Biology & Video Surveys of North Hoyle Wind Turbines

11th – 13th August 2004

by
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Synopsis

- This document reports on an investigation by divers into the marine colonisation of structures at the North Hoyle offshore wind farm, north Wales. The study took place between August 11th and 13th 2004 after the wind turbines had been in place for approximately 1 year and a meteorological mast for 3 months. In all cases the turbines were turning at the time of the visits, although not necessarily generating. At the time windspeeds were generally low and power generation was intermittent.
- Detailed descriptive information was obtained from two turbines and a recently installed meteorological mast using standard Phase 2 methodology. A further 4 turbines were surveyed briefly for comparison and to determine the zonation of communities. Digital underwater video was taken of all structures studied. A table of species identified together with abundances is presented.
- Although there was some variation between the turbines, a characteristic vertical zonation of communities was found to occur up and down these artificial structures. The dominant species included the barnacle *Balanus crenatus*, the amphipod *Jassa falcata* and the mussel *Mytilus edulis*. The common starfish *Asterias rubens* and the sea anemones *Metridium senile, Sagartia elegans* and *Sagartia troglodytes* were also conspicuous.
- A series of 0.01 m2 quadrats were scrapped clear of attached organisms in each zone (where practicable) on two turbines and the met mast. The samples were then weighed in order to obtain a rough estimate of biomass (wet weight). Based on the data obtained, it was calculated that the turbines would each have born around 1000 - 1300kg of attached marine life. The met mast having been in place for only six months bore just under 300 kg.
- Small invertebrate worms and crustaceans were picked out from the cleared quadrat samples and preserved for later laboratory determination. A list of the species obtained from the samples is enclosed with this report.
- The methodology together with the major findings of the survey is discussed. In summary, the species colonising the wind farm structure were all common species found on nearby hard substrata.
- Commercially fished species encountered during the survey included the whiting *Merlangius merlangu*s and the edible crab *Cancer pagurus* as well as mussels. Very large shoals of juvenile whiting were observed around each of the underwater structures studied. At the base of turbine support no 30 a single specimen of the cod *Gadus morhua* was found swimming amongst the whiting, and the plaice *Pleuronectes platessa* was recorded at low abundance from the adjacent seabed, this record probably representing a single specimen. The significance of the wind farm to these species is unknown and warrants further investigation.
- Although the divers were aware of noise from the operation of the turbines, there was no obvious indication that any of the fish were affected.

Reference: Bunker, F.StP.D, 2004. Biology & Video Surveys of North Hoyle Wind Turbines. 11th – 13th August 2004. A report to CMACS Ltd. by *MarineSeen*, Estuary Cottage, Bentlass, Hundleton, Pembrokeshire. SA71 5RN.

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1 Introduction

This document reports an investigation into the marine colonisation of the North Hoyle wind turbines and a recently constructed meterological mast ('Met Mast') approximately 8 km offshore from Prestatyn on the north Wales coast. Thirty wind turbine supports consisting of tubular steel piles approximately 4 m in diameter were installed between April and July 2003, arranged on an 800m by 350m grid spacing. The Met Mast, supported on a similar structure and situated just off the northwest corner of the wind farm complex, was more recently installed in February 2004.

A map showing the location of the wind farm is given in Figure 1.

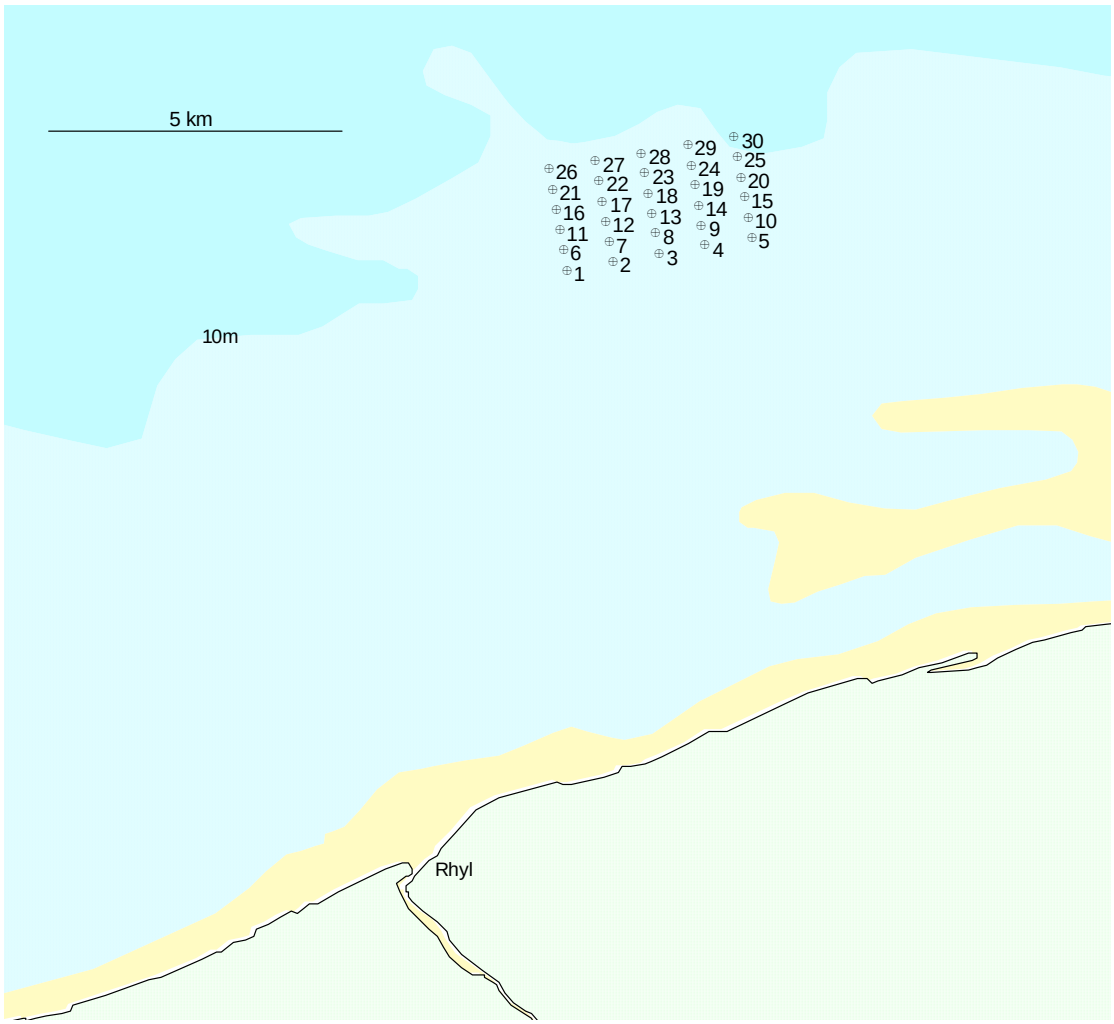

Figure 1 Map showing location of wind farm and numbered turbines

1.1 Aims & Objectives

This survey was carried out as part of the required surveys for the FEPA license associated with the North Hoyle wind farm. The specific requirements of the FEPA license were

"Colonisation of monopiles and scour protection must be determined by diver-operated video observations and analysis with some accompanying sample collection for verification and identification"

When the surveys were planned there was no scour protection in place, and the possible need for it was still being evaluated. At the time of the surveys it had been determined that scour protection was required at some of the turbine supports, and deposits of scour protection had been deposited during the previous few days around turbine support 21 Although the surveys included the immediately adjacent seabed as well as the turbine supports themselves, this is clearly too early to be considered as a survey of colonisation of the scour protection.

