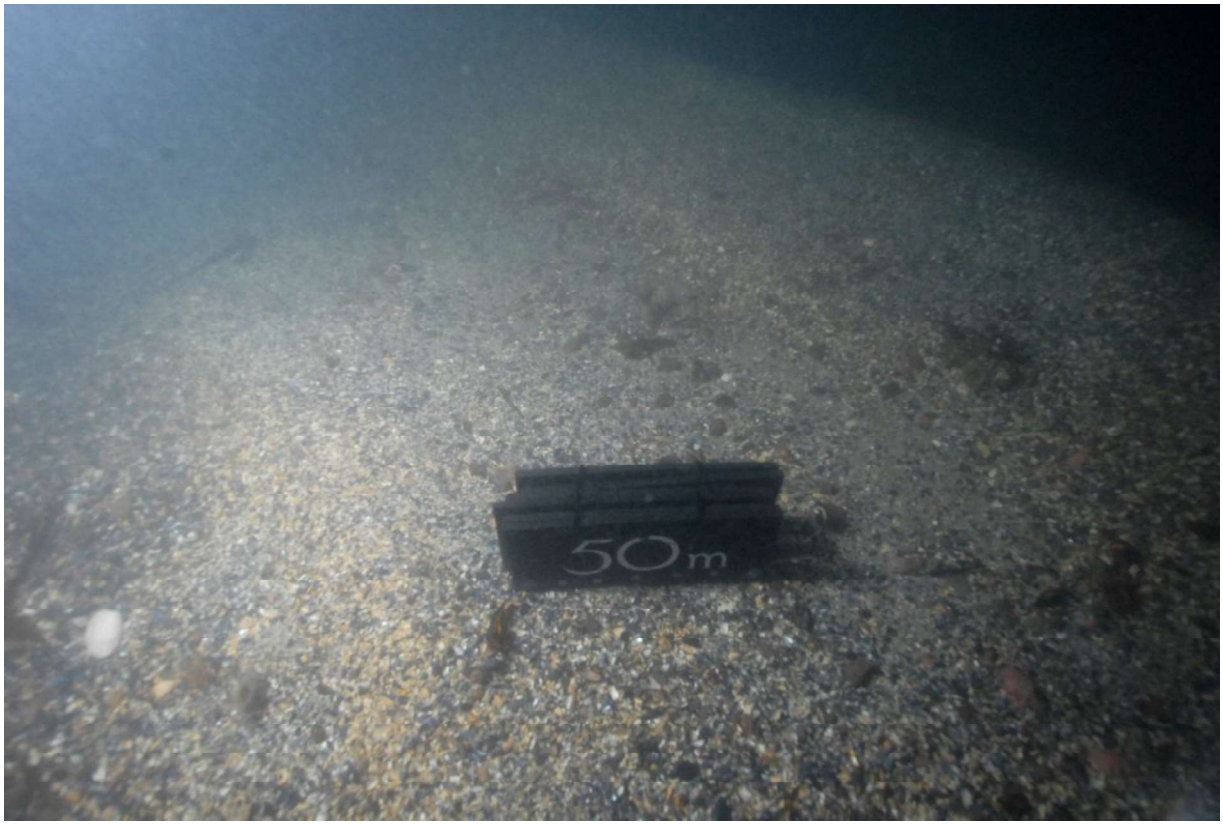

Figure 3.13: T2 – 50 m station, Deenish Island, 26th October 2017

3.2.3.6. Reference station

The reference site was chosen to provide an example of the natural conditions present at the site. The sediment was composed of numerous flat pebbles mixed with shell fragments. Drifting brown algae was distributed along the seafloor. As would be expected the influence of the adjacent aquaculture had no bearing on the benthic environment of the site.

Figure 3.14: Reference station, Deenish Island, 25th October 2017

3.2.4. Sediment Profile Imagery – Transect 2 & Reference

Figure 3.15 presents sediment profile images taken at the five stations visited on Transect 2 of the Deenish site and the reference station on 25th October 2017. The figure displays a single image and the maximum and minimum apparent redox potential discontinuity (ARPD) depths measured at each station. Each image is 15.5 cm × 25 cm.

Sediment type varied from medium sands under and close to the pen compared with higher proportions of gravel and shell with increasing distance from the pen. It was difficult to estimate ARPD depths from the station due to the nature of the substrate which didn't allow sufficient prism penetration of the SPI. Despite this, penetration was achieved on all stations and the oxidised sediment layer at the site was considered to be relatively deep, estimated to range from a minimum of 1.2 cm to a maximum of 12.2 cm recorded at the 20 m pen location. ARPD depths at the Reference station ranged from 2.6 cm to 5.1 cm and a mean ARPD of 3.9.

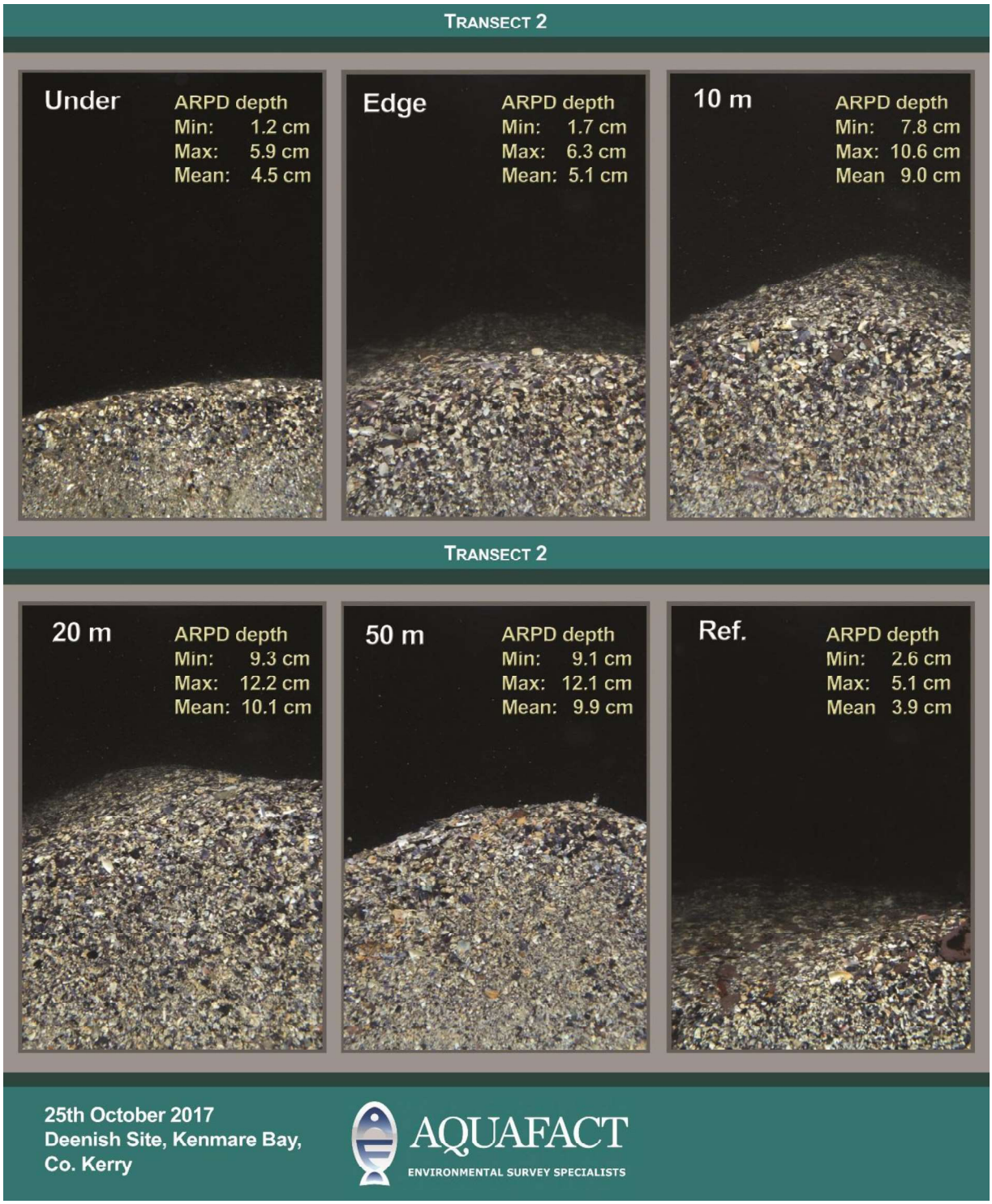

Figure 3.15: Representative photographs of the seafloor taken along Transect 2 by Sediment Profile Imagery

3.2.5. Transect Species List

Table 3.1 shows a list of species observed during the dives at the Deenish fish farm site on this and previous occasions.

Table 3.1: Species noted during dives on the seabed beneath the Deenish pens

Group	Species	Common Name
(Cnidaria) Hexacorallia	*Cerianthus lloydii*	Tube anemone
(Annelida) Polychaeta	*Spirobranchus* sp. *Lanice conchilega* *Chaetopterus variopedatus*	Tube worm The sand mason Parchment tube worm
(Mollusca) Bivalvia	*Pecten maximus* Faceliniidae Aeolidiida Nudibranch	King scallop Sea slugs Sea slugs Sea slugs
(Arthropoda) Decapoda	Paguridae	Hermit crab
Echinodermata	*Luidia ciliaris* *Asterias rubens* *Marthasterias sp* *Ophiura* sp. Amphiuridae sp.	Seven armed starfish Common starfish Starfish Brittlestar Brittlestar
(Chordata) Osteiichthyes	*Pomatoschistus* sp. *Trisopterus minutus* *Labrus bergylta*	Gobies Poor Cod Ballan Wrasse
Rhodophyta	*Delesseria sanguinea* *Phycodrys rubens* *Cryptopleura ramose* *Calliblepharis ciliata* *Lythophyllum* sp.	Sea beech Sea oak
Ochrophyta	*Alaria esculenta*	Edible kelp

3.2.6. Organic Carbon Analysis & ARPD Depths

Table 3.2 shows the organic carbon results from the Deenish stations. Organic carbon levels ranged from 2.28% (T2 50m) to 6.47% (T1 Under). Apart from the levels directly under the pens, organic carbon values are similar to that recorded at the Reference station.

Table 3.2: Organic carbon results for Deenish (% values, Loss on Ignition at 450°C).

T1	**Under**	**Edge**	**10m**	**20m**	**50m**	**100m**
LOI %	6.47	5.51	3.82	3.1	2.55	3.8
T2	**Under**	**Edge**	**10m**	**20m**	**50m**	**REF**
LOI %	-	3.87	2.69	2.84	2.28	3.04

Table 3.7 shows in tabular form the ARPD depths from the SPI images from Deenish (see Sections 3.1.4 and 3.1.7).

Table 3.3: ARPD Depths for Deenish, Kenmare Bay, 25th October 2017

Station		**Transect 1**	**Transect 2**
Under	Range (cm)	1.6-3.9	1.2-5.9
	Mean (cm)	3.1	4.5
Edge	Range (cm)	1.3-2.9	1.7-6.3
	Mean (cm)	2.1	5.1
10m	Range (cm)	-	7.8-10.6
	Mean (cm)	-	9.0
20m	Range (cm)	1.2-2.9	9.3-12.2
	Mean (cm)	2.1	10.1
50m	Range (cm)	-	9.1-12.1
	Mean (cm)	-	9.9
100m	Range (cm)	3.1-3.1	-
	Mean (cm)	3.1	-
Reference	Range (cm)	-	2.6-5.1
	Mean (cm)	-	3.9

4. Discussion

The extent to which an overlying fish farm impacts the seafloor is largely dependent on:

- the feeding regime at that farm, i.e. the amount of food that eventually ends up on the seafloor;
- the degree of current movement at the site in question; and
- the depth of water at that site.

These factors combine to form either erosional or depositional locations where organic material is either dispersed or it accumulates, and subsequently affects the receiving environment (*i.e.* the seafloor). The type of biotic community living at a particular site will also play a role in determining bottom conditions there. The influence of feeding activities of populations of starfish, polychaete worms, anemones, crabs and finfish at the Deenish site largely determine the level of impact of overlying farm operations on the benthos there.

Faunal feeding activity can remove large amounts of waste organic material from the seabed beneath a farm facility – with groups of mobile fauna capable of consuming large quantities of material. The fallowing schedule at a site also has a large bearing on benthic impact – most notably the length of time pens have been on site since the last fallow period. The presence of opportunistic deposit feeders such as *Capitella* sp., most notably at the under pen and pen edge stations will tend to help keep the benthic organics in a state of equilibrium at the fish farm sites. Sedimentary organic carbon levels in general are relatively higher at the under and edge of pen conditions at the Deenish site.

Mobile epibenthic scavengers such as starfish, fish and crabs also help in reducing the amount of waste material on the seafloor. This potential speed of the removal of waste was demonstrated in a previous study where photographic evidence was collected showing that epibenthic macrofauna were capable of removing, in less than 7 days, fish feed pellets spread at a density of 3.4 kg dry weight per m^2 on the sediment under a marine fish farm (Smith *et al.*, 1997).

Based on the on the observations during the current survey, It is evident that very little if any habitat degradation has occurred at the Deenish site. The results obtained from the previous year's survey in 2016 yielded similar results and the influence of the aquaculture was proposed to have minimal effect on the surrounding environment.

5. Conclusion

On the 25th of October 2017, a benthic audit survey was carried out on the Deenish fish farm site operated by Marine Harvest Ireland. The Deenish survey followed the DCMNR Level I monitoring protocols. The results from the current survey conclude that the overlying aquaculture had little to no influence on the seafloor. Stations observed at the edge of each transect and beyond had ARPD depths very similar to the reference station and the site can be considered of good environmental status.

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Environmental Survey

Beneath Finfish pens

at Deenish aquaculture site (T6/202),

Kenmare Bay,

Co. Kerry

May 2018

Produced by

AQUAFACT International Services Ltd

On behalf of

Marine Harvest Ireland

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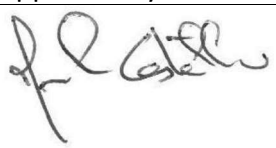
1	Draft	22/10/2018	JN1471 Deenish 2018 Audit	Hugh O'Sullivan	
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AQUAFACT

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1. Introduction

This report documents the environmental conditions of the seabed at a Marine Harvest Ireland finfish (Atlantic salmon *Salmo salar*) aquaculture site (Aquaculture Licence Reference T6/202) in Kenmare Bay, Co. Kerry recorded during surveys undertaken by AQUAFACT on 24th May 2018 (see Figure 1.1). The aquaculture site is situated close to Deenish Island, County Kerry on the northern shore of Kenmare River.

