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Benthic Monitoring Report 2010 Deenish Fish farm

For Marine Harvest Ireland
by Environmental Services at the Institute of Aquaculture

A Report to:

Marine Harvest Ireland

BENTHIC MONITORING REPORT 2010: DEENISH FISH FARM

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Introduction

This report presents the results of a level 1 environmental monitoring survey at a fish grow-out sea-cage site at Deenish Island, a small island off the south-western coast of Ireland. Called Deenish (Licence T6/202 AQ198) the site sits approximately 400m off a small island, to the west (Figure 1). The site sits approximately 5km from the mainland, just north of the entrance to Kenmare Bay.

The site is licensed and operated by Marine Harvest Ireland (MHI) for the production of Atlantic salmon (*Salmo salar* L.). The site is licensed for production up to 500T (MHI, 2010).

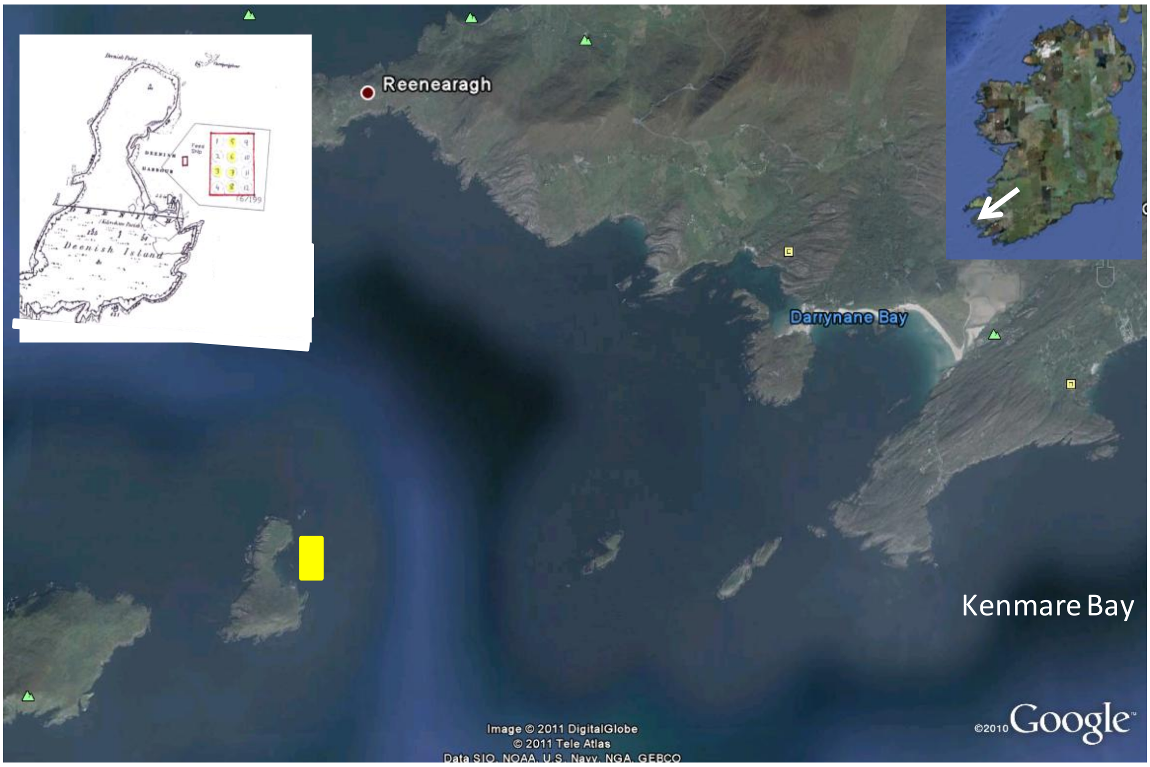

Figure 1: ***Diagram showing approximate location of Deenish fish farm (yellow square) operated by Marine Harvest Ireland for the production of Atlantic salmon.***

The monitoring protocols for the survey are those defined by the Department of Agriculture, Fisheries and Food (An Roinn Talmhaíochta, Iascaigh agus Bia) Monitoring Protocol No.1 for Offshore Finfish Farms – Benthic Monitoring, revision unknown, dated December 2008. Within this document are defined 2 levels of survey, evaluated through a combination of mean current speed and tonnage (Table 1).

Table 1: Matrix of production tonnage vs. Current speed to determine level of benthic monitoring required (from Monitoring Protocol 1).