The scope of the work was outlined as follows by CMACS Ltd.:

"To carry out studies on two of the turbines plus the met mast, consisting of phase 2 descriptions of habitats and communities at each zone of biological change located on the marine part of two of the turbines. Change of biological zone generally means change of community or habitat but would also include obvious changes in abundance of the same community. In addition:

- To obtain estimates of wet weight (biomass) of major species / groups of species in selected zones.
- To take specimens of species where necessary for further identification.
- To take video of the underwater communities at each site.
- Where time allows, to look briefly at other turbines in order to gauge how representative the two studied turbine piles appear to be."

1.2 Background Information

Colonisation of the wind turbines by marine growth will come from algal spores and larvae carried in the plankton. Nearby hard substrata will help seed the adjacent water masses and in order to predict the type of communities that could develop on the wind turbines, it is useful to have some knowledge of the typical hard substrata communities in the area.

Information on the typical marine communities for the north Wales coast is summarised in Covey (1999) and Brazier *et al* (2001). There is little in the way of bedrock in the shallow sublittoral along this stretch of coastline, with the nearest rocky cliffs being the Little Orme and Great Orme adjacent to Llandudno. Other than these limestone cliffs, hard substrata in the sublittoral is confined to cobble banks such as those present 3 km to the east of Great Orme Head (Brazier *et al* (2001). Coarse substrata including cobbles were also located around the Met Mast at the northwest corner of the wind farm and nearby cobble banks are known by local fishermen (Ian Bouch personal communication.). Submerged ship wrecks are also present close to the wind farm, including the steamer ship Calcium (Ian Bouch personal communication) and the submarine Resurgam (http://www.threeh.demon.co.uk/SitesResurgam2.htm).

There is a lack of basic survey information on the rocky sublittoral of the north Wales coast east of Anglesey. Brazier *et al* (2001) refer to a narrow zone dominated by the kelp *Laminaria hyperborea* which extends from chart datum to only one or two meters below, owing to the high turbidity. Other than this, sublittoral survey records have concentrated on sea caves such as those found along the Great Orme (Bunker and Holt, 2003). Dominant species here include a variety of sponges, sea anemones such as *Metridium senile* and *Sagartia elegans* and encrusting species

including the barnacle *Balanus crenatus*, the keel worm *Pomatoceros* spp. and encrusting bryozoans. Mats of the silt tube building worm *Polydora* sp. are also a feature of the cave environment.
Brazier *et al* (2001) provide a brief description of life on the cobble plain 3 km northeast of Great Ormes Head at a depth of 12 m. Here the larger rocks are dominated by deadman's fingers *Alcyonium digitatum* and hydroids including *Abietinaria abietina*, *Nemertesia antennina* and *Hydrallmania falcata*. The nearby wreck of the Resurgam is known to bear numerous Plumose anemones, *Metridium senile* (Rohan Holt personal communication). Although the seabed around the North Hoyle turbines is essentially formed from sand and gravel, all of the above species occur sporadically on boulders and stones, particularly in the central and western parts of the array (NWPO Ltd, 2002).

The only previous colonisation study at the wind farm site was a video survey of marine growth on an anemometer mast which was undertaken as part of an environmental impact assessment for National Wind Power. Studies were made of the communities colonising this mast after 18 months and 24 months and between surveys the base of the mast was scraped of encrusting organisms. After 18 months, the mast had been colonised by large numbers of common mussel *Mytilus edulis*, (commonly reported to be dense on Irish Sea Gas rigs) and dead-man's fingers *Alcyonium digitatum* (a soft coral), and an anemone of the genus Metridiidae. In addition the video shows that seaweeds had attached to the structure and barnacles were apparent. On the seabed at the base of the mast were a large number of common starfish *Asterias rubens*. (Terry Holt, CMACS Ltd., personal communication).

1.3 Environmental Conditions in the North Hoyle Area

The proximity of the Dee and Mersey estuaries to this site and the high sediment load carried downstream contributes to the general turbid nature of the water column. The seabed in the vicinity of the wind turbines is shallow (approximately 10 m below chart datum) and composed chiefly of sediments, some of which are coarse with scattered cobbles and pebbles but most of which are sandy.

Tidal flow is predominantly east-west and current information given on Admiralty charts (1978) suggests that maximum tidal flow in the area is approximately 0.8 knots during neap tides and 1.4 knots during spring tides. Also that during neap tides currents would be 0.2 knots or less for a couple of hours before and during low water, and for an hour or possibly more around low water. At springs currents would be 0.4 knots or less for a couple of hours before and during low water, and for an hour or so around low water. Advice from Vestas commercial divers was that there was little slack water during neap tides and that current speeds around the wind turbines were generally much higher than those predicted.

2 Methods

The intertidal and subtidal habitats encountered on two turbines, numbers 5 (on the inshore side of the wind farm) and 30 (on the offshore side of the wind farm) were studied in detail together with the recently installed Met Mast at the northwest corner of the site (approximately 200 m SW of turbine 30). Four further turbines (numbers 21, 7, 23 and 9) were also studied in a more cursory fashion. The location of these structures is given in Figure 1.

2.1 Survey Methods

Standard Phase 2 'MNCR' (Marine Nature Conservation Review) methodology (Hiscock, 1996) was used to describe the marine growth on and around turbines 5, 30 and the NW Met Mast. SCUBA diving marine scientists identified visually distinct biological zones and described them in terms of habitat, depths, species presence and abundance according to a predefined scale (see Appendix 3). Depending upon the state of the tide, intertidal parts of the supports were sometimes investigated from the boat. Where practical a 0.01 m^2 quadrat was scraped clear of marine growth in each zone and this was collected for subsequent weighing and biomass estimation.

For the turbines studied in less detail (numbers 21, 7, 23 and 9), the depths of each zone encountered together with dominant characterising species were recorded. This information was later transcribed to MNCR Site Forms.

All depths recorded (using diving computers) were corrected to chart datum using UK Hydrographic Office data for Llandudno derived from the computer program Tide Plotter 2004 (by Belfield Software).

Video footage of each structure studied was taken using a 3 CCD Sony PD170 DVCAM camcorder in an Amphibico housing.

Specimens were collected from each turbine studied and these were identified and / or preserved for further examination.