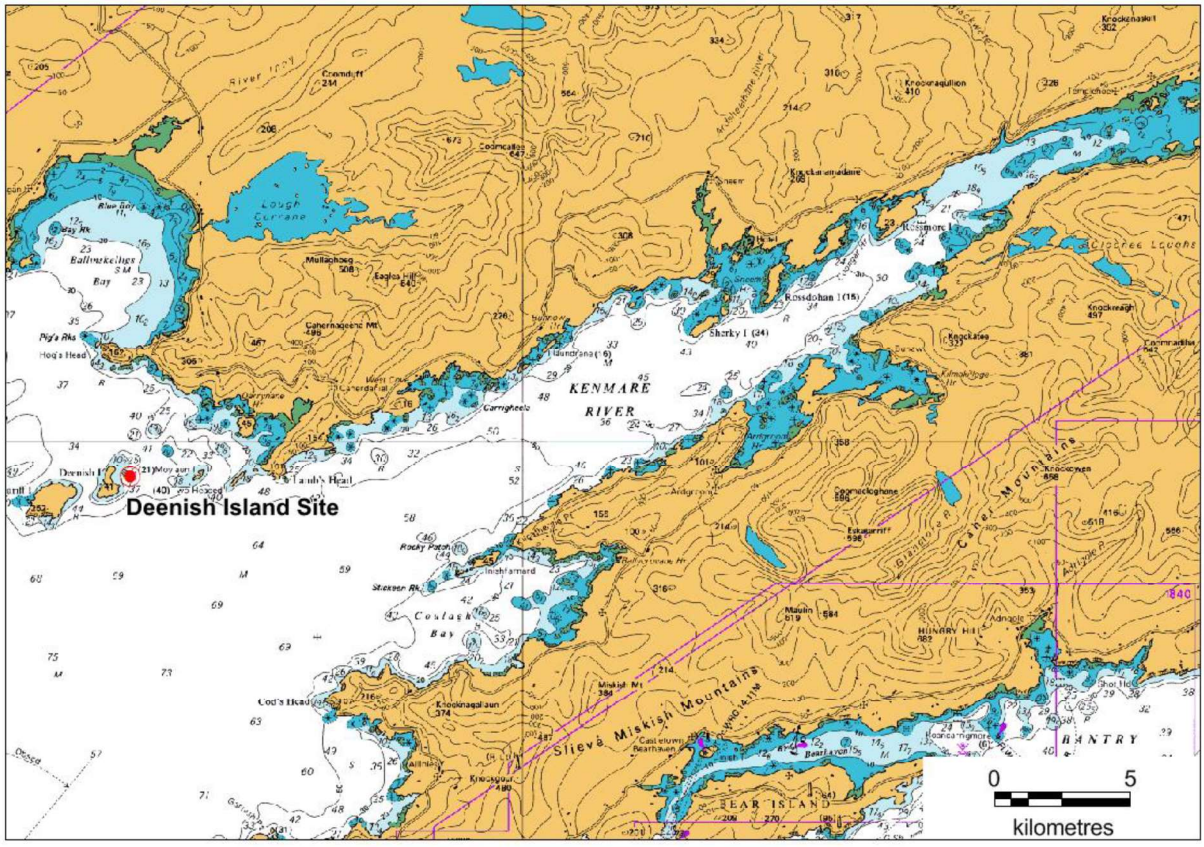

Figure 1.1: Map showing the location of the Deenish site surveyed in Kenmare Bay

1.1. Site description

Kenmare Bay, Co. Kerry, is a long and narrow, south-west facing bay. It is a deep, drowned glacial valley and the bedrock is mainly old red sandstone which forms reefs along the middle of the bay throughout

its length. Exposure to prevailing winds and swells at the mouth diminishes towards the head of the bay while numerous islands and inlets provide further areas of additional shelter.

Deenish Island is part of two Natura 2000 sites (see Figure 1.2), namely the Kenmare River cSAC (Site code: 002158) and the Deenish Island and Scariff Island SPA (Site code: 004175).

The diversity of environmental conditions, from exposed to ultra sheltered, that characterises Kenmare River cSAC results in the presence of a wide range of marine habitats including three listed on Annex I of the EU Habitats Directive, namely reefs, large shallow bay and caves. According to the cSAC site synopsis (available from www.npws.ie) Kenmare Bay is host to a high number of rare and notable marine species present (24) and some uncommon communities. The Kenmare River cSAC is the only known site in Ireland for the northern sea-fan, *Swiftia pallida* and is the only known area where this species and the southern sea-fan *Eunicella verrucosa* co-occur. Midway along the south coast of Kenmare River, a series of sea caves stretch back into the cliff, typically supporting a diversity of epifauna including encrusting sponges, ascidians and bryozoans.

Deenish Island and Scariff Island are small to medium size islands situated between 5 and 7 km west of Lamb's Head off the Co. Kerry coast and thus very exposed to the force of the Atlantic Ocean. The site is a Special Protection Area (SPA) under the E.U. Birds Directive due to its special conservation interest for seabirds including fulmar, Manx shearwater, storm petrel, lesser black-backed gull and Arctic tern. Scariff is the larger of the two islands, with very steep sides rising to a peak of 252 m with the highest cliffs located on the south side. Deenish is less rugged than Scariff, and rises to 144 m in its southern half; the northern half being lower and flatter. The vegetation is mostly grassland, with some heath occurring on the higher ground. Old fields are now overgrown with bracken and bramble. The sea areas within a 500m radius of both islands are included inside the SPA boundary to provide a 'rafting' area for shearwaters.

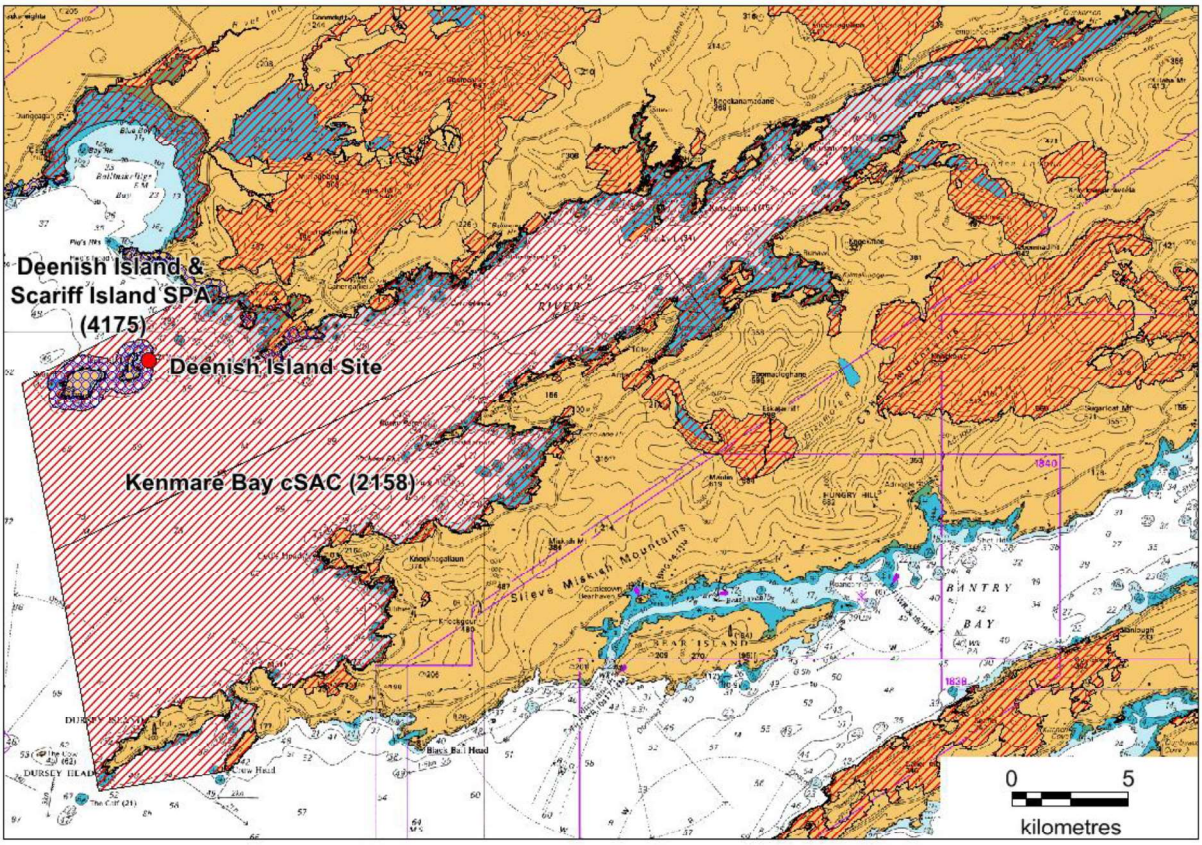

Figure 1.2: Map showing the locations of the relevant cSAC and SPA near Kenmare Bay, Co. Kerry

1.2. Offshore finfish farms – benthic monitoring

The main objective of the survey was to assess the overall state of the environment in relation to the salmon production process. The sites were surveyed according to the revised Benthic Monitoring Guidelines laid down by the Department of Agriculture, Fisheries and Food (December 2008). The benthic monitoring requirements at a fish farm are dependent on the level of biomass held at the site and the local hydrography. Table 1.1 below sets out the level of benthic monitoring required based on tonnage produced and mean current speeds at a fish farm.

Table 1.1: Matrix of production tonnage versus current speed to determine level of benthic monitoring required

	MEAN CURRENT SPEED (CMS^{-1})		
TONNAGE	**<5**	**5-10**	**>10**
0-499	Level I	Level I	Level I
500-999	Level II	Level I	Level I
>1000	Level II	Level II	Level I

The current speed is a mean value calculated from maximum current measurements over spring and neap tidal cycles at the surface and near the bottom. The tonnage refers to the maximum biomass predicted for each site. An annual survey must be carried out at each site (production and smolt) operated by a company. A level I or level II survey may be carried out as follows:

Level I: Video/photographic and visual observations and recordings shall be made at the following stations:

- At a minimum of 2 sites directly beneath the pens
- At the edges of the pens
- Two transects at right angles to each other. Along each transect sampling stations at +/- 10m, +/- 20m, +/- 50m and + 100m from the pens
- At a control site

In addition to the above, the following samples/measurements shall be taken at the same stations as above. These will be used to calculate sediment quality parameters.

- A minimum of one Redox potential reading shall be made at each sampling station.
- A single sediment sample for Organic Carbon measurement.

Level II: In addition to the above, two replicate grab samples shall be captured at each of the sample stations for faunal analysis. The exact locations of sampling points should be agreed in advance with the Department of Agriculture Fisheries and Food (DAFF). The identification and abundance of macro-faunal invertebrates shall be estimated and tabulated. Identification of fauna to the level of species will be

required.

It is important to take note that the exact position of the individual pen structures are not permanently fixed to a single position and there is a relatively large lateral movement due to depth, wind, currents and tides. For this reason, bottom stations particularly those under, at the edge and 10 m away from the pens are taken at the time of sampling but may vary relative to the overlying pen position under various environmental conditions.

2. Sampling Procedure & Processing

All survey work at the Deenish site took place on 24th May 2018. The dives were conducted at a maximum depth of 22.8 m and underwater visibility on the day was good at approximately 5m. The prevailing current direction at the site is north-south and as a result Transect 1 is orientated in this direction. Pen layouts at the time of survey, current direction, dive entry points and benthic transects followed by the divers are shown in Figure 2.1. Mean current speed at the Deenish finfish aquaculture site is 30 cm sec^{-1} (Marine Harvest *pers.comm*.). The fish biomass present in the pens at the time of survey was 1,532.7 tonnes. The survey was carried out at Level 1 as per the guidance matrix displayed in Table 1.1.

Disinfection

Prior to each dive survey for each location all diving equipment, suits and boats are thoroughly disinfected utilising both a dipping and spraying protocol.

2.1. Dive survey

Two dive transects were laid out from the sea surface at each site using a boat equipped with a GPS mapper. Pen locations were noted as DGPS positions. The underwater survey involved direct observation, sampling and recording (through photographs and *in situ* annotations) of benthic conditions by highly experienced, qualified marine biologists and scientific divers. The notes taken *in situ* were transcribed to logs upon surfacing. In addition to standard SCUBA gear the divers were equipped with:

- A high-end dSLR Nikon D200 in a Subal ND20 underwater housing fitted with a 12-24mm lens and two INON strobes. The camera was used to photograph the epibenthos and seafloor features;
- A diver-operated dSPI camera for photographing sediment profiles of the seafloor and calculate redox measurements. This unit uses a Canon EOS 450D camera with Nikkor optics;
- A compass for underwater navigation;
- Pre-labelled bags to store sediment samples for organic carbon analysis;
- Dive slates, torches and waterproof pencils for making observations/notes.

The divers photographed representative areas of the sediment and fauna and recorded observations in situ at the various stations investigated. Notes were completed immediately on surfacing and a map of the dive track was drawn up. Observations recorded during the dive include:

- Presence of bacterial mats and uneaten food;
- Presence of farm-derived litter;
- Presence of gas bubbles or anoxic areas;
- Animals visible or evidence of their presence;
- Macroalgae visible;
- Sediment characteristics, including colour and texture.

The seafloor was photographed at the following stations along two transects at the site (see Figure 2.1):

A. Directly under the pens;
B. Under the edge of the pen;
C. At 10m, 20m, 50m and 100m (on T1) from the pens along the transects.

A reference station was also assessed for each pen block to give a representation of ambient benthic conditions in the area immediately surrounding the pen installations for comparison purposes. The reference station was taken at a distance greater than 150 m from the pen installations to represent the assumed ‘undisturbed’ condition of the seafloor surrounding the sites.