	Mean current speed (cm sec^{-1})		
Tonnage	<5	>5 - <10	>10
0 – 499	Level 1	Level 1	Level 1
500 - 999	Level 2	Level 1	Level 1
>1000	Level 2	Level 2	Level 1

The Deenish site is newly acquired by MHI and so the mean current speed at the site is not known, but with a capacity of less than 500T the site requires a Level 1 monitoring survey. According to the DAFF Monitoring Protocol (2008) this entails completion of the following:

1) Transects on the seabed be taken in two directions and from the cages, along the main current flow direction (Transect A (=TA)) and perpendicular to it (Transect B (=TB)), and that a suitable control station be selected.

2) That along these transects and at the control station either a video or photographic record of the sediment condition be collected.

3) That at specific sampling stations (under the cages, at the cage edge [=0m], at 10m, 20m, 50m [and 100m in the main current flow direction] from the cages and at the control) measures of redox are taken and a sediment sample taken for analysis of organic carbon concentration.

Background

Video or photographic evidence provide a rough estimate of sediment condition, provides a visual record of the conditions at the time of sampling, including evidence for accumulation of fish feed and faeces, and enables basic assessment of observable or evidence of species presence.

The redox potential of sediments is defined as a measure of the ability of organisms to carry out reduction-oxidation reactions, whereby high redox levels predominate oxidative reactions (with oxygen), and low (negative) readings predominate reductive reactions (without oxygen). As such it is to some extent indicative of the level of oxygen available within the system, where oxygen is important for sediment turnover and processing. Under "normal" conditions the level of oxygen in sediment will naturally reduce with depth, depending influence by a range of conditions. This is enhanced, that is the depth of the oxygenated layer is reduced towards the surface, by the presence of additional factors adding nutrients to the system, such as fish farming. Measures of redox potential is a typical method to assess sediment condition, as a surrogate for actual measurement of oxygen flows that are both complex and expensive to carry out.

Redox in marine systems will be influenced by 1) the rate of oxygen diffusion between the water column and sediment; 2) oxygen concentration in the overlying water; 3) the rate of oxygen consumption by chemical and biological processes in the sediment and 4) bioturbation (sediment turnover) that create burrows and routes for water replenishment. Points 1 and 2 are a function of sediment grain size and hydrodynamic conditions that affect the rate of exchange of water between the sediment and water column. Point 3 is a function of chemical reactions, faunal respiration and microbial activity that utilise oxygen as an electron acceptor in the energetic processes that drive these activities. The latter point (4) is entirely dependant on the species types and to some extent the diversity present in the sediment.

Changes in organic input leading to variations in chemical properties combined with the physical nature of the sediment can in turn affect the biology characteristics through direct or indirect impacts on benthic fauna. In marine sediments, polychaetes form the dominant fauna and can be used as indicators of change. Increases in opportunistic species such as *Capitella* sp. and *Malacoceros fuliginosus* tend to dominate communities in organically enriched, oxygen depleted sediments (Pearson and Rosenberg, 1978). In areas where highly anoxic conditions exist, benthic infauna can be absent or severely reduced, and sediments can be characterised by the presence of sulphur reducing bacterium, *Beggiotoa*.

A pollution gradient usually occurs with increased distance from a point source of organic waste input along which sediment enrichment decreases. In the sediment around sea cages there may be distinct zones of impact that might be regarded as Gross, Heavy, Moderate and non-impacted (Henderson and Ross, 1995) although these zones can be indistinct in their separation. Such distinctions may or may not be visible through videographic or still photographic assessment, although such methods are routinely employed to evaluate impacts. Obvious impacts, such as the deposition of feed waste, for example, can be determined using observation techniques. They are, however, limited in the ability to quantitatively evaluate the outcomes of such deposition, other than in the broadest terms. The obvious manifestation of this is presence/absence of large invertebrate species, whereas species living within sediments or those that are small cannot necessarily be observed. The important factor with video/photographic methods is the ability to readily check and identify broad-scale impacts and if necessary conduct more quantitative assessment after this.

Broadly speaking the biology, chemistry and the physical nature of sediments, as they are impacted by fish farms, combine to provide an overall description of the benthic habitat. These are readily assessed through monitoring.

METHODS

Survey work was carried out on 23rd July 2010 by staff members of the Institute of Aquaculture, Stirling University, in cooperation with Marine Harvest Ireland staff, particularly the diving unit.

It is known that Deenish is a relatively new site for MHI. The biomass held on site at the time of the survey was unknown.

Location of samples collected at sea cage and control sites

Weighted seabed lines were positioned by divers from the cage edge and out to 100m in the principle (main current) direction and out to 50m in the cross-current direction.

Each of the site locations was identified on the seabed with the use of markers, identifiable in the photographs at (TA0m, TA10m, TA20m TA50m, TA100m in the main current direction; and TB0m, TB10m, TB20m and TB50m in the cross-current direction).