2.2 Biomass Studies

Biomass studies were undertaken on turbines 5, 30 and the Met Mast. Where it was practical to do so a 0.01 m^2 quadrat was scraped clear of all marine growth for wet weight (biomass) measurement. In some zones eg the scour zone and the green algal film zones this method was not practical as there was not much attached life or species were very small and encrusting and difficult to remove. An example of a cleared quadrat is given in Figure 2.

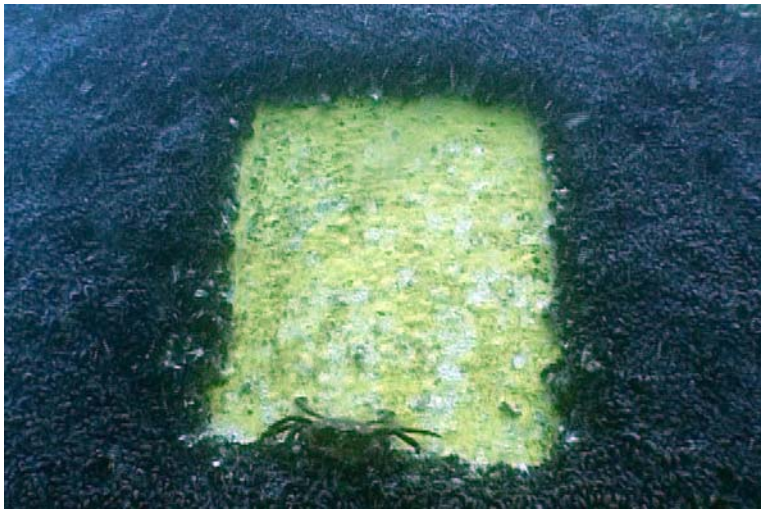

Figure 2 Example of a quadrat cleared for biomass (Tubine 5). Photographer: J. Perrins

Following collection in labelled bags, each sample was drained of water and species were sorted into different lots which were then weighed. Small animals such as polychaete worms and amphipod crustaceans were picked out of the samples for later identification and addition to the species list. See Figure 3 and Figure 4.

Figure 3 Example of a quadrat scrape prior to sorting and weighing. Photograph: J. Perrins

Figure 4 Sorting and weighing samples. Photograph: F. Bunker

2.3 Health & Safety

All diving was undertaken using standard SCUBA techniques under HSE (Heath and Safety Executive, 1997) and JNCC Guidelines (Holt, 1998).

Prior to and during the survey there was liaison with personnel, including commercial divers from the engineering firm Vestas who were working on the site at the time of the survey. Valuable information was obtained concerning safe working practices, currents etc.

2.4 Turbine Status at Time of Surveys

On the occasion of the visits to all six turbines, the turbine blades were rotating, although they were not necessarily generating. On those dates windspeeds were low and power generation was intermittent (information supplied by NWP).

3 Results

The results of the study are discussed in this section and a summary of the data obtained is given in Appendices at the end of the report. The raw data is contained in the Phase 2 forms as well as the underwater video footage.

3.1 Colonisation of the Turbines and Met Mast

Each wind turbine studied showed a clear pattern of zonation of organisms from the base to the intertidal zone. The pattern found on each turbine studied was essentially the same although there were minor differences. Cover of organisms was less dense on the Met Mast and the intertidal zone had not been colonised at the time of the survey, otherwise, the communities encountered here were also similar. The description and depths of the communities encountered on each structure is given in Table 1 below and a generalised diagram illustrating the pattern of zonation is given in Figure 5. The main features of each zone are now described.

A feature of each of the underwater structures studied were large shoals of the juvenile whiting (*Merlangius merlangus*).

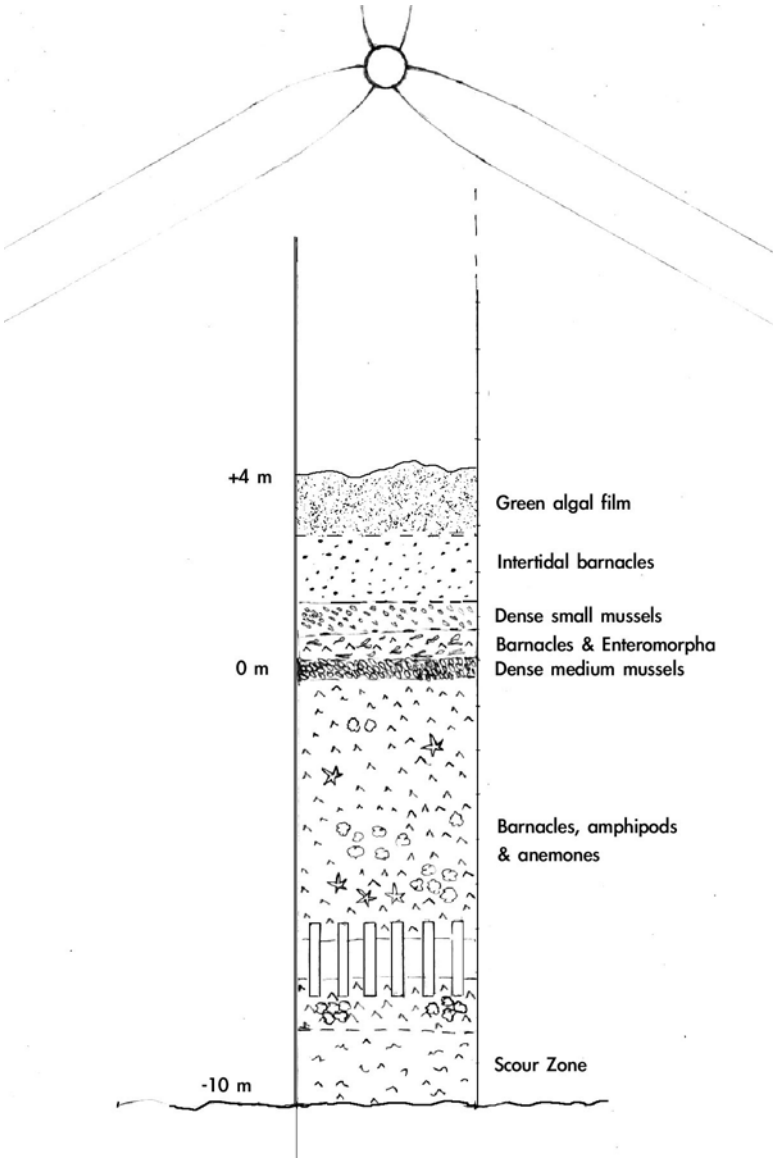

Figure 5 Stylised view of biological zonation recorded on a wind turbine (based on the observations of the present survey. Depths are approximate and corrected to chart datum.

3.1.1 Littoral green algal film

The upper limit of the littoral zone was marked by a patchy band of green algal film 1 m to 1.5 m wide (Figure 6). Living in amongst this thin algal film were the larvae of chironomid midges. Due to difficulty of both sampling and identification, the species present were not determined. This zone was present on each of the structures studied apart from the recently installed Met Mast.