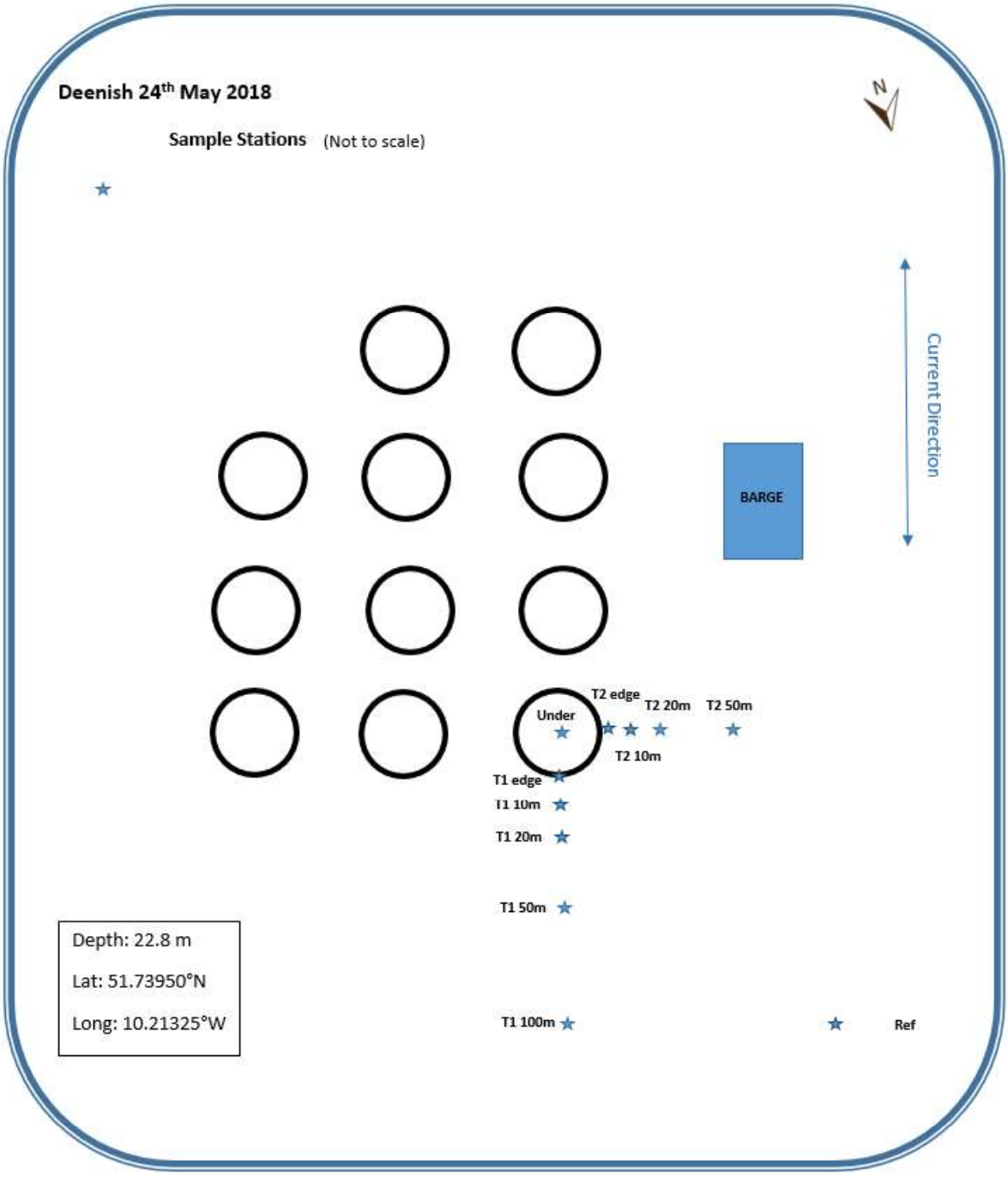

Figure 2.1: Transect seafloor station layout, Deenish finfish aquaculture site, Kenmare Bay, 24th May 2018

2.2. Sediment Profile Imagery (SPI)

Sediment profile images (SPI) obtained for each station along with ARPD depth measurements taken from the images were acquired using a diver-deployed sediment profile imaging camera system. This system is comprised of a digital SLR camera in a water-tight pressure vessel that is mounted above a prism that penetrates the upper 25 cm of sediment (see Figure 2.2). The sediment profile is viewed through a plexiglass window and the image is reflected to the camera lens via a plane mirror. Illumination is provided by an internally-mounted strobe. The prism unit is filled with distilled water – thus ambient water clarity is never a limiting factor in image quality. Upon arrival, the diver depresses the SPI unit into the seafloor and manually triggers the camera. This process is repeated at each station investigated.

Figure 2.2: Diver operated Sediment Profile Imaging camera. The left-hand image gives a view of the camera at the sediment surface. The right-and image shows the SPI camera when inserted into the sediment

A great deal of information about benthic processes is available from sediment profile images. Measurable parameters, many of which are calculated directly by image analysis, include physical/chemical parameters (i.e. sediment type measured as grain size major mode, prism penetration

depth providing a relative indication of sediment shear strength, sediment surface relief, condition of mud clasts, redox potential discontinuity depth and degree of contrast, sediment gas voids) and biological parameters (i.e. infaunal successional stage of a well documented successional paradigm for soft marine sediments (see Pearson and Rosenberg, 1978), degree of sediment reworking, dominant faunal type, epifauna and infauna, depth of faunal activity, presence of microbial aggregations).

For the purposes of the current survey, the primary feature of interest is the depth of oxygen penetration into the sediments in the vicinity of the finfish pens (this information is required to satisfy the requirements of the Benthic Monitoring Protocol (DAFF, 2008). In this case, the apparent redox potential discontinuity or ARPD depth is measured. Features of particular interest that may be gleaned from SPI images taken in sediments in the vicinity of finfish pens include the presence of:

- uneaten feed pellets (and depth of this material, see Figure 2.3)
- faecal casts
- and depth of shell gravel deposits
- of gas voids in the sediment

Figure 2.3: Typical sediment profile images with examples of features relevant to aquaculture operations

2.3. Sampling for organic carbon analysis

Sediment samples for organic carbon analysis were collected at all stations. Samples were stored in pre-labelled plastic bags, kept in cold freezer boxes onboard the vessel and frozen at -20°C on return to the laboratory. Organic carbon analysis was carried out by ALS laboratories using the Loss on Ignition (LOI) technique. This method involves oven drying the sediment sample in a muffle furnace (450°C for a period of 6 hours) after which time the organic content of the sample is determined by expressing it as a percentage the weight of the sediment after ignition over the initial weight of the sediment.

3. Results

3.1. Recent Stocking History

At the time of the audit, 1,532.7 tonnes of fish were stocked on site having been input to the site (44.6 tonnes) in March 2017 following a 10 week week fallow period. This gave an onsite biomass production of approximately 1,488 tonnes prior to the survey.

Figure 3.1: View of pens at Deenish Island site

3.2. Seabed physical and biological characteristics

The seabed was mainly composed of fine sand under and immediate vicinity of the pen with coarse sand with a shell gravel constituent, the majority of which was composed of the shell of the edible mussel *Mytilus edulis* amongst other species, at the stations further along the transects.

3.2.1. Photographic record; Transect 1

This transect began beneath the northwestern most pen moored on site (see Figure 2.1) and ran for a distance of 100 m north. A total of six stations were investigated.

3.2.1.1. Under pen

The seafloor located directly under the pens was characterised by a medium to fine sand that had a bumpy/dotted appearance due to the presence of a dense polychaete community (*Capitella* spp. complex). Drift brown and red algae were common on the seafloor. The lugworm, *Arenicola marina*, was also present. There were some observations of uneaten feed pellets and waste faecal matter from the above aquaculture pens. No observations of bacterial mats or outgassing were observed.

Figure 3.2: T1 – Under pen station, Deenish Island site, 24th May 2018

3.2.1.2. Edge of pen

The seafloor at the edge station was characterised by soft medium grained sand. As with the under station the surface was dotted with the surface tubes of the opportunistic polychaete infaunal community with a number of *A. marina* casts also present. Drift brown and red algae were scattered over the surface with some uneaten food pellets (see Figure 3.3). No outgassing or bacterial mats were observed at the station.

Figure 3.3: T1 – Pen edge station, Deenish Island, 24th May 2018

3.2.1.3. 10 m from pen

The seafloor conditions observed 10 m along Transect 1 were very similar to those observed at the edge station of the same transect. The sediment was composed of a fine grained sand with a dotted appearance due to the infaunal community. Brown drift algae and phytodetrital debris were also present. In general the benthic environment appeared to be in good condition.

Figure 3.4: T1 – 10m, Deenish Island, 24th May 2018

3.2.1.4. 20 m from pen

The seafloor conditions at the 20 m station along Transect 1 were characterised by fine grained sand. Brown, red and green drift algae were recorded on the seafloor while *A. marina* casts were common. The burrowing anemone *Cerianthus lloydii* was observed with feeding tentacles extended. The presence of the opportunistic *Capitella* sp. complex community indicated the organic input from the aquaculture activity although the seafloor had a healthy oxygenated appearance.

Figure 3.5: T1 – 20 m station, Deenish Island, 24th May 2018

3.2.1.5. 50 m from pen

On moving approximately 50 m away from the pens the seafloor conditions changed considerably, the fine grained sand gave way to coarser more shell dominated sediment. Drift algae and phytodetrital material were present along with the burrowing anemone *C. lloydii*. In general the sediment appeared oxygenated with some darker areas were the ARPD was closer to the surface. There were no obvious signs of impact from the aquaculture activities.

Figure 3.6: T1 – 50 m station, Deenish Island, 24th May 2018

3.2.1.6. 100 m from Pen

The seafloor conditions observed at the 100m station were similar to those observed at the 50m station along Transect 1. There was a high percentage of shell gravel predominately from the mussel *M. edulis*, generally accumulated in troughs with finer medium sand forming peaks. The burrowing anemone *C. lloydii* was common as was the lugworm *A. marina*. In general, the seafloor had an oxygenated appearance and the benthic environment appeared to be in good health (Figure 3.7).

Figure 3.7: T1 – 100 m station, Deenish Island, 24th May 2018

3.2.2. Sediment Profile Imagery – Transect 1

Figure 3.8 presents sediment profile images taken at the six stations visited on Transect 1 of the Deenish site. The substrate of the site was composed of fine and medium grained sand with shell gravel at the under pen station which gradually gave way to a coarser shelly gravelly sand with intact shell at the outer end of the transect. The energy levels experienced by the seafloor in this area is more than likely quite high particularly during winter storms.

The images display a single image and the maximum and minimum apparent redox potential discontinuity (ARPD) depths measured at each station. Each image is 15.5cm × 25cm. ARPD depths ranged from a minimum of 0.1 cm (T1 20m) to a maximum of greater than 13.2 cm (T1 Under). The dense *Capitella* sp. complex community is clearly evident in the under, edge and to a lesser extent 10 m stations. These species increase the ARPD by their bioturbating activity that increases the oxygen content of the sediment.

Due to the relatively coarse nature of the seafloor, the SPI camera achieved relatively low penetrations.

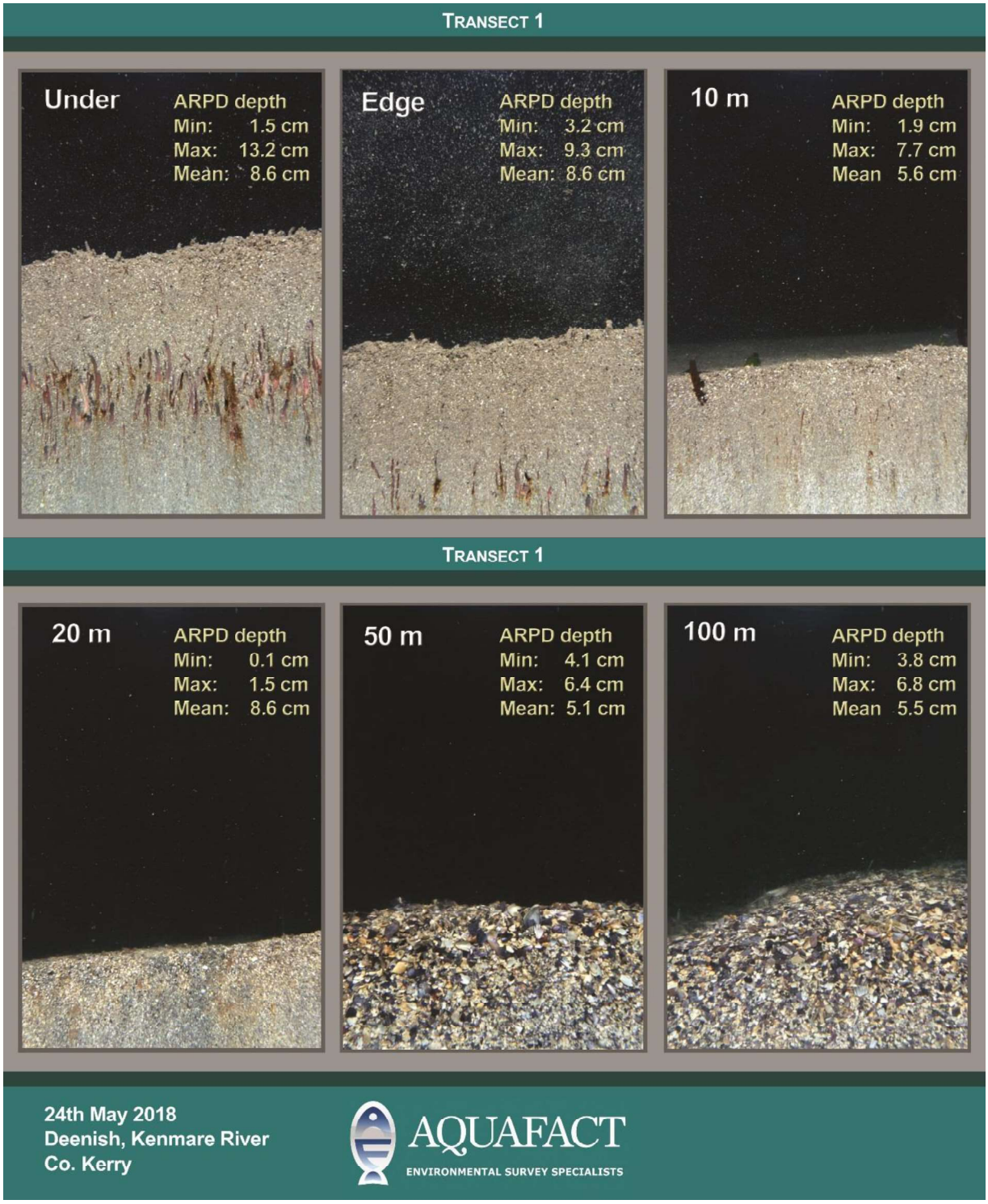

Figure 3.8: Representative photographs of the seafloor taken along Transect 1 by Sediment Profile Imagery (SPI) apparatus. Marine Harvest finfish aquaculture site, Deenish, Kenmare River, Co. Kerry, 24th May 2018.

3.2.3. Photographic Record; Transect 2

This transect began beneath the same pen as Transect 1 and ran for a distance of 50m west. A total of five stations were investigated on Transect 2 with an additional (Reference) station investigated just *c.* 150 m north of the pen edge (See Figure 2.1).

3.2.3.1. Under pen

The seafloor directly beneath the salmon pens on Transect 2 was very similar to the Under pen conditions observed on Transect 1. The sediment was made up of fine grained sand that had a dotted appearance due to the small tubes of the infaunal polychaetes protruding from the sediment surface. The red tentacles of these worms can be seen protruding from the tubes in places. *A. marina* casts were also observed on the sediment surface.

Figure 3.9: T2 – Under pen station, Deenish Island, 24th May 2018

3.2.3.2. Edge of pen

The Edge of pen station along Transect 2 was characterised by a fine grained sand. Drift algae and phytodetrital material were common along with *A. marina* casts resulting from the bioturbating activity in the sediment. Apart from some uneaten feed pellets scattered on the sea bed there were no obvious signs of impact from the overhead pens, and the benthic environment was in relatively good condition.

Figure 3.10: T2 – Pen edge station, Deenish Island, 24th May 2018

3.2.3.3. 10 m from pen

The seafloor conditions at the 10m station on Transect 2 were characterised by fine grained sand with a small amount of shell gravel mainly originating from the blue mussel *M. edulis*. Patches of darker sediment were observed where the deeper less oxygenated sediment had been bioturbated and brought to the surface by the worm *A. marina*. There were no observations of waste material from the adjacent aquaculture site visible on the seabed. In general, the benthic environment of the area seemed to be in good condition.

Figure 3.11: T2 – 10 m station, Deenish Island, 24th May 2018

3.2.3.4. 20 m from pen

Seafloor conditions at the 20m station on Transect 2 were characterised by fine grained sand with a light oxygenated appearance. However, there were some darker patches where the bioturbating activity of *A. marina* had brought less oxygenated sediment to the surface. The anemone *C. lloydii* was common buried in the sand. There were no obvious signs of impact from the above salmon farm activity, with no signs of waste faecal matter or uneaten feed pellets. In general the benthic environment appeared to be in good condition.