GPS positions of the transects and the control site are known.

Sediment organic carbon

Samples were collected on the seabed for analysis of organic carbon content using a Van Veen grab (0.025m^2) from which a sub-sample was taken. CN samples were stored in an airtight container and deep frozen for later analysis. Organic carbon (and nitrogen) content was measured using a Perkin Elmer 2400 Series ii CHNS/O analyser with an integrated 4AD-minibalance to allow for accurate pre-weighing and immediate downloading of starting dry weights. The CHNS/O analyser is a combustion method, which measures the extent of the gases produced during a complete combustion, to indicate carbon concentration. Samples had previously been dried in an oven at 90°C and stored in air-tight containers until analysis.

Sediment redox analysis

Sediment profile images were taken at each of the stations along each transect and at the control station. A single 70mm diameter Perspex core was pushed into the sediment and bunged when sufficiently penetrated. These samples were taken at each of the site locations (TA0m, TA10m, TA20m TA50m, TA100m, TB0m, TB10m, TB20m, TB50m and control) and were photographed as a visual record.

On retrieval a visual assessment of the sediment condition was made including colour, smell and texture. Redox potential of water above the sediment was measured when possible and within the sediment itself was measured in each of the individual core samples, at 1cm intervals, to a sediment depth of -6cm (where possible). The equipment used was a Russell CEPTR II/300 redox probe attached to a standard Jenway millivolt meter. At the Deenish site the sediment in the main consisted of hard packed very coarse sand, which resulted in less than 6cm depth being achieved. In the majority of cases only 1cm depth was achieved.

The probe was standardised against a standard Zobell's solution, at ambient temperature on the day of measurement. Measured values are then corrected (added to) for the reference potential measured in the field just before the samples are assessed. However, redox measures are temperature dependant and readings reduce with reduced temperature. Thus the true correction factor uses the standard readings identified above interpolated to readings at 10°C (deemed to be an average seabed water temperature, mid-summer), from a standard table. This resulted in field measured zobell's readings being multiplied by 94.86% (i.e. an adjustment for the temperature). After the field readings are added to the standard solution values and the correction factor is applied, readings of -100Mv or less are believed to be indicative of severely reduced (= severely impacted) conditions.

Benthic video/photography

Identification of impact was evaluated primarily through a photographic assessment using an underwater camera, collected by the MHI dive team.

Upon return the laboratory each photograph was assessed and a broad evaluation of observable information reported. Within this report, all information is summarised in broad terms, with specific comment on selected photographs only, where possible.

RESULTS

Location of samples collected at sea cage and control sites

Weather conditions during the survey were variable, with light to moderate winds. All necessary samples and information were collected satisfactorily, except where specified.

Sediment organic carbon

Total carbon levels in the sediments ranged between 3.9 and 15.8% across the stations, with the largest concentration of carbon at TB20m. Within the carbon fraction, a very low proportion was organic in origin, the highest proportions at TA0m and at TB20m (34.7% and 36.2% respectively – Table 2). The majority of carbon was in inorganic form (mainly calcium carbonate) derived from the large amount of shell debris in all samples (see core sample figures below), except those under the farm itself. No sample was collected at TA50m, the underlying surface being bedrock.

Table 2: ***Total carbon and total nitrogen (%) and Organic carbon (%) where known in sediments collected at Deenish site in 2010.***

SITE	Total C %	Organic C %	Organic C as % of total C	Total N %
Control	7.1		-	0.1
Under	6.2	1.8	29.2	0.1
TA 0m	14.6	5.1	34.7	0.1
TA 10m	7.8	0.6	7.9	0.1
TA 20m	8.0		-	0.1
TA 50m	No sample - bedrock			
TA 100m	12.3	3.0	24.4	0.1
TB 0m	4.8		-	<0.1
TB 10m	8.2		-	0.1
TB 20m	15.8	5.7	36.2	0.1
TB 50m	3.9		-	0.1

Sediment redox and condition

Corrected redox measures taken at stations at the Deenish site are presented in Table 3. Samples could only be collected in the water column above the sediment, at the sediment surface and to -1cm depth. The underlying nature of the grain sizes limited the depth reached.

Redox measures remained constant throughout the depth measured in each of the core samples, with little variation in the sediment to that measured in the water column above. The larger interstitial spaces resulting from coarse grain size (see below) mean that oxygenated water can readily flow through the sediment to replace oxygen lost through bacterial and other activity. Positive redox values indicate that settlement of particulates from the fish cages was not causing significant oxidative/reduction reactions in the sediment and none of the samples assessed was in a reduced state.