Figure 6 Littoral green algal film (Turbine 5) above the barnacle zone. Photograph: F. Bunker

3.1.2 Littoral barnacles

A zone of intertidal barnacles occurred on all structures (except the Met Mast) between approximately 1.3 m and 3.3 m above chart datum. The dominant species was *Elminius modestus* but also present was *Semibalanus balanoides* and a few *Balanus crenatus* were present towards the base of the zone. This zone was poorly developed on the recently installed Met Mast. A photograph of this zone is shown in Figure 7.

Figure 7 Intertidal barnacle zone (Turbine 7): Photographer: F. Bunker

3.1.3 Littoral small mussels

A zone of densely packed small *Mytilus edulis* was present under the littoral barnacle zone between approximately 3.3 to 1 m above chart datum (see Figure 8). Few other species were present apart from the occasional plant of *Porphyra* sp. and *Ulva* sp. This zone was absent from the recently installed Met Mast.

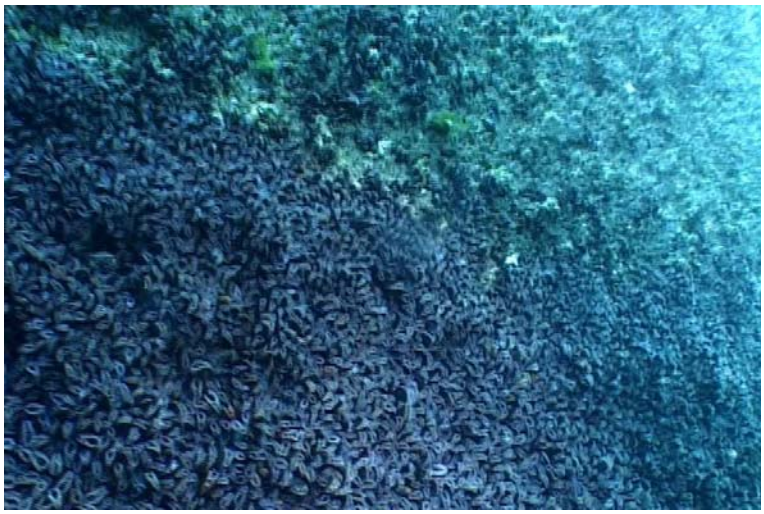

Figure 8. Densely packed small *Mytilus edulis* in the littoral zone (underneath the barnacle zone visible in the upper part of the photograph. Photographer: F. Bunker.

3.1.4 Littoral *Balanus crenatus* and *Enteromorpha*.

There was a narrow zone characterised by patches of the barnacle *Balanus crenatus* and the green alga *Enteromorpha* sp. between bands of mussels approximately 1 m to 0.3 m above chart datum (Figure 9). Other conspicuous species in this zone included the occasional sea anemone (including *Metridium senile*, *Sagartia elegans* and *Sagartia troglodytes*), swimming crab *Necora puber*, starfish *Asterias rubens* and patches of an encrusting bryozoan (too fragile to collect). Smaller animals also common here included the scale worm *Harmothoe impar*, the paddle worm *Anaitides mucosa* the amphipod *Jassa falcata,* the bootlace nemertean *Linnaeus* sp. and *Chironomidae indet.* The zone was less well developed on some turbines than others eg Turbine 23 where it was overgrown with small mussels.

A rather sparsely populated example of this zone was present on the recently installed Met Mast.

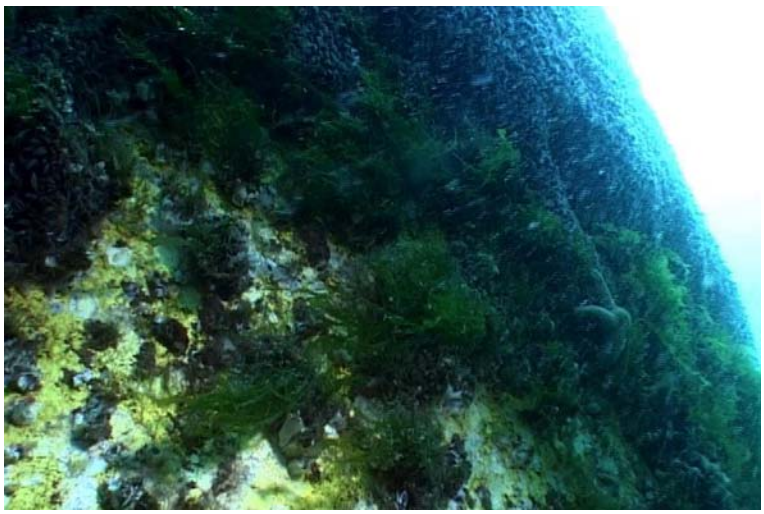

Figure 9 Narrow zone between *Mytilus* bands in the lower littoral dominated by *Balanus crenatus* and *Enteromorpha* sp. Photographer: F. Bunker

3.1.5 Sublittoral fringe medium sized *Mytilus edulis*

The sublittoral fringe on the turbines bore a characteristic zone dominated by medium sized mussels *Mytilus edulis* together with a few other species in low abundance (chiefly where *Mytilus* was absent). This zone varied from being quite narrow (e.g. Turbine 21, see Figure 10) to being more than 1 m wide (e.g. Turbines 7 and 23). Other species recorded included the anemones *Sagartia elegans* and *Sagartia troglodytes* and patches of the barnacle *Balanus crenatus* plus the predatory starfish *Asterias rubens*. Smaller species recorded among the mussel clumps included the polychaete worms *Nereis pelagica, Harmothoe impar, Lepidonotus squamata* and *Podarke capensis* together with the tube living amphipod *Jassa falcata* and the crab *Pisidia longicornis*. This narrow zone is illustrated in Figure 10.

Figure 10 Narrow band of mussels in the sublittoral fringe (Turbine 21). Photographer: F. Bunker

3.1.6 Sublittoral barnacles and amphipods

The most extensive zone on the turbines was dominated by the barnacle *Balanus crenatus* overgrown by silty tubes of the amphipod *Jassa falcata*. The barnacles were frequently densely packed and growing in an elongated form one centimetre or more in length. Other species common here included the predatory starfish *Asterias rubens* together with the sea anemones *Metridium senile, Sagartia elegans* and *Sagartia troglodytes.* On three of the structures studied, Turbines 9, 30 and the Met Mast, this zone was subdivided into a lower section with abundant anemones and an upper section with fewer anemones (Figure 11 and Figure 12). Other conspicuous but smaller species living amongst the barnacles included the nudibranch *Onchidoris bilamellata* which was very abundant and many were observed to be laying egg masses. Small animals recorded included three paddle worm species; *Anaitides mucosa, Lepidonotus squamata* and *Eulalia viridis,* the worm *Nereis pelagica* and the amphipod *Corophium acherusicum.*

Figure 11 Barnacle and amphipod zone (Turbine 30). Note that the clumps of barnacles (*Balanus crenatus*) are covered with grey tubes of the amphipod *Jassa falcata*. Also note abundant starfish *Asterias rubens* and the sea anemone *Metridium senile*. Photographer: Francis Bunker.