Figure 3.12: T2 – 20 m station, Deenish Island, 24th May 2018

3.2.3.5. 50 m from pen

The seafloor at the 50m station on Transect 2 was characterised by fine grained sand with a light oxygenated appearance. The arms of *Amphiura* sp. were observed suspended above the sediment surface feeding. The benthic environment appeared to be in good health.

Figure 3.13: T2 – 50 m station, Deenish Island, 24th May 2018

3.2.3.6. Reference station

A reference station was chosen to provide an example of the natural conditions that occur in the area with the absence of the aquaculture site. The sediment at this station was courser than at previous station, a considerable percentage of shell fraction was observed predominantly composed of *M. edulis*. Drift algae was scattered across the seafloor with the anemone *C. lloydii* and lugworm A. marina buried in the sediment.

Figure 3.14: Reference station, Deenish Island, 24th May 2018

3.2.4. Sediment Profile Imagery – Transect 2 & Reference

Figure 3.15 presents sediment profile images taken at the five stations visited on Transect 2 of the Deenish site and the reference station on 24th May 2018. The figure displays a single image and the maximum and minimum apparent redox potential discontinuity (ARPD) depths measured at each station. Each image is 15.5 cm × 25 cm.

Sediment type varied from medium sands under and close to the pen compared with higher proportions of gravel and shell with increasing distance from the pen. It was difficult to estimate ARPD depths from the station due to the nature of the substrate which didn't allow sufficient prism penetration of the SPI. Despite this, penetration was achieved on all stations and the oxidised sediment layer at the site was considered to be relatively deep, estimated to range from a minimum of 0.5 cm (T2 20m) to a maximum of 11.8 cm (T2 Under). ARPD depths at the Reference station ranged from 5.5 cm to 8.9 cm and a mean ARPD of 6.8 cm. The Capitella sp. complex community is evident at the under, edge and 10m stations while the arms of *Amphiura* sp. are noted protruding into the water column at both the 20m and 50m stations.

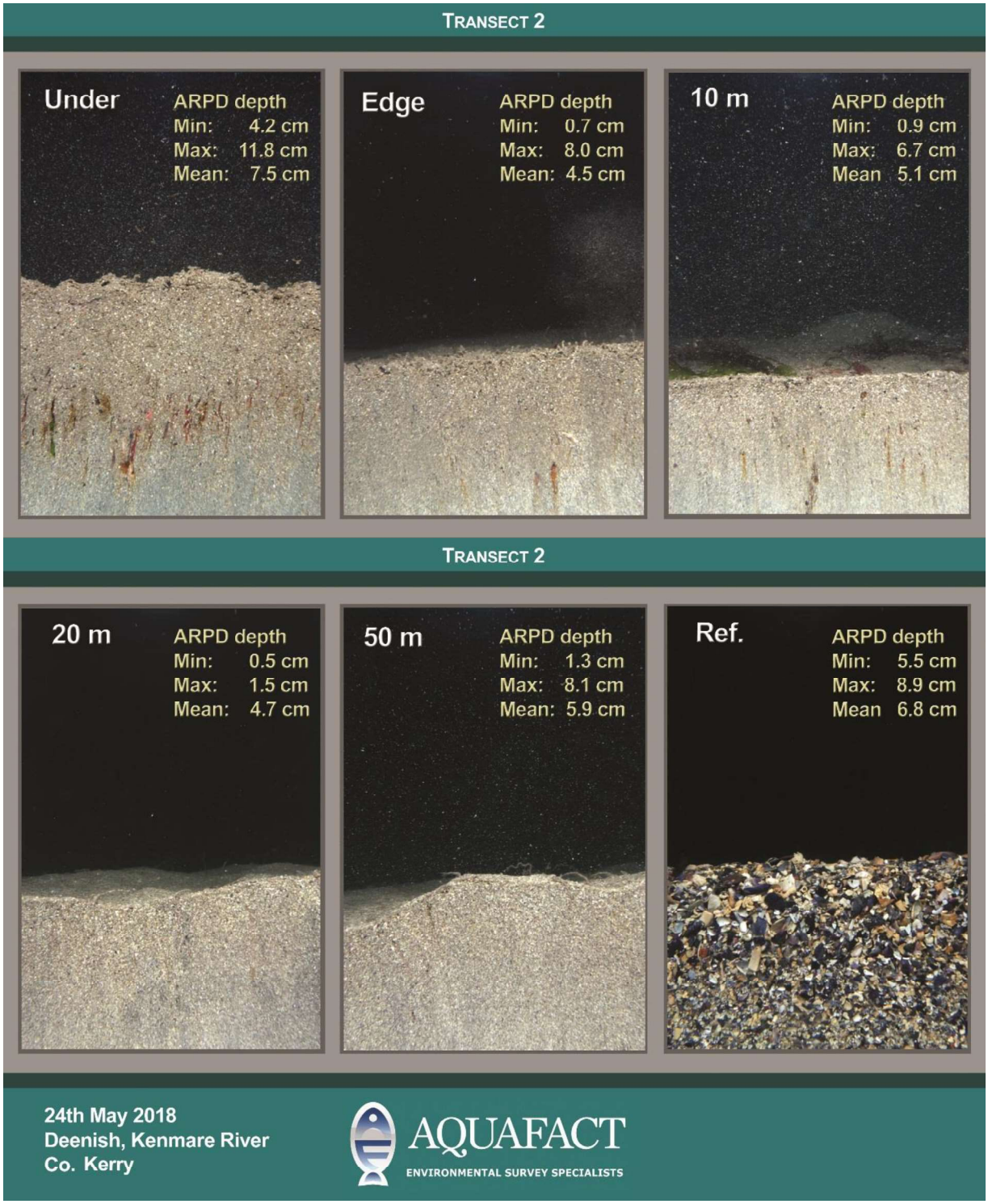

Figure 3.15: Representative photographs of the seafloor taken along Transect 2 by Sediment Profile Imagery (SPI) apparatus. Marine Harvest finfish aquaculture site, Deenish, Kenmare River, Co. Kerry, 24th May 2018.

3.2.5. Transect Species List

Table 3.1 shows a list of species observed during the dives at the Deenish fish farm site on this and previous occasions.

Table 3.1: Species noted during dives on the seabed beneath the Deenish pens

Group	Species	Common Name
(Cnidaria) Hexacorallia	*Cerianthus lloydii*	Tube anemone
(Annelida) Polychaeta	*Spirobranchus* sp. *Lanice conchilega* *Chaetopterus variopedatus* *Arenicola marina*	Tube worm The sand mason Parchment tube worm Lugworm
(Mollusca) Bivalvia	*Pecten maximus* Faceliniidae Aeolidiida Nudibranch	King scallop Sea slugs Sea slugs Sea slugs
(Arthropoda) Decapoda	Paguridae	Hermit crab
Echinodermata	*Luidia ciliaris* *Asterias rubens* *Marthasterias sp* *Ophiura* sp. Amphiuridae sp.	Seven armed starfish Common starfish Starfish Brittlestar Brittlestar
(Chordata) Osteiichthyes	*Pomatoschistus* sp. *Trisopterus minutus* *Labrus bergylta*	Gobies Poor Cod Ballan Wrasse
Rhodophyta	*Delesseria sanguinea* *Phycodrys rubens* *Cryptopleura ramose* *Calliblepharis ciliata* *Lythophyllum* sp.	Sea beech Sea oak
Ochrophyta	*Alaria esculenta*	Edible kelp

3.2.6. Organic Carbon Analysis & ARPD Depths

Table 3.2 shows the organic carbon results from the Deenish stations. Organic carbon levels ranged from 2.2% (T2 20m) to 5.91% (T1 Edge). Levels were higher beneath the cages when compared with the reference site (2.92%) and became lower the greater the distance from the aquaculture site.

Table 3.2: Organic carbon results for Deenish (% values, Loss on Ignition at 450°C).

T1	**Under**	**Edge**	**10m**	**20m**	**50m**	**100m**
LOI %	5.06	5.91	4.9	3.31	3.13	3.2
T2	**Under**	**Edge**	**10m**	**20m**	**50m**	**REF**
LOI %	-	4.42	3.18	2.2	2.3	2.92

Table 3.3 shows in tabular form the ARPD depths from the SPI images from Deenish (see Sections 3.2.2 and 3.2.4).

Table 3.3: ARPD Depths for Deenish, Kenmare Bay, 24th May 2018

Station		**Transect 1**	**Transect 2**
Under	Range (cm)	1.5-13.2	4.2-11.8
	Mean (cm)	8.6	7.5
Edge	Range (cm)	3.2-9.3	0.7-8.0
	Mean (cm)	8.6	4.5
10m	Range (cm)	1.9-7.7	0.9-6.7
	Mean (cm)	5.6	5.1
20m	Range (cm)	0.1-1.5	0.5-1.5
	Mean (cm)	8.6	4.7
50m	Range (cm)	4.1-6.4	1.3-8.1
	Mean (cm)	5.1	5.9
100m	Range (cm)	3.8-6.8	-
	Mean (cm)	5.5	-
Reference	Range (cm)	-	5.5-8.9
	Mean (cm)	-	6.8

4. Discussion

The extent to which an overlying fish farm impacts the seafloor is largely dependent on:

- the feeding regime at that farm, i.e. the amount of food that eventually ends up on the seafloor;
- the degree of current movement at the site in question; and
- the depth of water at that site.

These factors combine to form either erosional or depositional locations where organic material is either dispersed or it accumulates, and subsequently affects the receiving environment (*i.e.* the seafloor). The type of biotic community living at a particular site will also play a role in determining bottom conditions there. The influence of feeding activities of populations of starfish, polychaete worms, anemones, crabs and finfish at the Deenish site largely determine the level of impact of overlying farm operations on the benthos there.

Faunal feeding activity can remove large amounts of waste organic material from the seabed beneath a farm facility – with groups of mobile fauna capable of consuming large quantities of material. The fallowing schedule at a site also has a large bearing on benthic impact – most notably the length of time pens have been on site since the last fallow period. The presence of opportunistic deposit feeders such as *Capitella* sp., most notably at the under pen and pen edge stations will tend to help keep the benthic organics in a state of equilibrium at the fish farm sites. Sedimentary organic carbon levels in general are relatively higher at the under and edge of pen conditions at the Deenish site.

Mobile epibenthic scavengers such as starfish, fish and crabs also help in reducing the amount of waste material on the seafloor. This potential speed of the removal of waste was demonstrated in a previous study where photographic evidence was collected showing that epibenthic macrofauna were capable of removing, in less than 7 days, fish feed pellets spread at a density of 3.4 kg dry weight per m^2 on the sediment under a marine fish farm (Smith *et al.*, 1997).

In light of the observations obtained during the current survey, it appears that very little if any habitat

degradation has occurred at the Deenish Island site. Results obtained from both previous studies in 2016 and 2017 yielded similar results and it is proposed that the influence of salmon aquaculture has had a minimal effect on the surrounding benthic environment.

5. Conclusion

On the 24th of May 2018, a benthic audit survey was carried out on the Deenish fish farm site operated by Marine Harvest Ireland. The Deenish survey followed the DCMNR Level I monitoring protocols. The results from the current survey conclude that the overlying aquaculture had little or no effect on the seabed. Stations examined along each of the transects had ARPD depths that were very similar to those recorded at the reference and the site can be considered of good environmental status.

6. References

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Environmental Survey

Beneath Finfish pens

at Deenish aquaculture site (T6/202),

Kenmare Bay,

Co. Kerry

September 2019

Produced by

AQUAFACT International Services Ltd

On behalf of

MOWI Ireland

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Report Approval Sheet

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AQUAFACT

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1. Introduction

This report documents the environmental conditions of the seabed at a MOWI Ireland finfish (Atlantic salmon *Salmo salar*) aquaculture site (Aquaculture Licence Reference T6/202) in Kenmare Bay, Co. Kerry recorded during surveys undertaken by AQUAFACT on 13th September 2019 (see Figure 1.1). The aquaculture site is situated close to Deenish Island, County Kerry on the northern shore of Kenmare River.

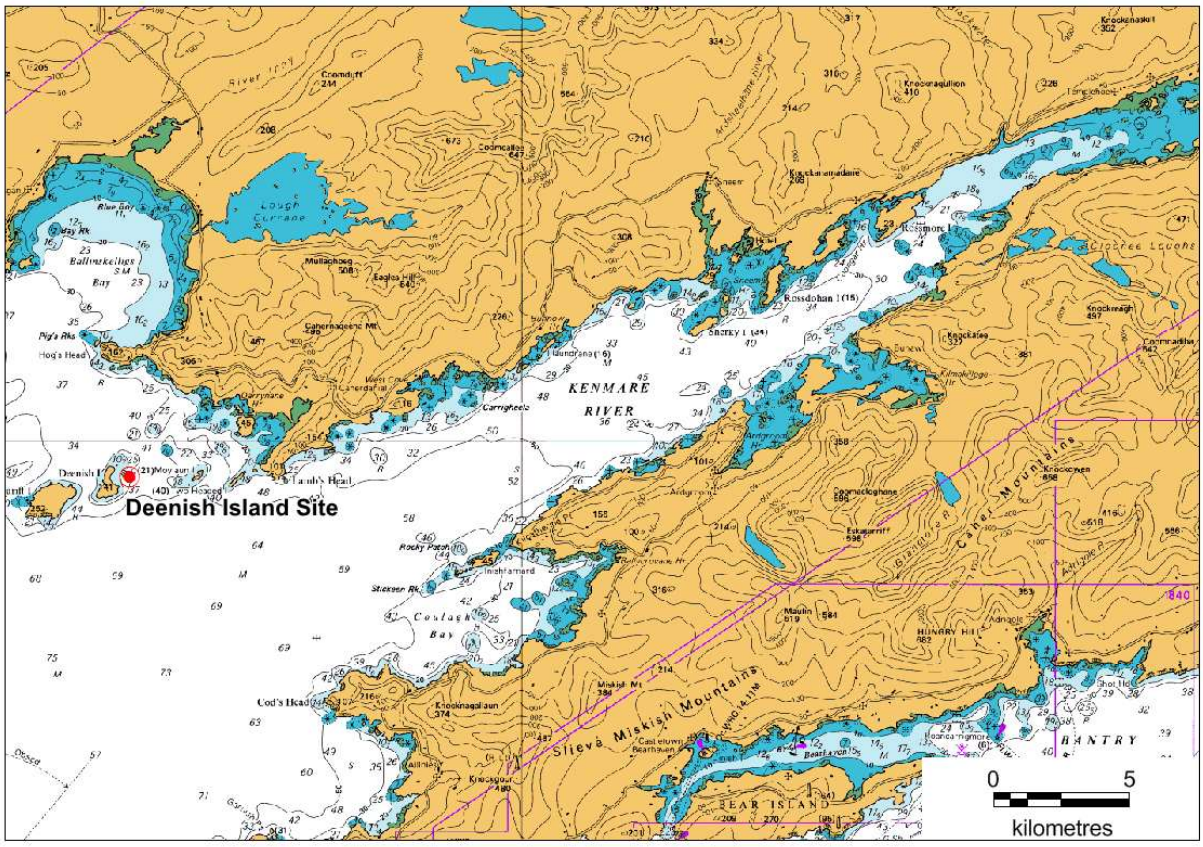

Figure 1.1: Map showing the location of the Deenish site surveyed in Kenmare Bay

1.1. Site description

Kenmare Bay, Co. Kerry, is a long and narrow, south-west facing bay. It is a deep, drowned glacial valley and the bedrock is mainly old red sandstone which forms reefs along the middle of the bay throughout its length. Exposure to prevailing winds and swells at the mouth diminishes towards the head of the bay while numerous islands and inlets provide further areas of additional shelter.