Table 3: Corrected redox (mV) measurement in sediment at stations along transects (A & B) at Deenish fish farm. Data shown are field measures corrected for zobell's solution measurements in the field and for temperature (times 94.86% - see methods text).

Sediment depth	Control	Under	TA 0m	TA 10m	TA 20m	TA 50m	TA 100m	TB 0m	TB 10m	TB 20m	TB 50m
+1	453	450	447	456	444		450	452	447	452	454
0	434	440	436	439	423		444	451	447	442	452
-1	440	435	434	428	428		439	441	445	440	449
-2			428								
-3											
-4											
-5											
-6											
Zobells	238	235	230	235	230	-	237	235	235	236	235

There was, however, a range of sediment conditions in core samples collected, which are identified below.

Under Cages

The core sample from underneath the cages (Figure 2) was a mix of medium sand. On the sample surface fine particulate material is in evidence, though no distinct feed and faecal material can be seen. The fine layer of material on the sediment surface (Figure 2) is also replicated in the other core samples taken from the site, but not at the control station and is therefore thought likely to result from fish farming activity, through the settlement of waste faecal material. There does not, however, appear to be a build up of such sediment. There was no discolouration of the sediment (say through bacterial activity, and conversion of iron to ferrous oxide) through any depth.

Figure 2: Core sample from Deenish fish farm site, taken from under the cages.

Transect A (left to right, 0m, 10m, 20m, 50m and 100m) – Figure 3

There was a general increase in grain size, with increased distance away from the farm. Sediment at TA0m contained significantly larger grains than in the sample taken from under the cages. At TA100m the grain sizes are very coarse, consisting of a high proportion of shell material, and small gravel.

In each of the samples, there was a clear thin layer of finer material, thought to derive from waste faecal material as mentioned above, but there is no significant build up of waste material in at any of the locations along transect A.

Figure 3: ***Core samples from Deenish fish farm site taken along Transect A at 0m, 10m, 20m and 100m from cage edge. TA50m maintained underlying bedrock and could not be collected.***

Transect B (left to right, 0m, 10m, 20m and 50m) – Figure 4 above

The majority of the core samples collected along transect B (Figure 4) are coarse to very coarse sand, consisting of shell fragments and fine gravel. Unlike transect A samples there is no apparent change in grain size with increased distance form the cage site. The look and character of the sediment was very much as described above, with the same thin layer of fine sediment, perhaps 2-3mm thick, over the sediment surface out to TB20m, though this is less visible in the sample at TB50m.

Figure 4: ***Core samples from Deenish fish farm site taken along Transect B at 0m, 10m, 20m, and 50m from cage edge.***

Deenish Control site

Sediment at the control station (Figure 5) was a mix of coarse to very coarse sand, consisting of a high proportion of shell and small gravel. The lack of fine grains suggests that current speeds at the control are reasonably high, which reduces the likelihood of fine materials being able to settle out on to the bottom.

Figure 5: ***Core sample from control station approximately 1km from Deenish fish farm site.***

Benthic photographic survey

The specific direction of travel away from the cages was determined through discussion with the fish farm staff, who had some knowledge of the current flows, based on their daily observations.

Under Cages

Figure 6 shows the condition of the sediments beneath the cages at Deenish fish farm. As has already been observed the sediment was a mix of medium sand. There was some flocculant material drifting over the sediment surface that could be waste faecal material. However, there was no distinct build of waste under the cages.

Figure 6: ***Sediment under Deenish fish farm cages. Picture taken using underwater camera.***

Transect A – TA0m

Visibility was satisfactory. Figure 7 shows that the sediment was a mixture of coarse and very coarse sand, mixed with shell fragments. Whole shell halves can also be seen. There were no species discernable in the photograph. There was no evidence of waste feed and faecal material on the sediment surface.