Figure 12. Lower part of the barnacle and amphipod zone covering the anodes (Turbine 21) with an abundance of the anemone *Metridium senile*. Photographer: F. Bunker

3.1.7 Sublittoral scour zone

The base of the turbines was in all cases scoured by the mobile seabed sediments (see Figure 13) with the extent of the scour ranging from approximately one metre to 4 m from the seabed. The characteristics of this zone were very similar to the barnacles and amphipods zone described above but with most species in low abundance. A characteristic species was the keel worm *Pomatoceros* sp.

Figure 13 Scour zone on Turbine 30. Note the bare un-colonised patches and the white squiggles of the tube worm *Pomatoceros* sp. Photograph: F. Bunker

3.1.8 The seabed

The seabed around most of the structures comprised of a mixture of unstable cobbles, pebbles, gravel and sand. The exceptions to this were Turbine 5 where the surrounding seabed was medium sand and Turbine 21 where ballast rock (small boulders and cobbles) had been dumped to address the problem of scouring of sediment around the [1]J-tubes. (At the time of the survey a program of rock dumping to cover and protect J-tubes had just commenced around the turbines. See Figure 14 and Figure 15).

The unstable mixed substrata encountered were generally pretty scoured and barren apart from the occasional barnacle or tube worm (*Pomatoceros* sp.), although starfish *Asterias rubens*, the dragonet *Callionymus lyra* and small crabs (particularly the hermit crab *Pagurus bernhardus* and the swimming crab *Liocarcinus depurator*) were also present.

The richest colonisation of seabed substrata was found around the Met Mast where cobbles bore scattered clumps of hydroids, especially *Sertularia cupressina* and patches of *Flustra foliacea*. The occasional *Metridium senile* was also present. *Pomatoceros* sp. and encrusting bryozoa and the starfish *Asterias rubens* was also common. Of interest was a small portion of mudstone with piddock burrows which was exposed by the sediment scour close to the Met Mast.

The boulders and cobbles dumped around the base of Turbine 21 were devoid of attached species because they had been deposited less than a week before the survey. The extent to which colonization of these occurs in the future will depend largely on scour effects and the stability of the stones themselves.

[1] J-tubes convey electrical cables away from the wind turbines under the sea bed. They should be buried in sediment but currents appear to have scoured the sediments away in the region of the turbines leaving them exposed.

Figure 14 J-tube lying exposed in what may be a scour pit around Turbine 17. Photographer: F. Bunker

Figure 15 Barren rock dumped to fill scour pit and cover J-tube at Turbine 21. Photographer: F. Bunker

Table 1 Zonation of communities encountered on each turbine studied together with reference to the depths encountered and habitat record number. Depths are corrected to chart datum.

Zone	Site 1 / Tubine 5 *		Site 2 / Tubine 30 *		Site 4 / Tubine 21		Site 5 / Tubine 7		Site 6 / Tubine 23		Site 7 / Tubine 9		Site 3 / Met Mast *	
	habitat	depth range	habitat	depth range	habitat	depth range	habitat	depth range	habitat	depth range	habitat	depth range	habitat	depth range
Filamentous green algae with chironomid larvae	8	+3.9 to +4.9	8	+2.6 to +4.1	8	+3.13 to +4.3	8	+2.3 to +4.0	8	+3.7 to +6.0	9	+4.1 to +5.2		absent
Intertidal barnacles	7	+1.7 to +3.9	7	+1.8 to +2.6	7	+1.33 to +3.13	7	+1.3 to +2.3	7	+1.3 to +3.7	8	+1.6 to +4.1	6	+0.4 to +4.4
Small *Mytilus edulis*	6	+1.0 to +1.7	6	+0.9 to +1.8	6	+0.93 to +1.33	6	+0.9 to +1.3		absent	7	+1.2 to +1.6		absent
Enteromorpha on barnacles (& sometimes *Mytilus*)	5	+0.2 to +1.0	5	+0.2 to +0.9	5	+0.3 to +0.93	5	+0.2 to +0.9	6	+0.1 to +1.3	6	+0.4 to +1.2	5	-0.4 to +0.4
Medium to large *Mytilus edulis*	4	-0.3 to +0.2	4	-0.4 to +0.2	4	-0.37 to +0.3	4	-2.0 to +0.2	5	-1.1 to +0.1	5	-0.4 to +0.4		absent
Barnacles & Amphipods - few anemones		absent		absent		absent		absent	4	-3.2 to -1.1	4	-3.1 to -0.4	4	-5.2 to -0.4
Barnacles & Amphipods - many anemones	3	-7.7 to -0.3	3	-6.9 to -0.4	3	-9.17 to -3.27	3	-9.6 to -2.0	3	-6.4 to -3.2	3	-6.7 to -3.1	3	-10.2 to -5.2
Scour Zone - extent and amount of scour variable	2	-7.7 to -8.7	2	-11.0 to -6.9	2	-10.17 to -9.17	2	-10.1 to -9.6	2	-11.4 to -6.4	2	-9.7 to -6.7	2	-12 .0 to -10.2
Seabed	1	-8.7	1	-11	1	-10.17	1	-10.1	1	-11.4	1	-9.7	1	-12

* = detailed habitat survey undertaken

3.2 Biomass Studies

A summary table showing the results of the biomass studies at Turbines 5, 30 and the Met Mast together with some very rough estimates of total biomass based on the habitat zones sampled is given in Table 2. (A full version of the table with lengths of zones on which the estimates were based is given in Appendix 1.)

Table 2 Biomass measurements from different zones on two turbines and the Met Mast based on scrapes from 0.01 m^2 quadrats.

Turbine 5 11/08/2004			
Habitat	**Description**	**Wet weight (gms)**	**Estimated biomass (kg) (based on length and diameter of structure)**
2	Scour zone		0
3	Barnacles & amphipods	680	675.0654294
4	Enteromorpha and barnacles	490	49.26017281
5	Small mussels (1600gms without mussels)	2890	254.2176775
6	Barnacles	1100	304.1061689
		Total	**1282.65 kg**
Turbine 30 11/08/2004			
2	Scour zone		0
3	Barnacles & amphipods	390	318.5574951
4	Mussels	3110	234.4884757
5	Enteromorpha & Balanus	1690	148.6601644
6	Small mussels & Ulva	1890	213.7539642
7	Intertidal barnacles	830	83.44070088
		Total	**998.9 kg**
Met Mast 12/08/2004			
2	Scour zone		0
3	Barnacles & amphipods (many anemones)	220	69.11503838
4	Barnacles & amphipods (few anemones & dense *Asterias*)	550	165.8760921
5	Mytilus & Enteromorpha	980	61.57521601
6	Intertidal barnacles		0
		Total	**296.6 kg**

3.3 Specimen Identification

59 species of animal and four plants were identified from the wind turbines. A list of the species recorded in the field on each structure together with an estimate of abundance is given in Appendix 3. This is supplemented in Appendix 2 by list of specimens identified in laboratory which chiefly came from the biomass samples. (These species are mainly polychaete worms and small crustaceans.)