Deenish Island is part of two Natura 2000 sites (see Figure 1.2), namely the Kenmare River cSAC (Site code: 002158) and the Deenish Island and Scariff Island SPA (Site code: 004175).

The diversity of environmental conditions, from exposed to ultra sheltered, that characterises Kenmare River cSAC results in the presence of a wide range of marine habitats including three listed on Annex I of the EU Habitats Directive, namely reefs, large shallow bay and caves. According to the cSAC site synopsis (available from www.npws.ie) Kenmare Bay is host to a high number of rare and notable marine species present (24) and some uncommon communities. The Kenmare River cSAC is the only known site in Ireland for the northern sea-fan, *Swiftia pallida* and is the only known area where this species and the southern sea-fan *Eunicella verrucosa* co-occur. Midway along the south coast of Kenmare River, a series of sea caves stretch back into the cliff, typically supporting a diversity of epifauna including encrusting sponges, ascidians and bryozoans.

Deenish Island and Scariff Island are small to medium size islands situated between 5 and 7 km west of Lamb's Head off the Co. Kerry coast and thus very exposed to the force of the Atlantic Ocean. The site is a Special Protection Area (SPA) under the E.U. Birds Directive due to its special conservation interest for seabirds including fulmar, Manx shearwater, storm petrel, lesser black-backed gull and Arctic tern. Scariff is the larger of the two islands, with very steep sides rising to a peak of 252 m with the highest cliffs located on the south side. Deenish is less rugged than Scariff, and rises to 144 m in its southern half; the northern half being lower and flatter. The vegetation is mostly grassland, with some heath occurring on the higher ground. Old fields are now overgrown with bracken and bramble. The sea areas within a 500m radius of both islands are included inside the SPA boundary to provide a 'rafting' area for shearwaters.

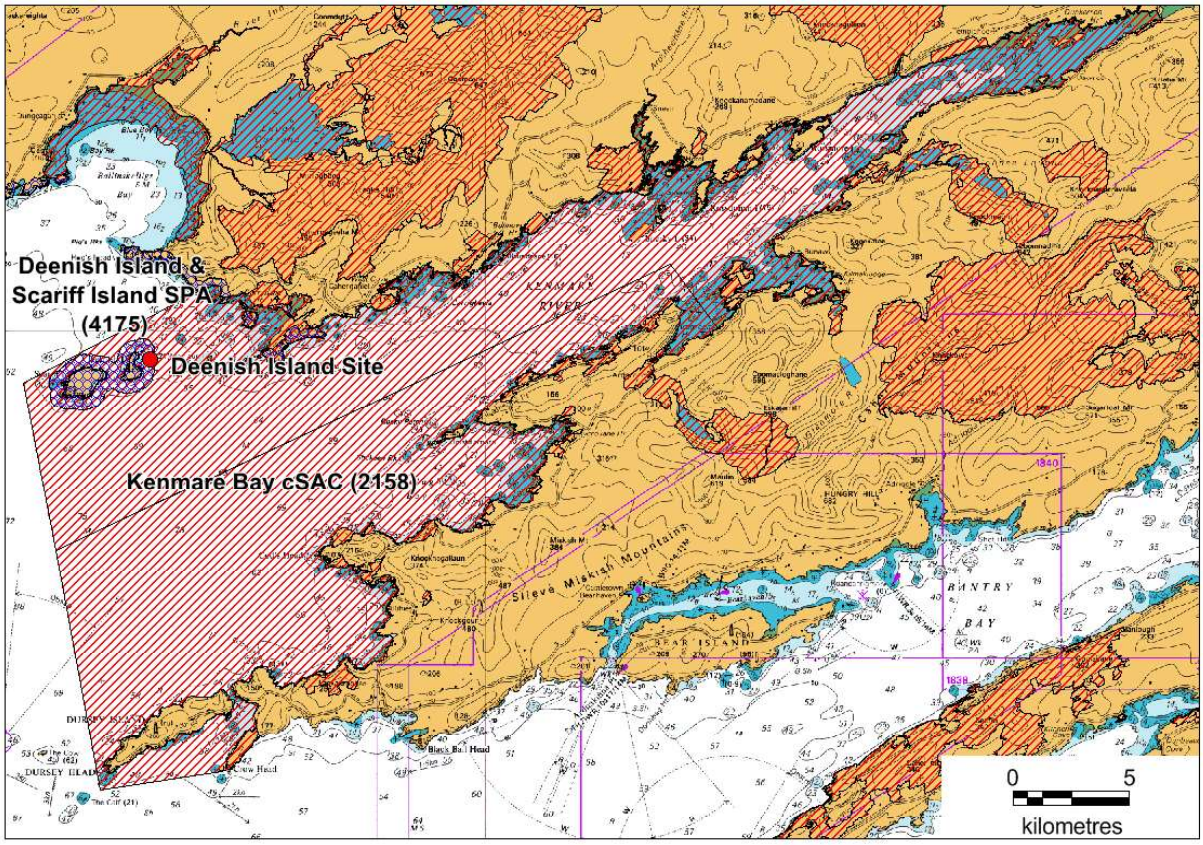

Figure 1.2: Map showing the locations of the relevant cSAC and SPA near Kenmare Bay, Co. Kerry

1.2. Offshore finfish farms – benthic monitoring

The main objective of the survey was to assess the overall state of the environment in relation to the salmon production process. The sites were surveyed according to the revised Benthic Monitoring Guidelines laid down by the Department of Agriculture, Fisheries and Food (December 2008). The benthic monitoring requirements at a fish farm are dependent on the level of biomass held at the site and the local hydrography. Table 1.1 below sets out the level of benthic monitoring required based on tonnage produced and mean current speeds at a fish farm.

Table 1.1: Matrix of production tonnage versus current speed to determine level of benthic monitoring required

	MEAN CURRENT SPEED (CMS^{-1})		
TONNAGE	**<5**	**5-10**	**>10**
0-499	Level I	Level I	Level I
500-999	Level II	Level I	Level I
>1000	Level II	Level II	Level I

The current speed is a mean value calculated from maximum current measurements over spring and neap tidal cycles at the surface and near the bottom. The tonnage refers to the maximum biomass predicted for each site. An annual survey must be carried out at each site (production and smolt) operated by a company. A level I or level II survey may be carried out as follows:

Level I: Video/photographic and visual observations and recordings shall be made at the following stations:

- At a minimum of 2 sites directly beneath the pens
- At the edges of the pens
- Two transects at right angles to each other. Along each transect sampling stations at +/- 10m, +/- 20m, +/- 50m and + 100m from the pens
- At a control site

In addition to the above, the following samples/measurements shall be taken at the same stations as above. These will be used to calculate sediment quality parameters.

- A minimum of one Redox potential reading shall be made at each sampling station.
- A single sediment sample for Organic Carbon measurement.

Level II: In addition to the above, two replicate grab samples shall be captured at each of the sample stations for faunal analysis. The exact locations of sampling points should be agreed in advance with the Department of Agriculture Fisheries and Food (DAFF). The identification and abundance of macro-faunal invertebrates shall be estimated and tabulated. Identification of fauna to the level of species will be

required.

It is important to take note that the exact position of the individual pen structures are not permanently fixed to a single position and there is a relatively large lateral movement due to depth, wind, currents and tides. For this reason, bottom stations particularly those under, at the edge and 10 m away from the pens are taken at the time of sampling but may vary relative to the overlying pen position under various environmental conditions.

2. Sampling Procedure & Processing

All survey work at the Deenish site took place on 13th September 2019. The dives were conducted at a maximum depth of 23.0 m and underwater visibility on the day was very good at approximately 6m. The prevailing current direction at the site is north-south and as a result Transect 1 is orientated in this direction. Pen layouts at the time of survey, current direction, dive entry points and benthic transects followed by the divers are shown in Figure 2.1. Mean current speed at the Deenish finfish aquaculture site is 30 cm sec^{-1} (MOWI *pers.comm*.). The fish biomass present in the pens at the time of survey was 387.2 tonnes. The survey was carried out at Level 1 as per the guidance matrix displayed in Table 1.1.

Disinfection

Prior to each dive survey for each location all diving equipment, suits and boats are thoroughly disinfected utilising both a dipping and spraying protocol.

2.1. Dive survey

Two dive transects were laid out from the sea surface at each site using a boat equipped with a GPS mapper. Pen locations were noted as DGPS positions. The underwater survey involved direct observation, sampling and recording (through photographs and *in situ* annotations) of benthic conditions by highly experienced, qualified marine biologists and scientific divers. The notes taken *in situ* were transcribed to logs upon surfacing. In addition to standard SCUBA gear the divers were equipped with:

- A high-end dSLR Nikon D200 in a Subal ND20 underwater housing fitted with a 12-24mm

lens and two INON strobes. The camera was used to photograph the epibenthos and seafloor features;

- A diver-operated dSPI camera for photographing sediment profiles of the seafloor and calculate redox measurements. This unit uses a Canon EOS 450D camera with Nikkor optics;
- A compass for underwater navigation;
- Pre-labelled bags to store sediment samples for organic carbon analysis;
- Dive slates, torches and waterproof pencils for making observations/notes.

The divers photographed representative areas of the sediment and fauna and recorded observations in situ at the various stations investigated. Notes were completed immediately on surfacing and a map of the dive track was drawn up. Observations recorded during the dive include:

- Presence of bacterial mats and uneaten food;
- Presence of farm-derived litter;
- Presence of gas bubbles or anoxic areas;
- Animals visible or evidence of their presence;
- Macroalgae visible;
- Sediment characteristics, including colour and texture.

The seafloor was photographed at the following stations along two transects at the site (see Figure 2.1):

A. Directly under the pens;
B. Under the edge of the pen;
C. At 10m, 20m, 50m and 100m (on T1) from the pens along the transects.

A reference station was also assessed for each pen block to give a representation of ambient benthic conditions in the area immediately surrounding the pen installations for comparison purposes. The reference station was taken at a distance greater than 150 m from the pen installations to represent the assumed 'undisturbed' condition of the seafloor surrounding the sites.

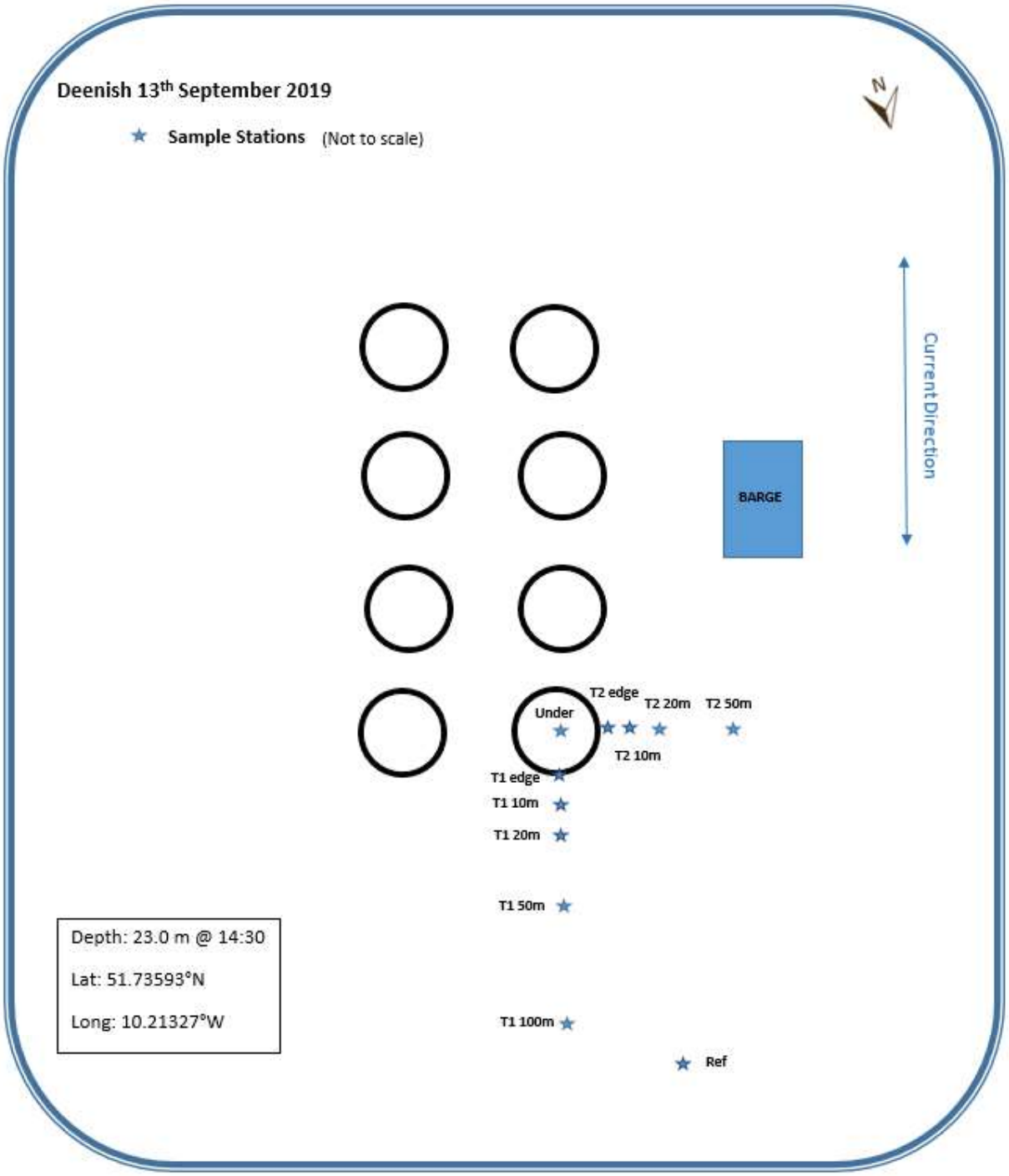

Figure 2.1: Transect seafloor station layout, Deenish finfish aquaculture site, Kenmare Bay, 13th September 2019

2.2. Sediment Profile Imagery (SPI)

Sediment profile images (SPI) obtained for each station along with ARPD depth measurements taken from the images were acquired using a diver-deployed sediment profile imaging camera system. This system is comprised of a digital SLR camera in a water-tight pressure vessel that is mounted above a prism that penetrates the upper 25 cm of sediment (see Figure 2.2). The sediment profile is viewed through a plexiglass window and the image is reflected to the camera lens via a plane mirror. Illumination is provided by an internally-mounted strobe. The prism unit is filled with distilled water – thus ambient water clarity is never a limiting factor in image quality. Upon arrival, the diver depresses the SPI unit into the seafloor and manually triggers the camera. This process is repeated at each station investigated.