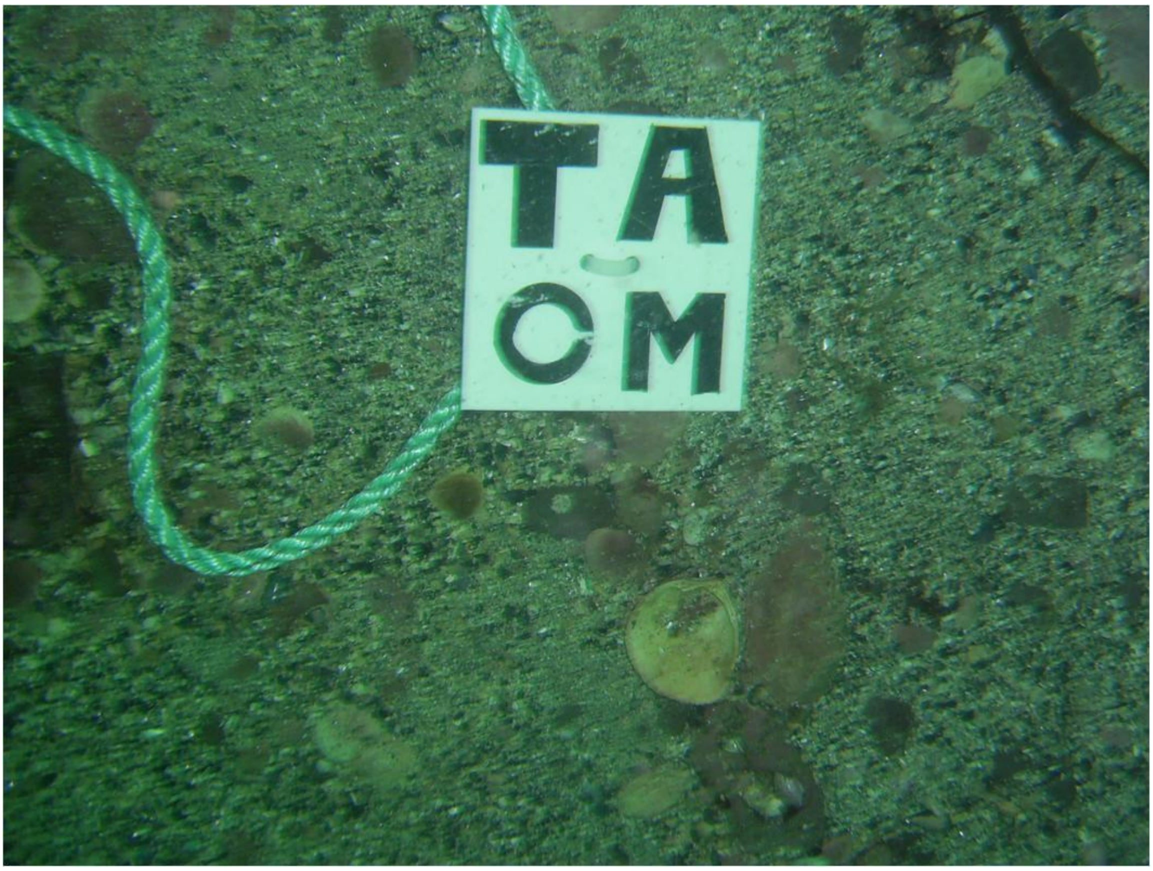

Figure 7: Sediment at fish cages along Transect A at 0m from cage edge (Station TA0m) at Deenish fish farm site. Picture taken using underwater camera.

Transect A - TA10m

Visibility was good. The surface sediment at TA10m (Figure 8) was coarse grained sand, mixed with occasional larger gravel and pebbles. Condition of the sediment seemed normal and no influence from the fish cages could be seen. Generally hard compacted there was little evidence of surface dwelling species.

Figure 8: ***Sediment at fish cages along Transect A at 10m from cage edge (Station TA10m) at Deenish fish farm site. Picture taken using underwater camera.***

Transect A - TA20m

Visibility was reasonable. Surface sediments were medium to coarse sand with gravel and pebbles and shell fragments. Red alga can be seen floating over the surface. There were no obvious visible benthic macrofauna at the station. There was no evidence of impacts from the fish farm.