4 Discussion

The methods used for the current study provide for an overall description of the state of colonisation of the wind turbines. The methods used were semi-quantitative and so are of limited use for the purposes of monitoring for change involving any statistical techniques. However together with the video archive, the results provide a good record of the status quo of those turbines studied in August 2004.

The dynamics and ecology of epibiota colonising hard substrata in temperate waters is poorly understood (Svane and Peterson, 2001) and the development of offshore wind farms provides us with a good opportunity to undertake studies in order to gain a greater understanding.

4.1 Colonisation and Predicted Succession

Although there was some variation between structures, a generalised and distinctive pattern of zonation was obvious from the 6 turbines studied together with the Met Mast. It is almost certain that the communities present in August 2004 will change over time. Exactly how the communities might develop is unclear and it is not certain that there will be a succession to a stable 'climax community'. Certainly a 13.5 year study of pier piles by Butler and Connolly (1996, 1999) failed to demonstrate that the communities had reached a stable condition. In the case of the North Hoyle turbines, it is anticipated that the piles may well be scraped periodically in order to reduce hydrodynamic drag.

The common species found both on the turbines and Met Mast are all known to occur on hard substrata near to the area and have most likely been recruited from nearby locations.

The most common member of the macro biota encountered on the structures studied was the barnacle *Balanus crenatus*. This was a dominant species both on the wind turbines and the recently installed Met Mast. *Balanus crenatus* larvae are present in the plankton between April and October (Rainbow, 1984) and so will have had ample opportunity to settle both on the turbines which have been in place for over a year and the Met Mast which was installed in February 2004.

Very large numbers of the amphipod *Jassa falcata* were present on the surface of the barnacles. This species builds tubes from collected silt and then feeds on matter suspended in the water column. The turbid waters off North Hoyle and the tide swept wind farm structures provides an ideal habitat for *J. falcata*. This species is well known as a 'fouling organism' due to its habitat of occurring in large numbers and encrusting substrata with its silty tubes (Hill, 2000).

The nudibranch *Onchidoris bilamellata* was particularly abundant over the major barnacle and amphipod zone of the turbines. This is a species that feeds on barnacles (Thompson, 1976) and has been recorded in large numbers as a first coloniser by the author on a long sea outfall off Scarborough in 1991 (F. Bunker unpublished observation).

The mussel *Mytilus edulis* was common in the shallow water and intertidal zone on each wind turbine studied This species is common both in estuaries and along the open coast and readily colonises artificial substrata such as pier piles, ropes and wind turbines. Peak spawning occurs in spring and early summer and the swimming larvae can be transported long distances in the water column (Tyler-Walters, 2002). The absence of *Mytilus* on the Met Mast was probably because it was put in place after the main settlement.

A common species both on the seabed and artificial underwater structures was the starfish *Asterias rubens*. This is species is a predator, feeding on both mussels and barnacles, both of which occurred in abundance on the underwater structures.

The anemone species *Metridium senile, Sagartia elegans* and *Sagartia troglodytes* were all common on the underwater structures. These are all common species on artificial substrata in the sea, particularly the plumose anemone *Metridium senile* which is known to adorn the nearby submarine wreck the Resurgam (Rohan Holt personal communication).

Very few algal species were found colonising the structures of the wind farm and even the most abundant species *Enteromorpha* sp. was not present in great abundance. Due to the turbid waters in the area, it is unlikely that algal growth would extend very deep but it is probable that in time shallow algal communities will become better established.

4.2 Commercially Interesting Species

A few species of commercial interest were recorded from the area. These are worth a special mention as much has been made of the ability of artificial reefs to have the potential to enhance local fisheries. Whether or not this is the case remains to be proven (Svane and Petersen, 2001).

4.2.1 The Mussel – *Mytilus edulis*

Mussels were abundant on all the structures studied apart from the Met Mast and this species is discussed in Section 4.1 above. From a commercial point of view it is probable that North Hoyle wind farm is too exposed a location for successful cultivation of mussels for commercial purposes as they are likely to get torn off during storms once they reach a large size. However, there may be potential to harvest the small mussels for seed to be relayed in more sheltered locations.

4.2.2 Edible Crab – *Cancer pagurus*

The edible crab *Cancer pagurus* was recorded from each of the structures studied. The specimens can be assumed to have migrated in from nearby areas to feed on the sessile animals present such as mussels and barnacles (see Figure 16). Juvenile crabs were also found in amongst the barnacles and mussels scraped off for biomass estimation. It is probable that these have settled out from the plankton. The significance of the artificial structures as a nursery area or food source to *Cancer pagurus* is unknown.

Figure 16. Edible crabs (*Cancer pagurus*) feeding on mussels on Turbine 7. Photograph: F. Bunker

4.2.3 Whiting – *Merlangius merlangus*

The most dramatic observation made was of large shoals of juvenile whiting *Merlangius merlangus*. These were present around all the underwater structures studied and appeared to be feeding on the amphipod *Jassa falcata*.

This observation is noteworthy because the whiting is listed in the UK Biodiversity Grouped Action Plan for commercial marine fish (http://www.ukbap.org.uk/). The importance of the wind farm structures to these populations of fish is unknown.

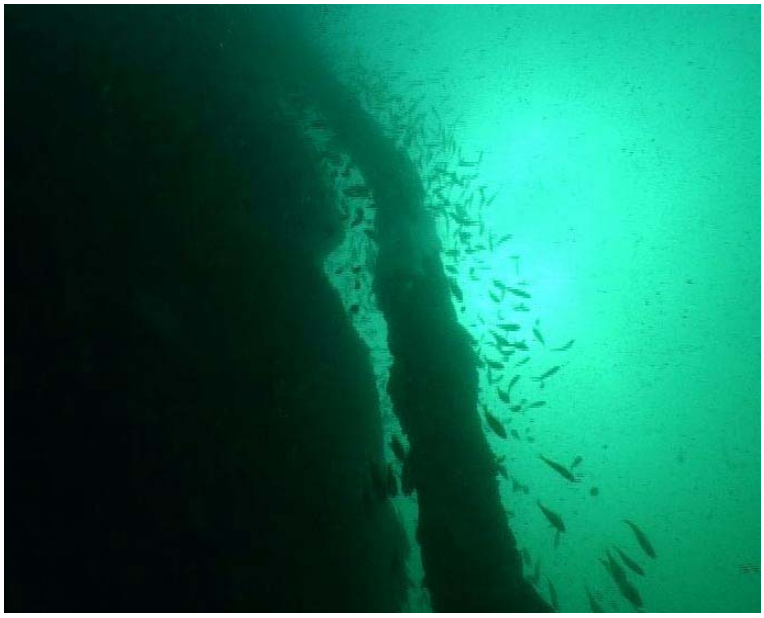

Figure 17 Shoals of whiting on the Met Mast. Photographer: F. Bunker

Figure 18 Dense shoal of juvenile whiting (on Turbine 5) feeding on the tube dwelling amphipod *Jassa falcata* which occurs in abundance on the turbine and met mast columns. Photograph: F. Bunker

It is also interesting to note that on each occasion the turbines were rotating (although not necessarily generating). The divers were aware of noises associated with the operation of the turbines, although the levels are not known. However, there was no obvious indication that the whiting (or other fish) were affected by the noise.