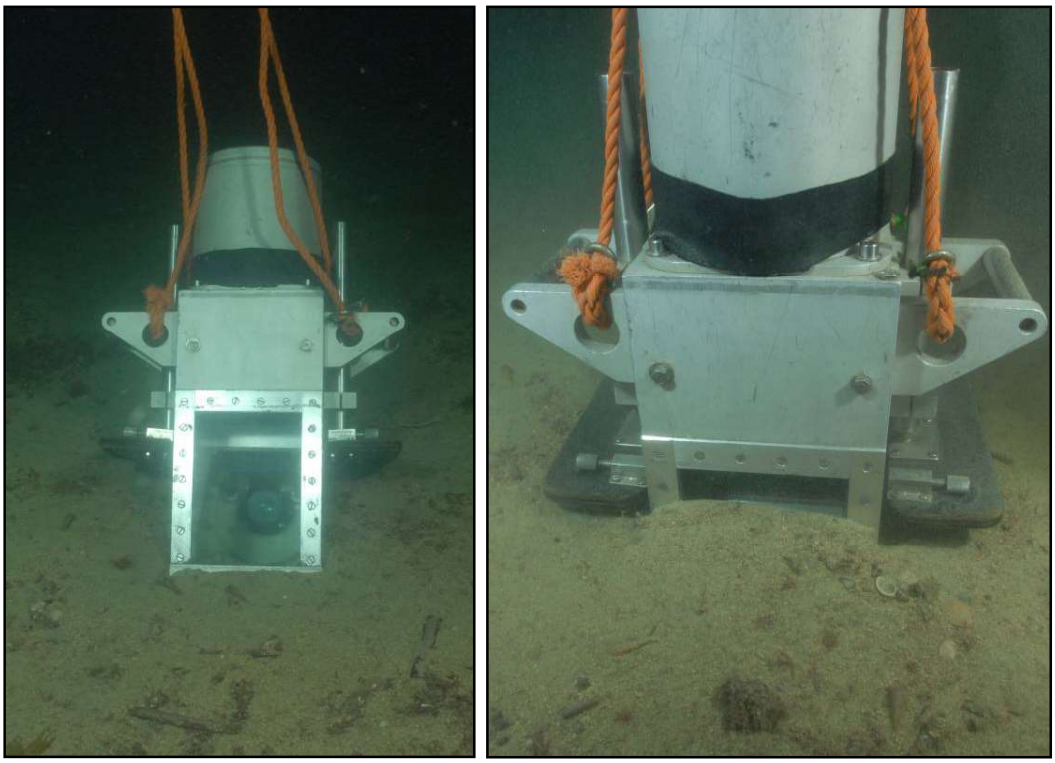

Figure 2.2: Diver operated Sediment Profile Imaging camera. The left-hand image gives a view of the camera at the sediment surface. The right-and image shows the SPI camera when inserted into the sediment

A great deal of information about benthic processes is available from sediment profile images. Measurable parameters, many of which are calculated directly by image analysis, include physical/chemical parameters (i.e. sediment type measured as grain size major mode, prism penetration

depth providing a relative indication of sediment shear strength, sediment surface relief, condition of mud clasts, redox potential discontinuity depth and degree of contrast, sediment gas voids) and biological parameters (i.e. infaunal successional stage of a well documented successional paradigm for soft marine sediments (see Pearson and Rosenberg, 1978), degree of sediment reworking, dominant faunal type, epifauna and infauna, depth of faunal activity, presence of microbial aggregations).

For the purposes of the current survey, the primary feature of interest is the depth of oxygen penetration into the sediments in the vicinity of the finfish pens (this information is required to satisfy the requirements of the Benthic Monitoring Protocol (DAFF, 2008). In this case, the apparent redox potential discontinuity or ARPD depth is measured. Features of particular interest that may be gleaned from SPI images taken in sediments in the vicinity of finfish pens include the presence of:

- uneaten feed pellets (and depth of this material, see Figure 2.3)
- faecal casts
- and depth of shell gravel deposits
- of gas voids in the sediment

Figure 2.3: Typical sediment profile images with examples of features relevant to aquaculture operations

2.3. Sampling for organic carbon analysis

Sediment samples for organic carbon analysis were collected at all stations. Samples were stored in pre-labelled plastic bags, kept in cold freezer boxes onboard the vessel and frozen at -20°C on return to the laboratory. Organic carbon analysis was carried out by ALS laboratories using the Loss on Ignition (LOI) technique. This method involves oven drying the sediment sample in a muffle furnace (450°C for a period of 6 hours) after which time the organic content of the sample is determined by expressing it as a percentage the weight of the sediment after ignition over the initial weight of the sediment.

3. Results

3.1. Recent Stocking History

407,568 fish, with a total biomass of 42.4 tonnes were put to sea in February 2019 following an eight week fallow period. At the time of the audit, 342,362 fish with a total biomass of 387.2 tonnes remained on site giving an onsite biomass production of 344.8 tonnes prior to the survey .

Figure 3.1: View of pens at Deenish Island site

3.2. Seabed physical and biological characteristics

The seabed located immediately beneath the pens at the Deenish site was characterised by fine oxygenated sand that became courser moving towards the outer stations along both transects particularly T1 where large boulders were noted at the extremity.

3.2.1. Photographic record; Transect 1

This transect began beneath the northwestern most pen moored on site (see Figure 2.1) and ran for a distance of 100 m north. A total of six stations were investigated.

3.2.1.1. Under pen

The seafloor beneath the pens was characterised by fine grained sand sediment with an oxygenated appearance. Waste feed material from the above pens was observed on the seabed where several large common starfish *Asterias rubens* were noted scavenging. There were no signs of outgassing or bacterial mats at the station.

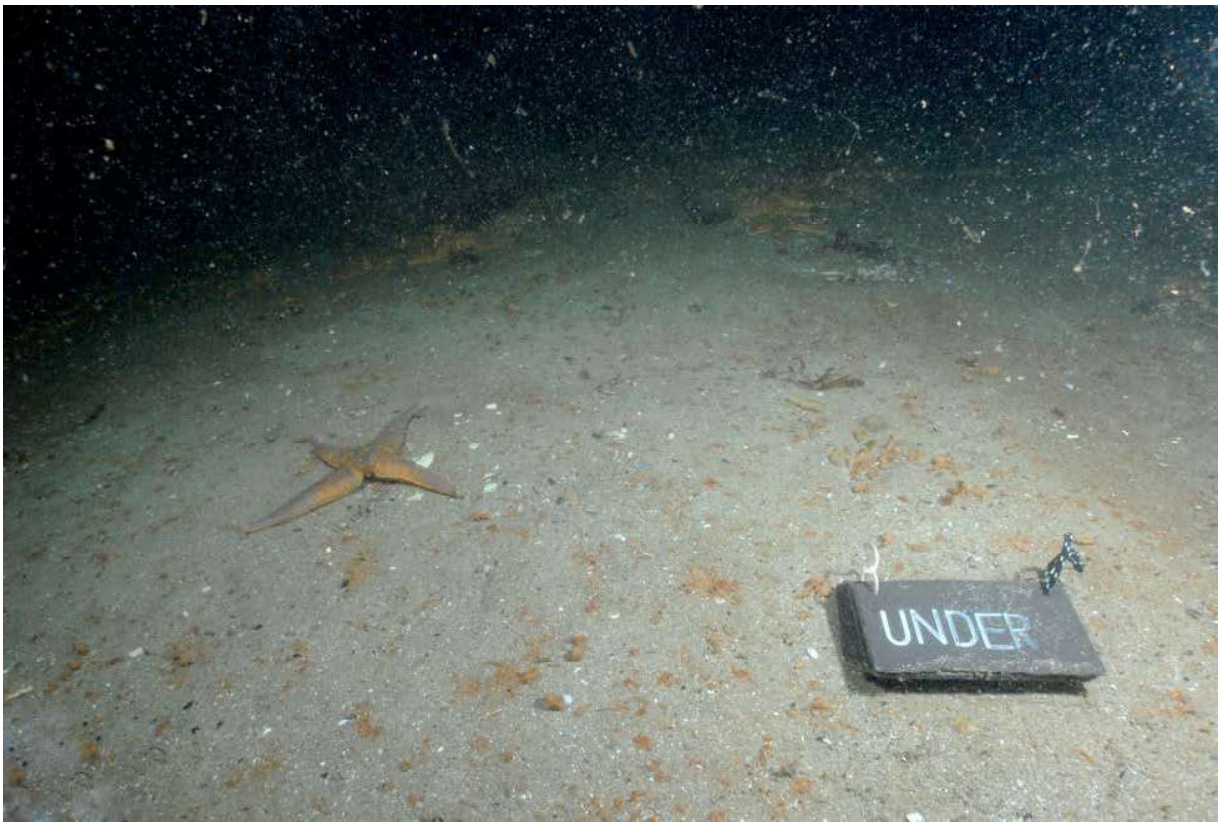

Figure 3.2: T1 – Under pen station, Deenish Island site, 13th September 2019

3.2.1.2. Edge of pen

The seafloor located towards the edge of the pen at the Deenish site was characterised by fine grained sand with mussel shell, waste feed pellets and faecal casts from adjacent pens scattered over the surface. The casts of the lugworm *Arenicola marina* were noted on the seafloor along with several starfish (*A. rubens*) scavenging on the waste organic material. There were no signs of outgassing or bacterial mats.

Figure 3.3: T1 – Pen edge station, Deenish Island, 13th September 2019

3.2.1.3. 10 m from pen

Moving 10m along Transect 1 the fine sand of previous stations (Under and Edge) gave way to courser sand with a higher percentage of shell fragment. Large clumps of shell from the mussel *Mytilus edulis* were observed on the seabed where numerous starfish *A. rubens* were scavenging. The anemone *Sagartia elegans* was noted with its feeding tentacles extended. Some drift algae of various species were also noted (Figure 3.4). There were no signs of outgassing or bacterial mats.

Figure 3.4: T1 – 10m, Deenish Island, 13th September 2019

3.2.1.4. 20 m from pen

Conditions at the 20m station remained similar to that recorded at the 10m station on Transect 1 with a coarse sand/gravel sediment with a high percentage of shell fragments throughout. Large fronds of brown algae were noted on the seafloor where there were few if any macrofauna feeding. No signs of outgassing or bacterial mats were recorded at the 50m station.

Figure 3.5: T1 – 20 m station, Deenish Island, 13th September 2019

3.2.1.5. 50 m from pen

Seafloor conditions at the 50m station were characterised by a coarse sand/gravel that appeared to be better mixed than previous stations. Large fronds of brown algae still attached were noted along with drift red algae (Figure 3.6). There was no macrofauna observed within the immediate vicinity of the station. No signs of outgassing or bacterial mats were observed at the 50m station.

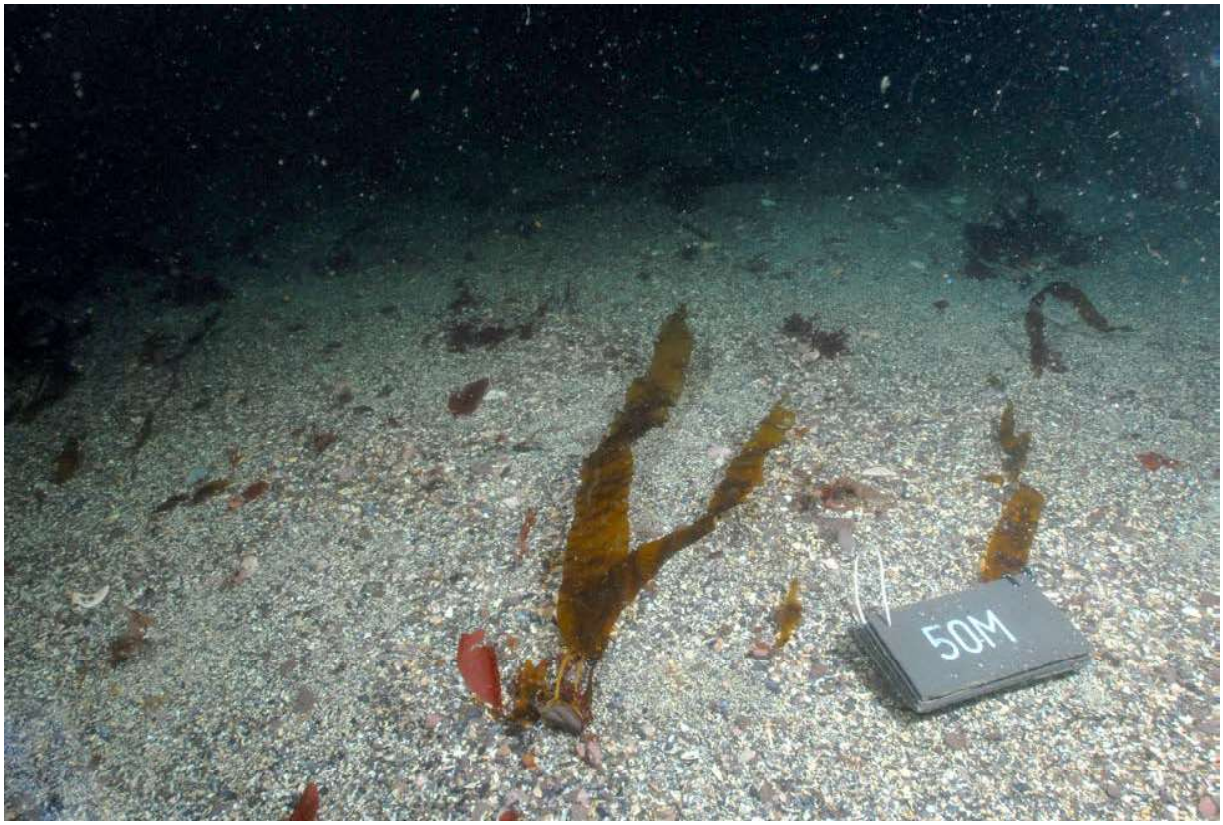

Figure 3.6: T1 – 50 m station, Deenish Island, 13th September 2019

3.2.1.6. 100 m from Pen

The seafloor at the 100m station was characterised by coarse sand with an oxygenated appearance and a high percentage of shell fragments mixed throughout. The fronds of brown algae were visible along with some drift red algae (Figure 3.7). There were no signs of outgassing or bacterial mats observed at the 100m station with the benthic conditions appearing healthy.