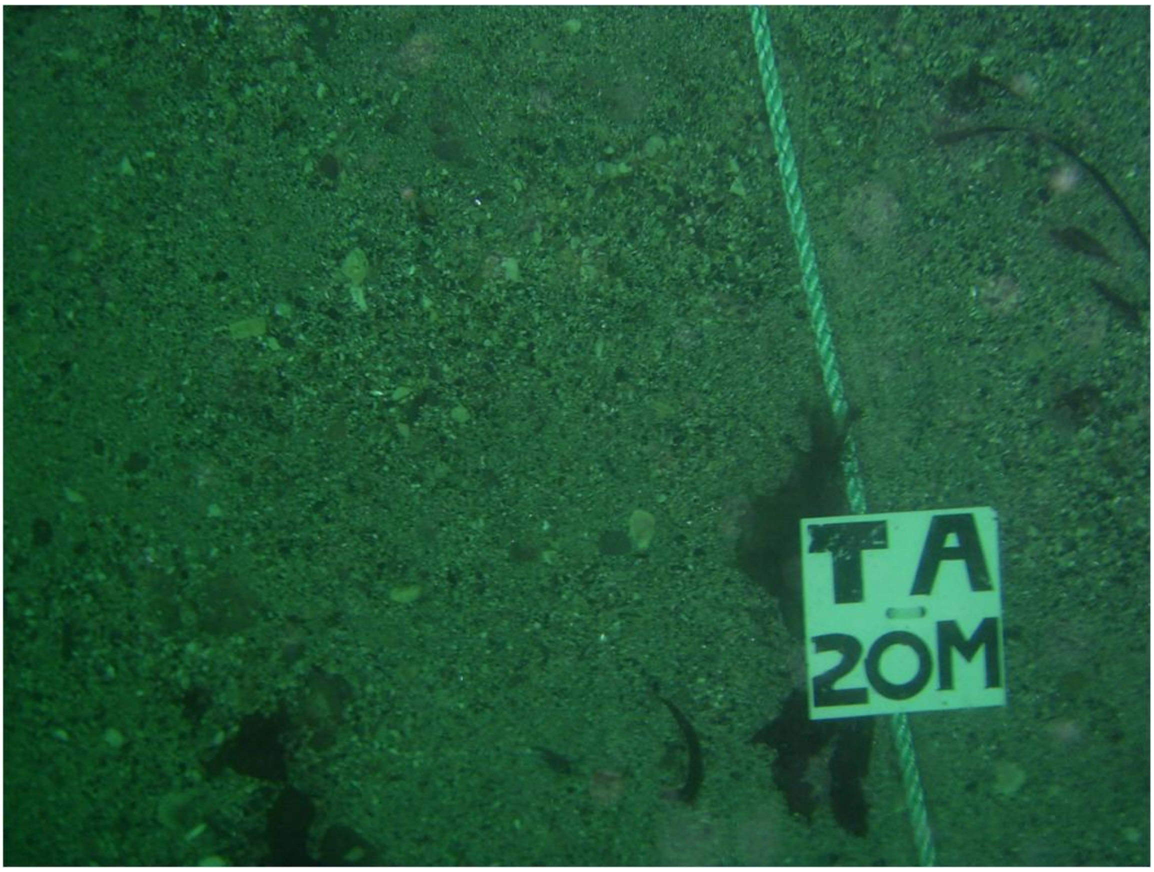

Figure 9: ***Sediment at fish cages along Transect A at 20m from cage edge (Station TA20m) at Deenish fish farm site. Picture taken using underwater camera.***

Transect A - TA50m

Visibility was satisfactory to poor. The underlying surface at TA50m (Figure 10) was bedrock, which was covered in a layer of finer sediment. Settled over the whole area were what was thought to be Devonshire cup coral (*Caryophyllia* sp.)