4.2.4 Cod – *Gadus morhua*

A single juvenile cod *Gadus morhua* was noted swimming amongst the shoals of whiting. The Atlantic cod is listed in the UK Biodiversity Grouped Action Plan for commercial marine fish (http://www.ukbap.org.uk/) and so its presence around the wind farm may be of significance. However the importance of the wind farm structures to cod is unknown.

Figure 19 A juvenile cod found swimming in amongst the shoals of whiting in the vicinity of Turbine 30. Photograph: F. Bunker

4.2.5 Plaice – *Pleuronectes platessa*

Plaice was recorded by the divers at low abundance ("rare") from the seabed adjacent to turbine no 30. It is almost certain that this represents a single specimen observed, but no further information is available.

4.3 Biomass Studies

The wet weight biomass measurements calculated during this survey can only give a very rough indication of the total biomass present on the wind turbines. A far more rigorous study would have to be undertaken to get any sort of accurate estimates of biomass. That having been said, the figures obtained do highlight the large biomass that has colonised over the short time period since the wind farm was constructed, with an estimate of around 1000 and 1280 kg of organisms on the two turbines studied. The met mast,which had been in place for only around six months, had an estimated biomass of just under 300 kg.

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Appendix 1 - Table to show the results of the biomass studies

The table below details the biomass (wet weight) obtained from 0.01 m^2 quadrat scrapes from selected zones (Habitats) on two turbines and the Met Mast at the North Hoyle wind farm. Estimates of biomass based on the length of the zones and diameter of the structure have also been calculated. These estimates were calculated using the following formula: Pi x D x Ht x (Wt/Sq m). The diameter of each turbine is estimated as 4 m. Habitats relate to those given in Table 1).

Habitat	Lower Depth range (SL) m	Upper Depth range (SL) m	Lower depth (CD)	Upper depth (CD)	Sample Depth (SL) m	Sample Depth (CD)	Wet weight (gms)	Description	Estimated biomass (kg) (based on length and diameter of structure)
Turbine 5 11/08/2004									
	11:13-12:04		Correction:-3.93 (11:33)	Correction:-3.93 (11:33)	12:23-13:03	Correction:-3.14 (12:45)			
3	12.1	4.2	8.17	0.27	8.3	5.16	680	Barnacles & amphipods	675.0654294
4	3.7	2.9	-0.23	-1.03	2.6	-0.54	490	Enteromorpha and barnacles	49.26017281
5	2.9	2.2	-1.03	-1.73	1.8	-1.34	2890	Small mussels (1600gms without mussels)	254.2176775
6	2.2	0	-1.73	-3.93	0.5	-2.64	1100	Barnacles	304.1061689
								Total Biomass (kg)	**1282.649449**
Turbine 30 11/08/2004									
	13:52-14:22		Correction:-2.63 (14:08)	Correction:-2.63 (14:08)	15:04-15:31	Correction - 2.69 (15:17)			
1	13.6	13.6	10.97	10.97				Seabed	0
2	13.6	9.5	10.97	6.87				Scour zone	0
3	9.5	3	6.87	0.37	7.5	4.81	390	Barnacles & amphipods	318.5574951
4	3	2.4	0.37	-0.23	2.6	-0.09	3110	Mussels	234.4884757
5	2.4	1.7	-0.23	-0.93	2.2	-0.49	1690	Enteromorpha & Balanus	148.6601644
6	1.7	0.8	-0.93	-1.83	1.3	-1.39	1890	Small mussels & ulva	213.7539642
7	0.8	0	-1.83	-2.63	0.5	-2.19	830	Intertidal barnacles	83.44070088
								Total Biomass (kg)	**998.9008001**

Habitat	Lower Depth range (SL) m	Upper Depth range (SL) m	Lower depth (CD)	Upper depth (CD)	Sample Depth (SL) m	Sample Depth (CD)	Wet weight (gms)	Description	Estimated biomass (kg) (based on length and diameter of structure)
Met Mast 12/08/2004									
	11:36-12:34		Correction:-4.03 (12:26)	Correction:-4.03 (12:26)	13:06-13:38	Correction -3.36 (13:17)			
1	16	16	11.97	11.97				Seabed	0
2	16	14.2	11.97	10.17				Scour zone	0
3	14.2	9.2	10.17	5.17	9.4	6.71	220	Barnacles & amphipods (many anemones)	69.11503838
4	9.2	4.4	5.17	0.37	6.8	4.11	550	Barnacles & amphipods (few anemones & dense *Asterias*)	165.8760921
5	4.4	3.4	0.37	-0.63	2.6	-0.09	980	Mytilus & Enteromporpha	61.57521601
6	3.4	0	-0.63	-4.03		-2.69		Intertidal barnacles	0
								Total Biomass (kg)	**296.5663465**

Appendix 2 - Small invertebrate species identified from the samples collected to determine biomass (Habitats relate to those given in Table 1)

Turbine 30

Habitat 3
Nereis pelagica
Anaitides mucosa
Lepidonotus squamata
Eulalia viridis
Jassa falcata

Habitat 4
Nereis pelagica
Anaitides mucosa
Lepidonotus squamata
Harmothoe impar
Podarke capensis
Pisidia longicornis
Cancer pagurus
Jassa falcata

Habitat 5
Anaitides mucosa
Harmothoe impar
Pisidia longicornis
Cancer pagurus
Jassa falcata

Habitat 6
Anaitides mucosa
Cancer pagurus
Jassa falcata

Habitat 7
Cancer pagurus
Jassa falcata
Chironomidae indet.

Turbine 5

Habitat 3
Anaitides mucosa
Eulalia viridis
Lepidonotus squamata
Harmothoe impar
Corophium acherusicum
Jassa falcata

Habitat 4
Pisidia longicornis
Jassa falcata
Harmothoe impar
Corophium acherusicum

Habitat 5
Harmothoe impar
Anaitides mucosa
Linnaeus sp. Indet.
Jassa falcata
Chironomidae indet

Habitat 6
Chironomidae indet
Liocarcinus juv. indet.

