Assessing impact from wind farms at subtidal, exposed marine areas

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SUMMARY

Marine renewable energy conversion typically takes place at locations characterised by harsh physical parameters which are a challenge for monitoring of the marine environment. These challenges are caused both by the lack of experience on what to expect in terms of impact, but also by a general lack of proven methods suitable for the monitoring of high-energy subtidal marine habitats. In this chapter we use the first offshore wind farm to be built in Norwegian waters, a project called Havsul I, as a model to give (i) an overview contrasting the known effects and monitoring methods used at more sheltered offshore wind farms with those expected at a rocky, high energy site; (ii) a description and short assessment of the physical environment (bathymetry, current, wave and wind data) and marine communities at the site, (iii) an assessment of five methods used during the baseline study at Havsul I including sediment grabs, kelp stipes community samples, video mosaics, fish community and harbour porpoise.

Keywords: Marine renewable energy, rocky sea-bed, monitoring, video-mosaic, kelp

1 INTRODUCTION

The siting of offshore renewable energy devises are going through a development from near shore and shallow water in the early years, to further offshore and in deeper water during the last years (EWEA, 2011). One of the drivers of this development is the lack of space on land and conflict with land property owners claiming visual disturbance from near shore wind farms (Esteban *et al.,* 2011). Another potential conflict is the one with shipping routes or alternative uses of the seabed, such as fishing or pipelines and cables (Buckhard *et al.,* 2011).

One could also add the increase in the quality of the wind and wave resource at a larger distance from shore. All of these incentives also apply to areas that are highly exposed to open ocean wind and wave energies such as steep and energetic seabed's off the coasts of Portugal, Ireland, Scotland and Norway in Europe and counties such as Chile and California in other regions (e.g. Dvorak *et al.,* 2010).

With few exceptions offshore wind farms have to date been placed in relatively shallow seas on flat sea-beds in the Southern Baltic and North Sea. Main environmental concerns regarding impact on marine life in these areas relate to noise and sedimentation during the construction phase, and habitat change and noise during the operation phase (Gill, 2005, Wilhelmsson *et al.,* 2010). The few studies of effects from the operation phase of a wind farm that have been published in peer-reviewed journals suggest that monitoring programs have problems to detect any significant changes (e.g. Lindeboom *et al.,* 2011, Scheidat *et al.,* 2011). A large volume of recently published reports from government agencies, research programs and developers also indicate an absence of significant changes in community structure, species abundance and diversity after a few years of wind farm operation (e.g. Stenberg *et al.,* 2011, Degraer *et al.,* 2011, Bergström *et al.,* 2012a, Bergström *et al.,* 2012b). But physical and biological conditions are dramatically different in more energetic coastal areas such as the Norwegian Sea (Shields *et al.,* 2009). Bathymetry along the Norwegian coastal zone is typically steep and allows little room for offshore wind developments with a current maximum depth of around 50 m (Fig. 1). This kind of Norwegian offshore "banks" typically consist of pre-cambrian crystalline rock with a rugged shape from glacial erosion. The resulting bathymetry is complex that give such banks a mosaic of different benthic habitat types. In the top 10-15 m dense populations of kelp dominated by the species *Laminaria hyperboria* are forming a highly productive and diverse community (Mann, 1972, Moore, 1973). Below about 25 meters light intensities are too low to sustain brown algal growth and the wave action is too high to allow any sediment accumulation. With yearly occurring significant wave heights in excess of 15 meters a low light and highly eroded sea bed extend down to around 70 meters depth. This forms a diverse habitat dominated by crust forming algae and sessile invertebrates such as hydrozoans (Paine, 1966). Sediment accumulation is permitted in the deeper trenches (in access of 100 m deep) where the hydrodynamic forces are lower. Because of the highly productive kelp community in the very near vicinity, the deeper trenches are organically rich and sustain an abundant and often diverse infauna community.