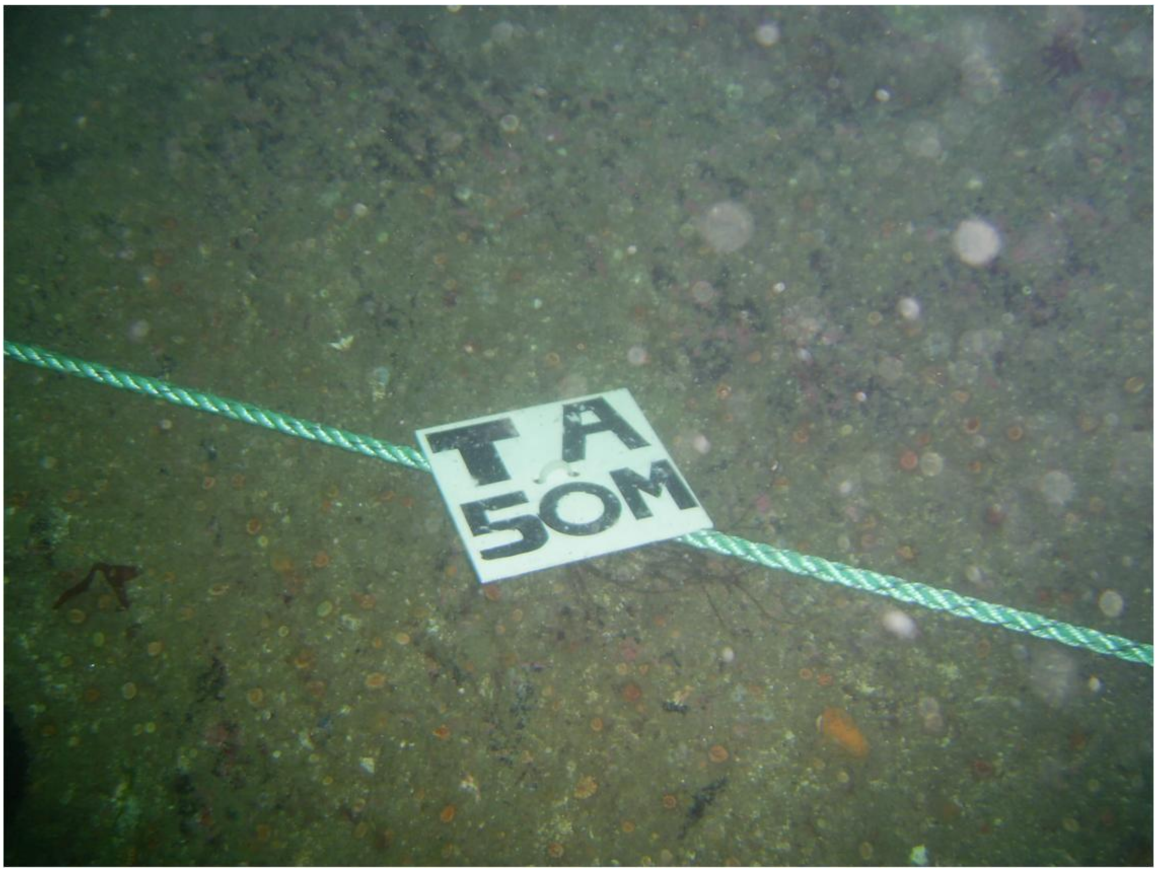

Figure 10: Sediment at fish cages along Transect A at 50m from cage edge (Station TA50m) at Deenish fish farm site. Picture taken using underwater camera.

Transect A - TA100m

Visibility was good. Surface sediments at TA100m (Figure 11) were very coarse sand and gravel. No discernable species living in the surface.

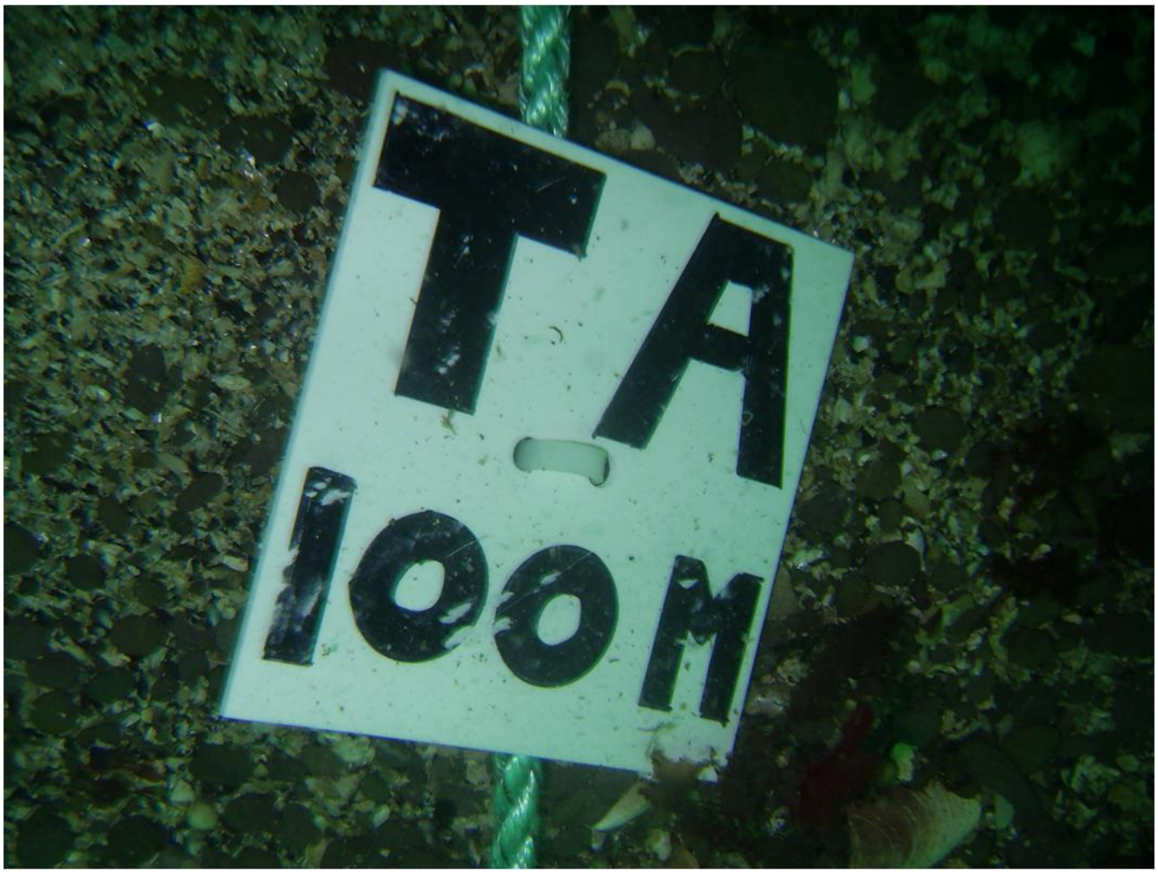

Figure 11: **_Sediment at fish cages along Transect A at 100m from cage edge (Station TA100m) at Deenish fish farm site. Picture taken using underwater camera._**