Met Mast

Habitat 3
Pisidia longicornis
Cancer pagurus
Jassa falcata
Chironomidae indet
Harmothoe impar
Pomatoceros lamarckii

Habitat 4
Pisidia longicornis
Cancer pagurus
Jassa falcata
Chironomidae indet

Habitat 5
Cancer pagurus
Jassa falcata
Chironomidae indet

Appendix 3 - Species recorded from *in situ* Phase 2 surveys

Species abundances are recorded as Superabundant, Abundant, Common, Frequent, Occasional or Rare as defined in the accompanying table

	Met Mast habitats							Turbine 5 habitats									Turbine 30 habitats							
	J-tube	1	2	3	4	5	6	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8
Hydrozoa																								
Tubularia indivisa				O	R														R					
Eudendrium sp.				O					F									F						
Halecium halecinum				O	O																			
Plumularia setacea				O					R															
Abietinaria abietina		O																						
Hydrallmania falcata		O																						
Sertularia argentea	F		R		R												R							
Sertularia cupressina	O	F																						
Obelia dichotoma				O																				
Anthozoa																								
Alcyonium digitatum																		O						
Metridium senile		C	R					R	C	F							O	C	F	R				F
Sagartia elegans	O		O	F	O				F	F	R						R	C	O	R			F	
Sagartia troglodytes	C			A	O	R			C	F	O							C		R				
Sagartiogeton undatus		R																						
Nemertea																								
Lineus longissimus	R																							
Polychaeta																								
Harmothoe sp.	C																							
Lanice conchilega		C																						
Pomatoceros lamarcki		F																C						
Pomatoceros sp.			O	O	F				F								O				O	O		

	Met Mast habitats							Turbine 5 habitats									Turbine 30 habitats							
	J-tube	1	2	3	4	5	6	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8
Sabella pavonina																	R							
Sabellidae indet.										O									O					
Phyllodocidae indet.										O														
Crustacea																								
Elminius modestus							C					A	C											A
Semibalanus balanoides						P	F					C	O											A
Balanus crenatus	C	R		S	A	P	R		C		O	R						A	C	F	C	C		R
Jassa falcata	S	O		S	S	F			C									A	S	F	O	O		
Decapoda																								
Caridea indet.	R																							
Pagurus bernhardus		R						R									R							
Pisidia longicornis	C																							
Inachus phalangium		R																						
Cancer pagurus	O	R						R	C								R	O	O					
Liocarcinus depurator	R																R							
Necora puber	F	C	R	R	R			R	C	F							R	O	O					
Carcinus maenas	C																							
Insecta																								
Chironomidae							P						O											
Opisthobranchia																								
Polycera quadrilineata				P																				
Facelina annulicornis	F			R						R													O	
Onchidoris bilamellata	C									O														
Eubranchus farrani				R																				
Janolus cristatus					R				R															
Flabellina pedata									O															

	Met Mast habitats							Turbine 5 habitats									Turbine 30 habitats							
	J-tube	1	2	3	4	5	6	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8
Onchidoris bilamellata									C										R					
Bryozoa																								
Electra pilosa		F																						
Flustra foliacea		O																						
Bugula flabellata			O		R				R															
Bryozoa indet. Crusts		F	C	O					O	O								O	O					
Anguinella palmata				F	F																			
Pelecypoda																								
Mytilus edulis	O					S					S								R	S	F		S	
Asteroidea																								
Asterias rubens	C		A	A	S			A	S	S	C						A	C	C	A	C	C		
Holothuroidea																								
Pawsonia saxicola				R																				
Pisces																								
Pholis gunnellus	F	R	R	R														R						
Callionymus lyra		O						O									O							
Pleuronectes platessa																	R							
Merlangius merlangus	S							A									A	A	A					
Gadus morhua																	R							
Chlorophyta																								
Enteromorpha sp.						O															O			
Green algal film																F								
Porphyra sp.																							F	R
Ulva sp.																							O	

Appendix 3 continued

Abundance scales used; taken from MNCR rationales and methods (Hiscock, 1996).

S = Superabundant, A = Abundant, C = Common, F = Frequent, O = Occasional, R = Rare

GROWTH FORMS			INDIVIDUALS					
% COVER	CRUST/ MEADOW	MASSIVE/ TURF	<1cm	1-3cm	3-15cm	>15cm	DENSITY	
>80%	S		S				>1/0.001m^2 (1x1cm)	>10,000/m^2
40-79%	A	S	A	S			1-9/0.001m^2	1000-9999/m^2
20-39%	C	A	C	A	S		1-9/0.01m^2 (10x10cm)	100-999/m^2
10-19%	F	C	F	C	A	S	1-9/0.1m^2	10-99/m^2
5-9%	O	F	O	F	C	A	1-9/m^2	
1-5% or density	R	O	R	O	F	C	1-9/10m^2 (3.16x3.16m)	
<1% or density		R		R	O	F	1-9/100m^2 (10x10m)	
					R	O	1-9/1000m^2 31.6x31.6m)	
						R	<1/1000m^2	

EXAMPLES OF GROUPS OR SPECIES FOR EACH CATEGORY

PORIFERA	Crusts *Halichondria*	Massive spp *Pachymatisma*		Small solitary *Grantia*	Lge solitary *Stelligera*	
HYDROZOA		Turf species *Tubularia* *Abietinaria*		Small clumps *Sarsia* *Aglaophenia*	Solitary *Corymorpha* *Nemertesia*	
ANTHOZOA	*Corynactis*	*Alcyonium*		Small solitary *Epizoanthus* *Caryophyllia*	Med solitary *Virgularia* *Cerianthus* *Urticina*	Large solitary *Eunicella* *Funiculina* *Pachycerianthus*
ANNELIDA	*Sabellaria spinulosa*	*Sabellaria alveolata*	*Spirorbis*	Scale worms *Nephtys* *Pomatoceros*	*Chaetopterus* *Arenicola* *Sabella*	
CRUSTACEA	Barnacles Tube-dwelling amphipods		*Semibalanus* Amphipods	*B balanus* *Anapagurus* *Pisidia*	*Pagurus* *Galathea* Small crabs	*Homarus* *Nephrops* *Hyas araneus*
MOLLUSCA	*Mytilus* *Modiolus*		Sml gastropods *L neritoides* Small bivalves *Nucula*	Chitons Med gastropods *Patella* *L littorea* *Turritella* Med bivalves *Mytilus* *Pododesmus*	Lge gastropods *Buccinum* Lge bivalves *Mya* *Pecten* *Arctica*	
BRACHIOPODA				*Neocrania*		
BRYOZOA	Crusts	*Pentapora* *Bugula, Flustra*			*Alcyonidium* *Porella*	
ECHINODERMATA				*Echinocyamus* *Ocnus*	*Antedon* Small starfish *Echinocardium* *Aslia, Thyone*	Large brittlestars *Echinus* *Holothuria*
ASCIDIACEA	Colonial *Dendrodoa*			Small solitary *Dendrodoa*	Lge solitary *Ascidia, Ciona*	*Diazonas*
PISCES					Gobies Blennies	Dogfish Wrasse
PLANTS	Crusts Maerl *Audouinella* Fucoids/kelp *Desmarestia*	Foliose Filamentous			*Zostera*	Kelp *Halidrys* *Chorda* *Himanthalia*