Some of the largest of such areas are in Norway found off the coast of Møre and Romsdal county and have been subject to offshore wind farm consent applications (Havsul I-IV). One project (Havsul I) was granted consent in 2009 and extended investigations were undertaken of bathymetry, geology, oceanography, wind resources and biology. The consent was given for a set of installations capable of producing 350 MW, and covering an area of 49 km^2. The area has a centre in the position 62°49'37''N 06°18'29''E and is situated 8 km from the closest inhabited island Harøya (Fig. 1). The type of foundations or the size of turbines used, has not yet been decided at the writing of this chapter but will, because of the rocky seabed, exclude monopiles. Since noise generated from pile-driving of monopiles is the most

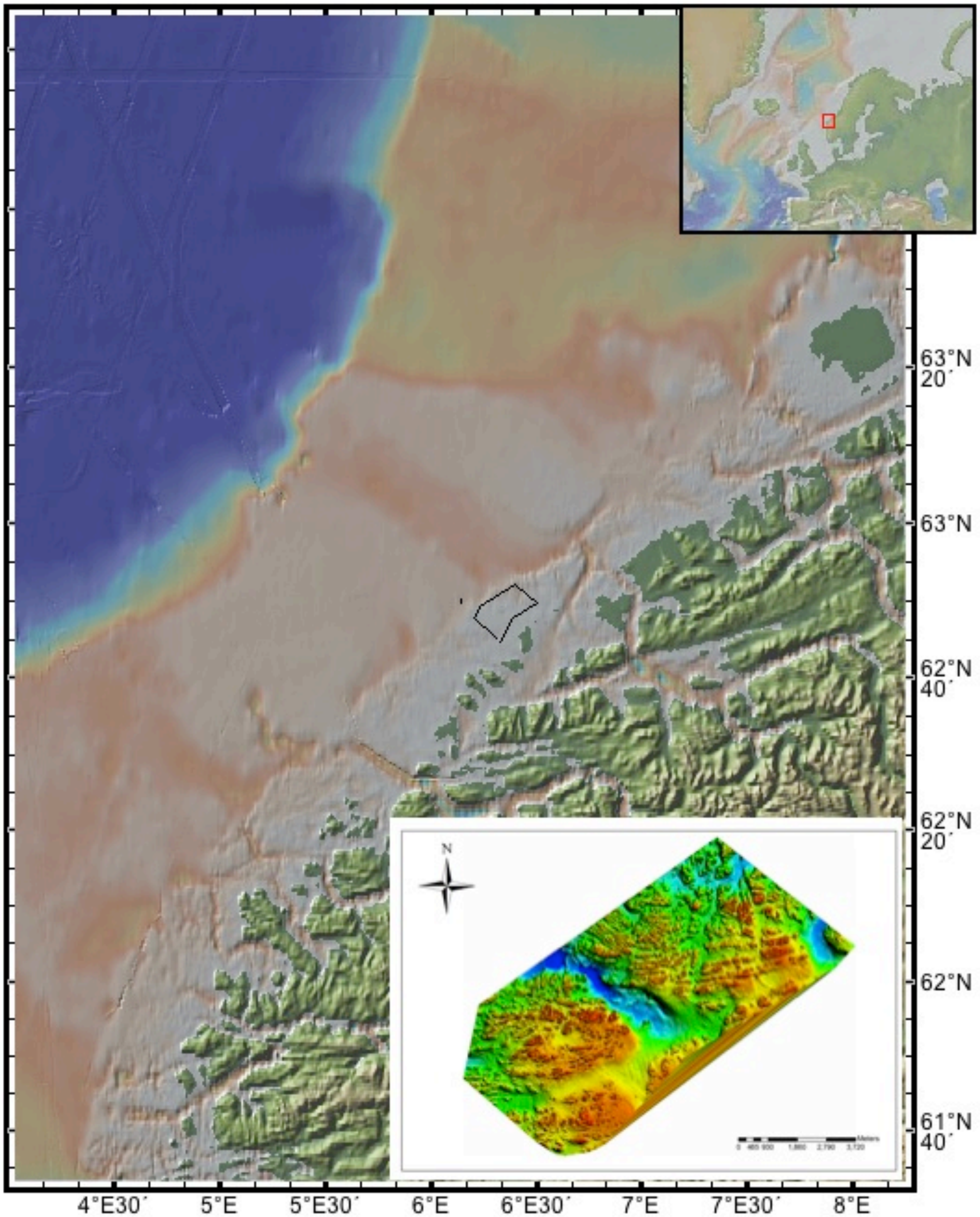

Figure 1. Havsul I offshore wind farm. The site is indicated with a black rectangle. The insert at the lower right is a multibeam bathymetric map of the actual area.