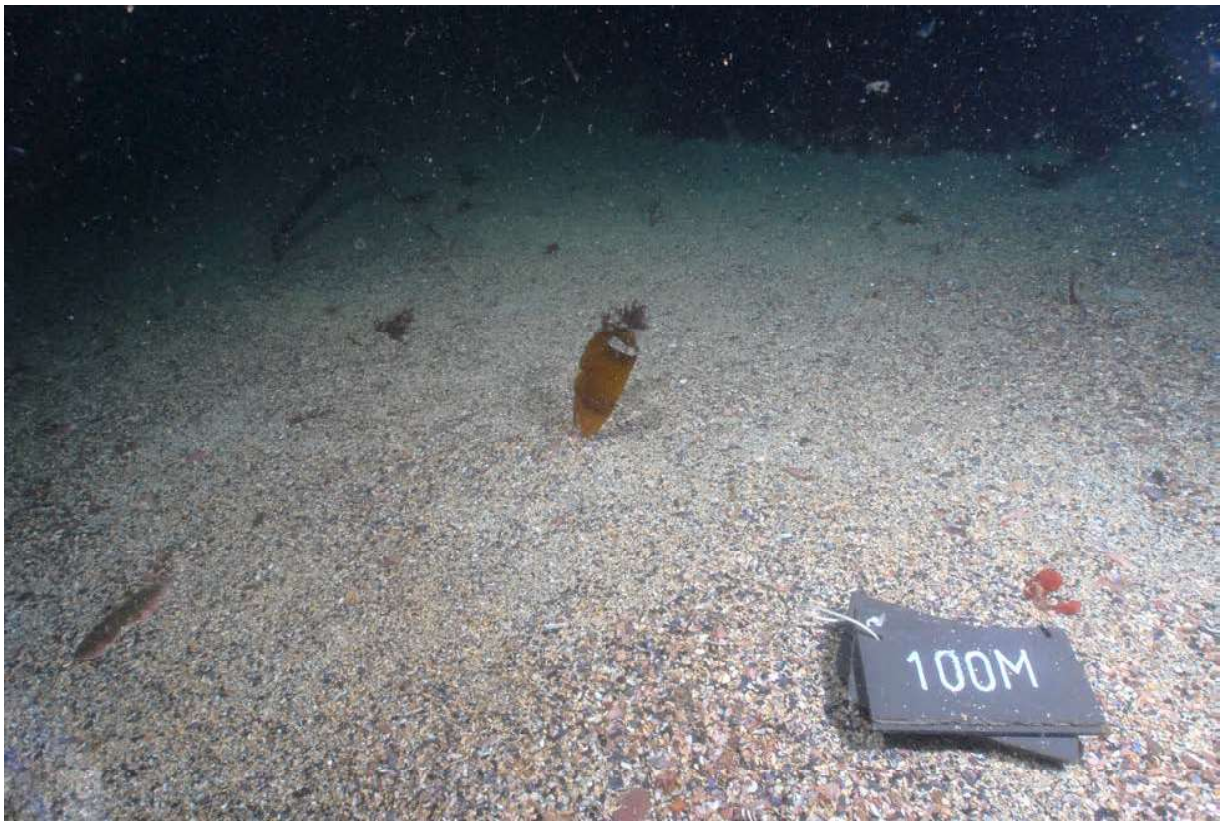

Figure 3.7: T1 – 100 m station, Deenish Island, 13th September 2019

3.2.2. Sediment Profile Imagery – Transect 1

Figure 3.8 presents sediment profile images taken at the six stations visited on Transect 1 of the Deenish site. The substrate of the site was composed of fine and medium-grained sand with shell gravel at the under pen station which gradually gave way to a coarser shelly gravelly sand with intact shell at the outer end of the transect. The energy levels experienced by the seafloor in this area is more than likely quite high particularly during winter storms.

The images display a single image and the maximum and minimum apparent redox potential discontinuity (ARPD) depths measured at each station. Each image is 15.5cm × 25cm. ARPD depths ranged from a minimum of 0.5 cm (T1 10m) to a maximum of greater than 7.1 cm (T1 Edge). Due to the relatively coarse nature of the seafloor, the SPI camera achieved relatively low penetrations.

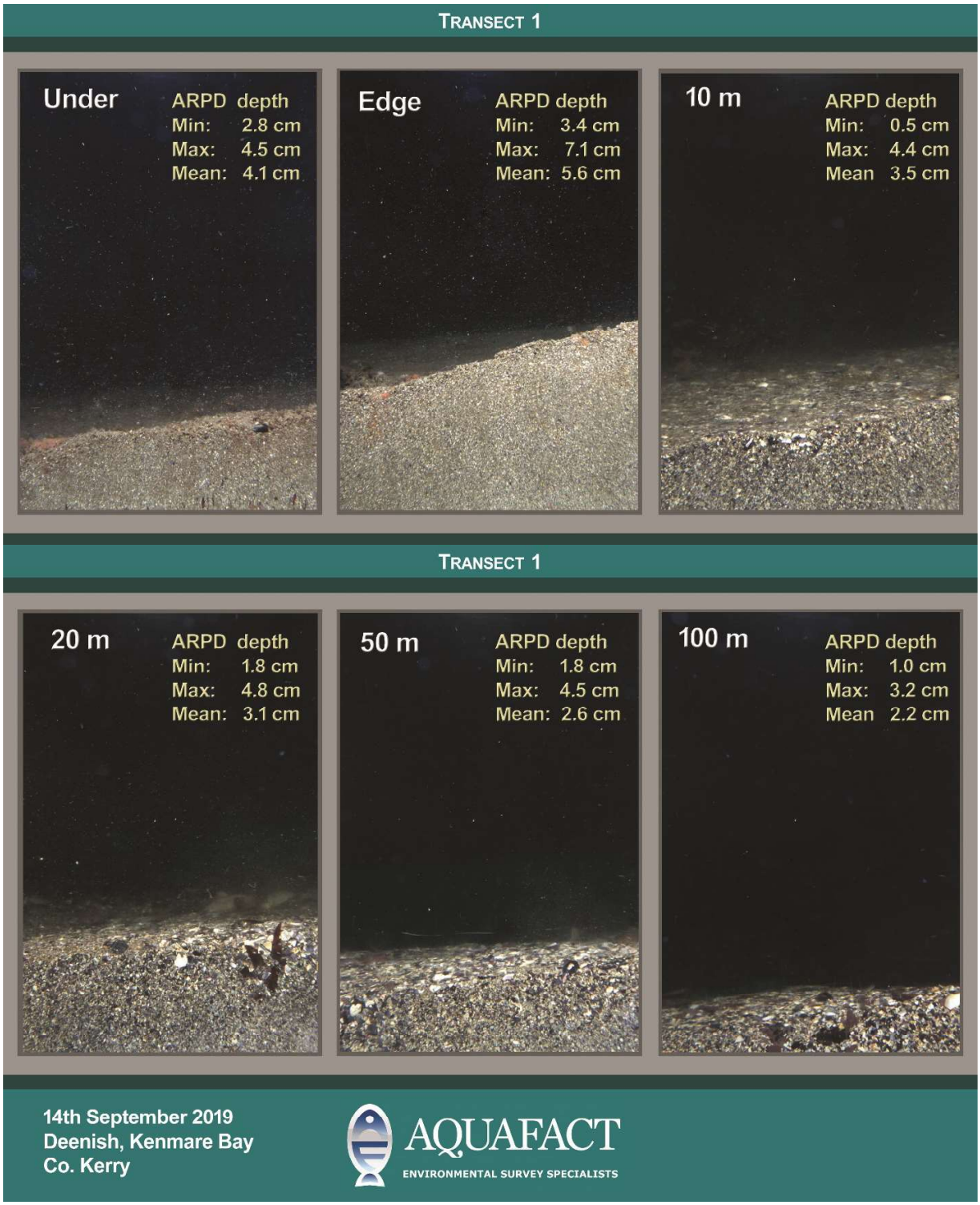

Figure 3.8: Representative photographs of the seafloor taken along Transect 1 by Sediment Profile Imagery (SPI) apparatus. MOWI finfish aquaculture site, Deenish, Kenmare River, Co. Kerry, 13th September 2019.

3.2.3. Photographic Record; Transect 2

This transect began beneath the same pen as Transect 1 and ran for a distance of 50m west. A total of five stations were investigated on Transect 2 with an additional (Reference) station investigated just *c.* 150 m north of the pen edge (See Figure 2.1).

3.2.3.1. Under pen

The seafloor beneath the salmon pens on Transect 2 consisted of sediment that was made up of fine grained sand that had an oxygenated appearance. The remnants of waste feed material were common on the seafloor originating from the above pens. There were no signs of outgassing or bacterial mats at the T2 Under station.

Figure 3.9: T2 – Under pen station, Deenish Island, 13th September 2019

3.2.3.2. Edge of pen

The seafloor located beneath the edge of the pens was characterised by a medium/ fine grained sand with a percentage of shell material throughout. Some whole/ fragments of shell were scattered across the sediment surface the majority originating from the blue mussel *M. edulis* (Figure 3.10). The amount of waste feed observed on the sediment surface had decreased considerably moving away from the Under station. There were no signs of outgassing or bacterial mats observed at the Edge station of Transect 2.

Figure 3.10: T2 – Pen edge station, Deenish Island, 13th September 2019

3.2.3.3. 10 m from pen

The seafloor 10m along Transect 2 consisted of fine sand formed into small ripples due to the prevailing tidal current. Small amounts of waste feed material was observed and brown drift algae were present across the seabed. There were no signs of bacterial mats or outgassing at the T2 10m station.

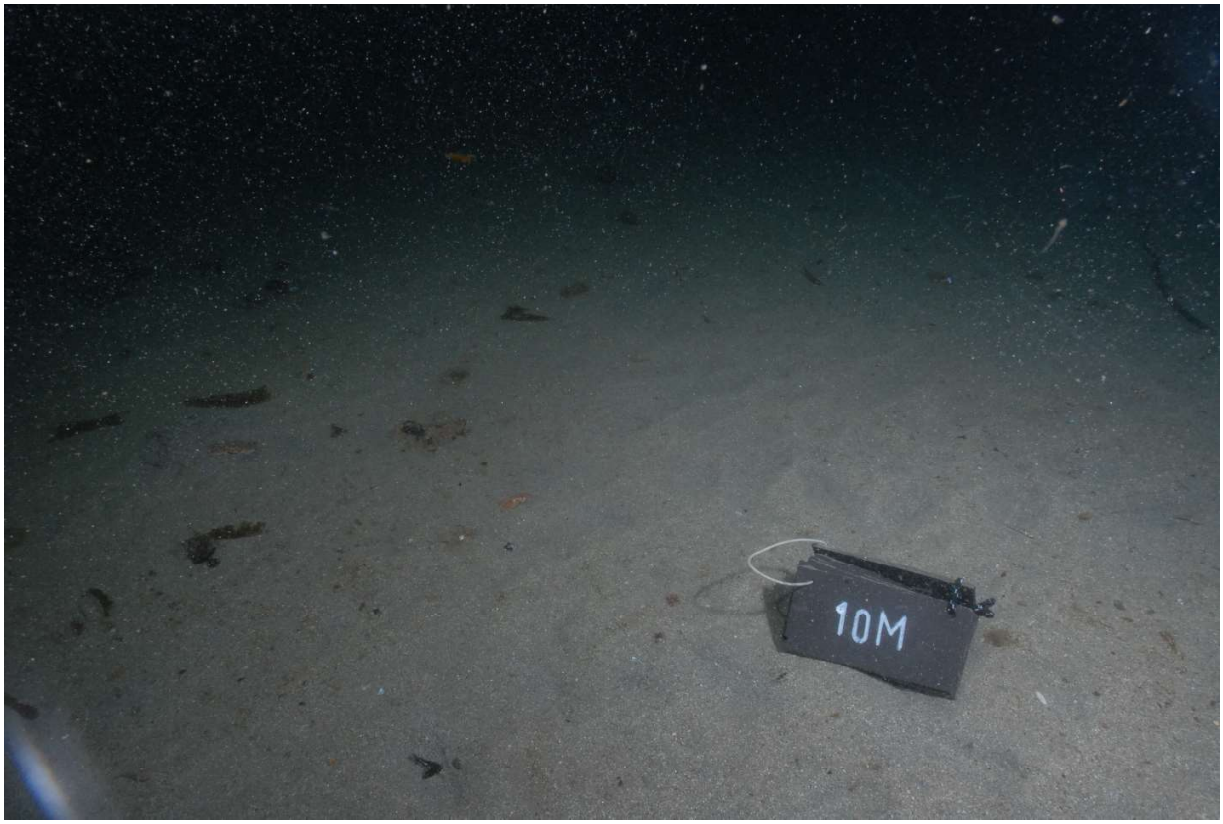

Figure 3.11: T2 – 10 m station, Deenish Island, 13th September 2019

3.2.3.4. 20 m from pen

Seafloor conditions at the 20m station on Transect 2 were characterised by fine grained sand with a light oxygenated appearance. The sand had been manipulated into ripple patterns by the prevailing tidal current (Figure 3.12). Brown drift algae were present across the seabed and there were no signs of macrofauna feeding in the immediate vicinity of the station. No observations of bacterial mats or outgassing were made at this station.

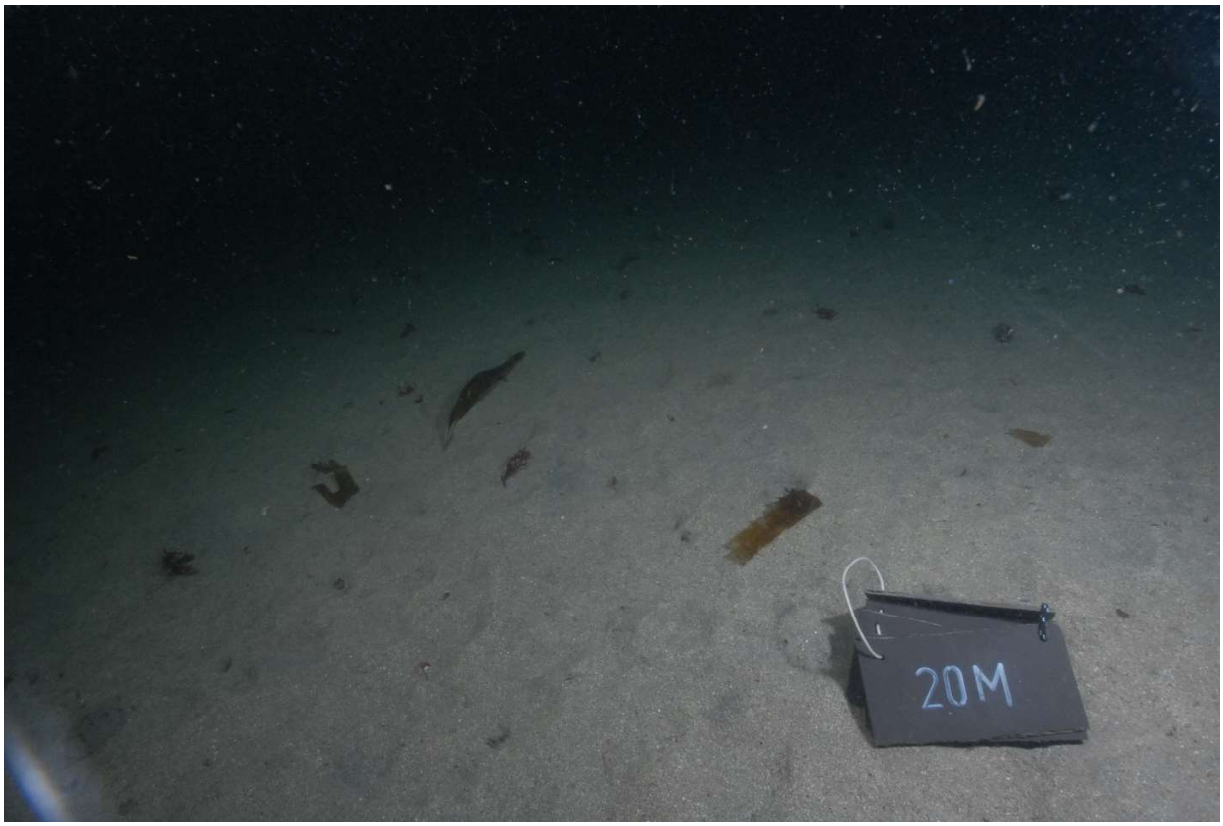

Figure 3.12: T2 – 20 m station, Deenish Island, 13th September 2019

3.2.3.5. 50 m from pen

Seafloor conditions at the 50m station on Transect 2 were characterised by fine grained sand with a light oxygenated appearance. The sand had been manipulated into ripple patterns by the prevailing tidal current (Figure 3.12). Brown drift algae were observed across the seabed and several hermit crabs *Pagurus bernhardus* were observed foraging across the seabed (Figure 3.13). There were no signs of bacterial mats or outgassing made at this station and in general the appearance of the seafloor was healthy.