Transect B - TB0m

Visibility was satisfactory. The sediments at the cage edge (TB0m) at Deenish (Figure 12) were of coarse and very coarse sand. Floating over the surface were detached frond of *Laminaria* sp. No other species were discernable. No feed and faecal pellets were visible on the sediment surface.

Figure 12: ***Sediment at fish cages along Transect B at 0m from cage edge (Station TB0m) at Deenish fish farm site. Picture taken using underwater camera.***

Transect B - TB10m

Visibility was good. The sediments 10m from the cage edge (TB10m) (Figure 13) were very coarse sand, with gravel, pebbles and shell fragments of difference sizes. No feed and faecal material evident. No species were discernable.

Figure 13: ***Sediment at fish cages along Transect B at 10m from cage edge (Station TB10m) at Deenish fish farm site. Picture taken using underwater camera.***

Transect B - TB20m

Visibility was good. The sediments 20m from the cage edge (TB20m) at Deenish (Figure 14) were a mix of very coarse sand, gravel and shell fragments. No feed pellets were visible and no faecal materials were in evidence. No species were obviously discernable.

Figure 14: ***Sediment at fish cages along Transect B at 20m from cage edge (Station TB20m) at Deenish fish farm site. Picture taken using underwater camera.***

Transect B - TB50m

Visibility was good. Floating over the surface at TB50m (Figure 15) were detached frond of *Laminaria* sp. in different states of decay. Sediment was coarse with a high proportion of shell fragments. No discernable species present.

Figure 15: Sediment at fish cages along Transect B at 50m from cage edge (Station TB50m) at Deenish fish farm site. Picture taken using underwater camera.

Deenish control

Sediment at the control site (Figure 16) was a mix of very course sand, with a high proportion of shell fragments. A single tube dwelling anemone (possibly *Cerianthus* sp.) was observed (arrowed). No other discernable species.

Figure 16: ***Sediment at Deenish control site. Picture taken using hand held underwater camera.***

General conclusions

This report presents the results of the 2010 survey to assess sediment quality at the Deenish fish farm. A level 1 survey was carried out according to the requirements of the Department of Agriculture, Fisheries and Food (An Roinn Talmhaíochta, Iascaigh agus Bia) Monitoring Protocol No.1 for Offshore Finfish Farms – Benthic Monitoring, revision unknown, dated December 2008.

Monitoring encompassed:

- A visual assessment of the sediment during sample collection,
- Measures of redox readings with accompanying pictures as a visual record of the cores taken,
- Samples taken for analysis of organic carbon content
- A visual assessment using a Seabotix LBV200-4 miniROV (CD available) with snapshot pictures in the report.

All sediment samples collected and photographed were a mixture of medium sand (under the cages) to coarse and very coarse sand at most other locations. The seabed at Deenish is variable and some locations (e.g. TA50m) have underlying bedrock. The nature of the sediment suggests that current flows at the site are high that means that fine particulates are unable to settle. Such a current speed is also likely to disperse waste feed and faecal material over a large area. Under the cages there were no obvious signs of any significant settlement of such wastes. On the surface of most cores taken near to the cages was a thin layer of finer sediment; that probably derives from the fish farm or locally. There was no such layer at the control site, for example.

Redox measures could not be taken through the full depth to 6cm, due to the large particle sizes. Although limited in depth, there was no reduction in redox measurements in the top 2cm.

Total carbon content was high at most locations, due to the high proportion of shell material in the sediment (calcium carbonate), which also resulted in a low proportion of organic carbon. Where the grain size was smaller, such as under the fish cages the level of total carbon was lower, but the proportion from organic sources was slightly higher.

The pictorial assessment highlighted few species visible on the sediment surface, almost certainly as a result of a degree of mobility in the sediment due to the underlying current flows. On hard surfaces (rock) relatively near to the cage (TA50m) there was a high degree of abundance, although diversity of the rock surface was not assessed.

From the evidence collected there does not appear there was a significant impact from the fish farm activity on the seabed. If the finer grain size under the cages was due to the altered current flows brought about by the cages (and there was no evidence this was the case) then there may be some settlement of waste here. This would be normal and the faster water flows (not measured) would likely clear this away over time.