important source of environmental concern during the construction phase of a wind farm (Wilhelmsson *et al.,* 2010), disturbance effects from the construction phase will not be further addressed here. In this chapter we will discuss the challenges associated with planning and conducting environmental monitoring programs suitable for marine renewable energy conversion in areas with high hydrodynamic forces. Calculated annual wave energy off the county Møre coast is amongst the highest in the world with an average of 438 MW/m/year (Golmen, 2007). So-called extreme events are common and cause an average of yearly maximum significant wave heights at 10.5 m for the period 1980 to 2006 (Golmen, 2007) with two events in excess of 15 m significant wave height during the last 3 months of 2011 (Fig. 2).

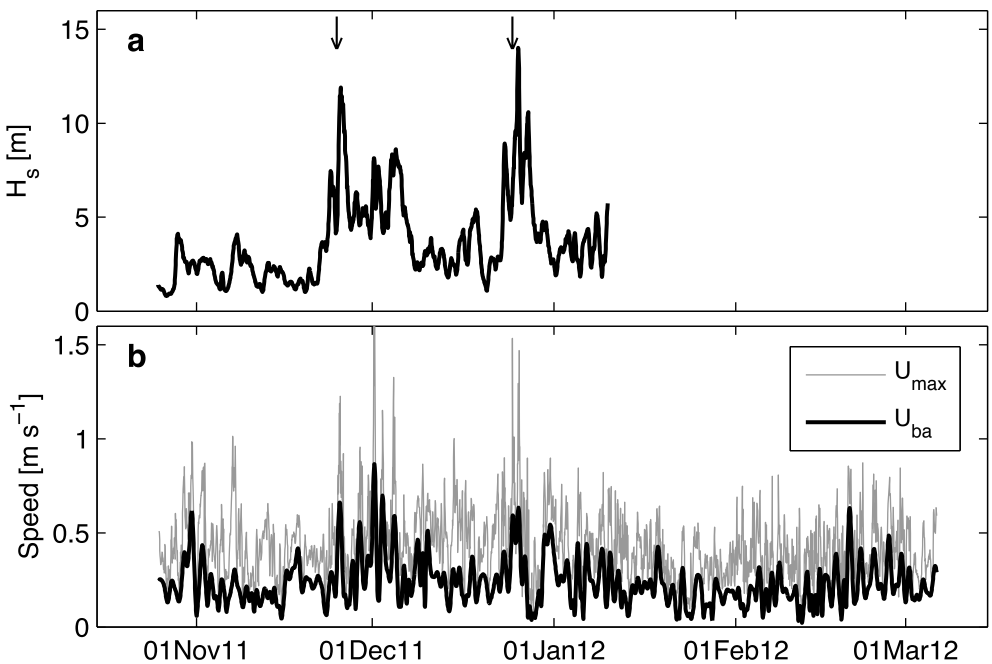

Figure 2. Havsul I offshore wind farm. Position 62°50'07"N 06°08'14"E. Time series of a) significant wave height, b) magnitude of the maximum hourly velocity (Umax, gray) and the depth-averaged 25-hour low-passed velocity (Uba, black) at Havsul-I region measured at approximately the 130 m isobath. The arrows in a) mark the storms Berit and Dagmar in late November and December 2011, respectively.