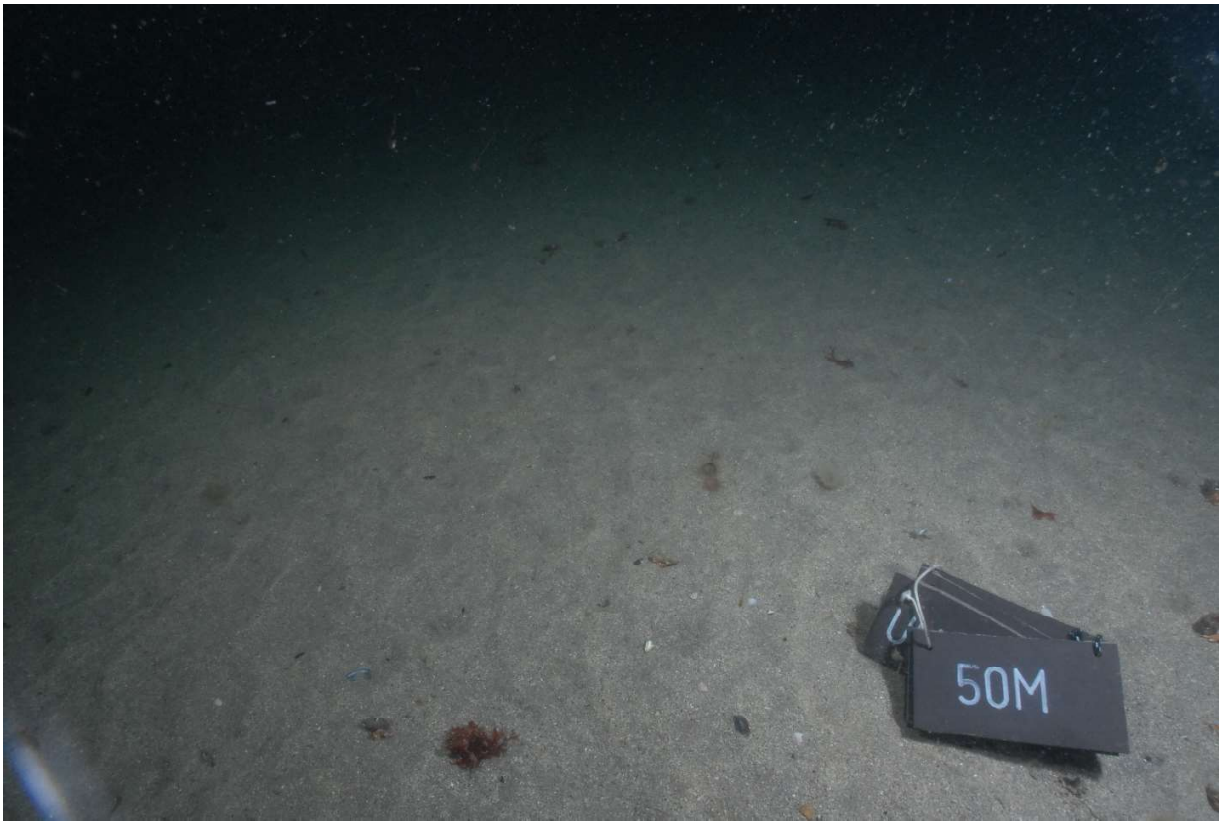

Figure 3.13: T2 – 50 m station, Deenish Island, 13th September 2019

3.2.3.6. Reference station

A reference station was conducted at approximately 150m distance from the pens and was chosen as an example of ambient conditions for the Deenish site. The reference station allows for comparison against stations located along both Transect 1 and 2 in order to quantify the effect of the aquaculture activities on the surrounding environment. The reference station was characterised by coarse sand/ gravel with a high percentage of fragmented shell material. A large frond of brown algae was noted towards the centre of the image (Figure 3.14).

Figure 3.14: Reference station, Deenish Island, 13th September 2019

3.2.4. Sediment Profile Imagery – Transect 2 & Reference

Figure 3.15 presents sediment profile images taken at the five stations visited on Transect 2 of the Deenish site and the reference station on 13th September 2019. The figure displays a single image and the maximum and minimum apparent redox potential discontinuity (ARPD) depths measured at each station. Each image is 15.5 cm × 25 cm.

Sediment type varied from medium sands under and close to the pen compared with higher proportions of shell material with increasing distance from the pen. It was difficult to estimate ARPD depths from the station due to the nature of the substrate which didn't allow sufficient prism penetration of the SPI. Despite this ARPD depths for the stations were relatively deep estimated to range from a minimum of 0.1 cm (T2 20m) to a maximum of 6.6 cm (T2 Edge). ARPD depths at the Reference station ranged from 2.3 cm to 3.7 cm and a mean ARPD of 3.0 cm.

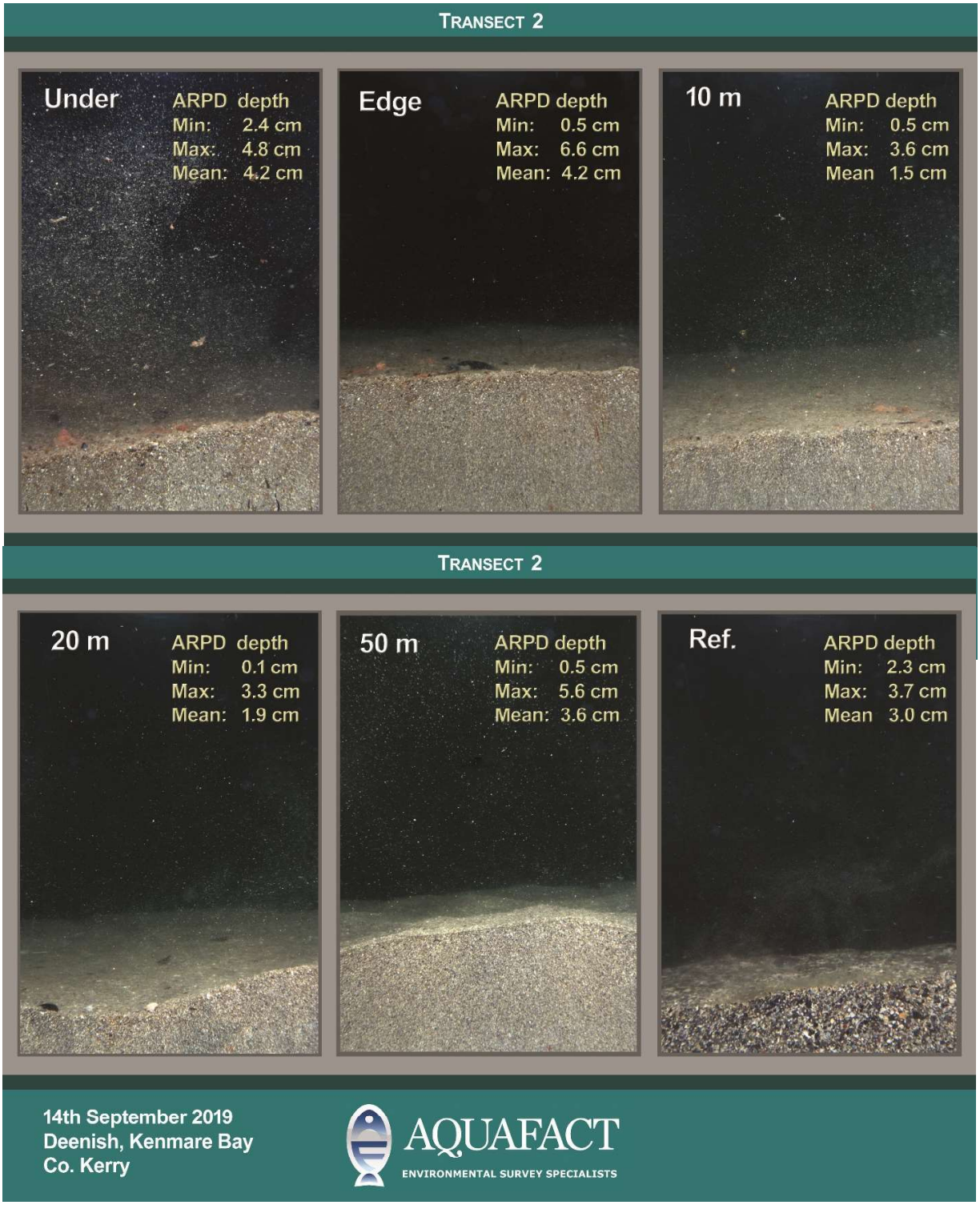

Figure 3.15: Representative photographs of the seafloor taken along Transect 2 by Sediment Profile Imagery (SPI) apparatus. MOWI finfish aquaculture site, Deenish, Kenmare River, Co. Kerry, 13th September 2019.

3.2.5. Transect Species List

Table 3.1 shows a list of species observed during the dives at the Deenish fish farm site on this and previous occasions.

Table 3.1: Species noted during dives on the seabed beneath the Deenish pens

Group	Species	Common Name
(Cnidaria) Hexacorallia	*Cerianthus lloydii*	Tube anemone
	Sagartia elegans	Sea anemone
(Annelida) Polychaeta	*Spirobranchus* sp.	Tube worm
	Lanice conchilega	The sand mason
	Chaetopterus variopedatus	Parchment tube worm
	Arenicola marina	Lugworm
(Mollusca) Bivalvia	*Pecten maximus*	King scallop
	Faceliniidae	Sea slugs
	Aeolidiida	Sea slugs
	Nudibranch	Sea slugs
(Arthropoda) Decapoda	Paguridae	Hermit crab
Echinodermata	*Luidia ciliaris*	Seven armed starfish
	Asterias rubens	Common starfish
	Marthasterias sp	Starfish
	Ophiura sp.	Brittlestar
	Amphiuridae sp.	Brittlestar
(Chordata) Osteiichthyes	*Pomatoschistus* sp.	Gobies
	Trisopterus minutus	Poor Cod
	Labrus bergylta	Ballan Wrasse
Rhodophyta	*Delesseria sanguinea*	Sea beech
	Phycodrys rubens	Sea oak
	Cryptopleura ramose	
	Calliblepharis ciliata	
	Lythophyllum sp.	
Ochrophyta	*Alaria esculenta*	Edible kelp

3.2.6. Organic Carbon Analysis & ARPD Depths

Table 3.2 shows the organic carbon results from the Deenish stations. Organic carbon levels ranged from 1.79% (T2 20m) to 3.56% (T1 10m). Levels at all stations were generally higher closer to the pens. Levels were relatively similar to the reference station (2.69%) at all stations.

Table 3.2: Organic carbon results for Deenish (% values, Loss on Ignition at 450°C).

T1	**Under**	**Edge**	**10m**	**20m**	**50m**	**100m**
LOI %	3.16	3	2.52	2.61	2.87	2.31
T2	**Under**	**Edge**	**10m**	**20m**	**50m**	**REF**
LOI %	-	3.41	3.56	1.79	2.06	2.69

Table 3.3 shows in tabular form the ARPD depths from the SPI images from Deenish (see Sections 3.2.2 and 3.2.4). Values are similar to the Reference Station at all Stations.

Table 3.3: ARPD Depths for Deenish, Kenmare Bay, 13th September 2019

Station		**Transect 1**	**Transect 2**
Under	Range (cm)	2.8-4.5	2.4-4.8
	Mean (cm)	4.1	4.2
Edge	Range (cm)	3.4-7.1	0.5-6.6
	Mean (cm)	5.6	4.2
10m	Range (cm)	0.5-4.4	0.5-3.6
	Mean (cm)	3.5	1.5
20m	Range (cm)	1.8-4.8	0.1-3.3
	Mean (cm)	3.1	1.9
50m	Range (cm)	1.8-4.5	0.5-5.6
	Mean (cm)	2.6	3.6
100m	Range (cm)	1.0-3.2	-
	Mean (cm)	2.2	-
Reference	Range (cm)	-	2.3-3.7
	Mean (cm)	-	3.0

4. Discussion

The extent to which an overlying fish farm impacts the seafloor is largely dependent on:

- the feeding regime at that farm, i.e. the amount of food that eventually ends up on the seafloor;
- the degree of current movement at the site in question; and
- the depth of water at that site.

These factors combine to form either erosional or depositional locations where organic material is either dispersed or it accumulates, and subsequently affects the receiving environment (*i.e.* the seafloor). The type of biotic community living at a particular site will also play a role in determining bottom conditions there. The influence of feeding activities of populations of starfish, polychaete worms, anemones, crabs and finfish at the Deenish site largely determine the level of impact of overlying farm operations on the benthos there.

Faunal feeding activity can remove large amounts of waste organic material from the seabed beneath a farm facility – with groups of mobile fauna capable of consuming large quantities of material. The fallowing schedule at a site also has a large bearing on benthic impact – most notably the length of time pens have been on site since the last fallow period. The presence of opportunistic deposit feeders such as *Capitella* sp., most notably at the under pen and pen edge stations will tend to help keep the benthic organics in a state of equilibrium at the fish farm sites. Sedimentary organic carbon levels were slightly elevated at the Under and Edge stations however relatively similar to levels observed at the reference station.

Mobile epibenthic scavengers such as starfish, fish and crabs also help in reducing the amount of waste material on the seafloor. This potential speed of the removal of waste was demonstrated in a previous study where photographic evidence was collected showing that epibenthic macrofauna were capable of removing, in less than 7 days, fish feed pellets spread at a density of 3.4 kg dry weight per m^2 on the sediment under a marine fish farm (Smith *et al.*, 1997).

In consideration of the observations obtained during the survey at the Deenish site, it would seem that very little if any habitat degradation has taken place. Impacts are limited to the immediate footprint of the cage and can be summarized as a small amount of waste organic material and slightly elevated OC levels. Results obtained from reports conducted in 2016, 2017 and 2018 revealed similar results to the present survey and it is proposed that the salmon aquaculture site has had little influence on the surrounding benthic environment.

5. Conclusion

On the 14th of September 2019, a benthic audit survey was carried out on the Deenish fish farm site operated by MOWI Ireland. The Deenish survey followed the DCMNR Level I monitoring protocols. The results obtained during the survey suggest that the salmon aquaculture operations in the area are having little to no effect on the surrounding benthic ecology outside the immediate footprint of the pens. Recorded OC levels and ARPD depths were similar to those recorded at the Reference station and can therefore be considered of good environmental status.

6. References

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