This environment is, therefore, very harsh on any type of instrumentation left in situ to collect continuous data over a period of time. This applies both for instruments to collect physical data such as current speed, temperature and salinity, but also biological data such as recording of cetacean noise. Since the start of the project at Havsul I, no less than ten oceanographical, meteorological and biological instruments have been damaged or lost. The weather windows available for field-work is also limited due to the high average wind speeds and exposure to oceanic swell breaking over shallow sites. Navigation in the area by larger, less weather sensitive research vessels that would allow for more predictive field-work from a stable and safe platform, is limited due to narrow channels and limited depths.

Deeper offshore marine habitats in the Norwegian and North Sea have for around 30 years been subject to intense environmental monitoring warranted by the petroleum extraction activities (e.g. Kingston, 1992), but monitoring at exposed offshore rocky banks are not routinely conducted and standard methods are lacking (Shields *et al.,* 2009). In fact, the limiting factors for researchers to work in such areas render them as *de facto* remote, and not very different from polar regions. For monitoring programs, this means that systematically collected baseline data are not present and our understanding of the ecological responses to new stressors are limited (Shields *et al.,* 2009, 2011). The poor knowledge of these habitats is also reflected by the absence of comprehensive species lists and a relatively large number of newly discovered species found in recent years.

A major challenge for programs trying to monitor environmental change at energy conversion structures placed in high-energy sites such as Havsul I, is that hypotheses regarding expected impact are not well developed. In contrast to the relatively shallow, low energetic and soft sediment marine environments where offshore wind farms have been operating for up to a decade now, little is known about what to expect at high-energy sea-bed communities. The highly energetic offshore areas of the Norwegian coast can be regarded as less affected by the most serious threats to European marine communities, and therefore arguably also more vulnerable to low levels of disturbance. Compared to coastal sediment habitats, energetic hard seabed communities are more often regarded as less affected by accumulation of toxins, less affected by habitat-degrading fishing activities such as bottom trawl, and less affected by eutrophication (e.g. Gray, 1997, but see Piola and Johnston, 2008). Following the ideas of Foley (e.g. Foley *et al.,* 2011) we should strive to reduce the environmental footprint from energy and food production by concentrating on a stop on a stop of area use expansion. A better area use efficiency could be achieved also in coastal and offshore regions by placing wind farms in already impacted areas and combine the wind farms with *e.g.* aquaculture (Buck *et al.,* 2008).

Direct impact from offshore wind farms, such as habitat-change from the introduction of hard substrates in areas otherwise devoid of that, or habitat-loss from excavation of sand and replacement of soft sediments with hard scour protection blocks, is not easily discernible at high-energy sites. If turbine foundations are placed at more exposed sites one may expect a reduction of hydrodynamic drag leading to a sheltering effect and an increase in available microhabitats for faunal elements like crabs (Langhamer and Wilhelmsson, 2009). Parts of the planned wind farm Havsul I overlap with an area where kelp is trawled for the alginate industry and the industrial harvest of kelp can be compared to the bottom trawl fishery excluded from some wind farms in sediment areas. By removing kelp from part of the Havsul area on a regular five year rotation basis, the practice has been shown to increase net kelp productivity but decrease diversity of associated fauna (Steneck *et al.,* 2002, Lorentzen *et al.,* 2010). Here, the relaxation of kelp removal by banning kelp trawl activities within the wind farm would probably increase the diversity of associated fauna. An increased diversity of fish species was observed at Horns Rev wind farm in Denmark, probably caused by an increase in habitat heterogeneity (Stenberg *et al.,* 2011). The end (or reduction) of kelp trawling at Havsul is expected to result in increased species richness because of a changed demography of the kelp community towards increased longevity of kelp plants (Christie *et al.,* 2003). The fauna and flora associated with kelp stipes and holdfasts is getting more and more diverse the older the kelp community becomes, and the recovery of the associated fauna from regular kelp removal by trawling depends on the dispersal capabilities and community structure of the surrounding kelp forests (Christie *et al.,* 1998).

While sessile benthic fauna will be directly impacted by all phases of the Havsul I wind park construction, operation and decommission, mobile fauna such as fish and mammals have the the “choice” of entering or leaving the area. Laboratory simulations have suggested that harbour porpoises (*Phocoena phocoena*) and common seals (*Phoca vitulina*) can detect the noise generated from a 2 MW wind turbine at sea (Koschinski *et al.,* 2003). The Harøy archipelago has a large population of common seal that frequently use the Havsul I area for foraging and haul out (Bjørge *et al.,* 2002). Harbour porpoises are known to occur in the fjord systems all along the Norwegian coast, but little is known about the abundance in offshore areas outside of the North Sea where a regional wide census was undertaken in 1994 (Bjørge and Øien 1995, Hammond *et al.,* 2002). The current understanding of the impact on seal and porpoise populations from operational offshore wind farms is limited but suggest that if the area is important for foraging, the long term abundance of seals and porpoises within the farm will not be significantly affected (Tougaard *et al.,* 2003, Tougaard *et al.,* 2006). One study suggest that the abundance of porpoises may even increase, possibly due to lower disturbance by fishing vessels and a higher patchiness in fish abundance that are increasing the foraging success (Petersen and Malm, 2006, Scheidat *et al.,* 2011).

To monitor environmental change in a mosaic of different habitats with limited access to evidence-based impact hypotheses, a diverse set of methods will be required. Infauna diversity and abundance of the deeper areas with soft sediment can successfully be monitored using established grab methods, but other less proven methods, are required at rocky seabeds and in kelp forests. Below we outline some of these methods and discuss our experiences from assessing them during the baseline study at the Havsul I wind farm site.

2 MONITORING AT HAVSUL I OFFSHORE WIND FARM

In the following assessment of methods we have been limited to the ones that are being considered by the developing company and responsible authorities for baseline studies at the Havsul I area and the associated reference area. In particular we are investigating the technical challenges, limitations and potential sensitivity specific to the extreme physical environment (chaotic bathymetry, currents, wind and wave action) experienced at this offshore high-energy site. The following methods have been adopted:

- Physical oceanography
- Sediment habitat community structure with traditional van Veen grab samples
- Rocky seabed habitats with video mosaics
- Kelp ecosystem diversity and demography with samples of kelp achieved using a traditional "kelp-dredge"
- Fish community with traditional bottom set long-lines, nets, traps and fyke-nets
- Porpoise abundance with c-pods

2.1 Physical oceanography

On 25 October 2011 an oceanographic mooring consisting of instrumentation to measure the vertical distribution of ocean currents, temperature and salinity was deployed approximately 6 km offshore of the Havsul-I area off the coast of Ålesund. The water depth at the mooring site was about 130 m and the hourly averaged time series for currents were obtained between 10 to 120 m, and for hydrography between 25 to 115 m. The mooring was recovered on 6 March 2012. An additional subsurface buoy (at about 10 m depth at the 130 m isobath) equipped with high-resolution pressure and motion sensors, was deployed to infer surface wave parameters. The wave spectra and the corresponding wave parameters were obtained using 15-min long segments of data, after applying the appropriate corrections for the vertical acceleration and pitch motion of the platform and the transfer function for the attenuation of surface wave pressure signal with depth. Wave data were collected from 25 October 2011 until 10 January 2012 only. Current measurements were made by RD-Instruments 300 kHz acoustic Doppler current profiler and a pair of Nortek Aquadopp current meters. Temperature and salinity measurements were made by Sea-Bird Electronics (SBE) loggers (6 Microcats and 2 Seacat) distributed evenly in the vertical. The measurement period covers two storm periods with wind speeds in excess of about 20 m/s and 30 m/s (the storms *Berit* and *Dagmar*, respectively) as measured at the nearby Vigra Airport meteorological station on 25 November and 25 December 2011. To say the least, the site is highly energetic (Fig. 2). The significant wave height, Hs, typical of the region varies between 1 - 5 m, which increases to in excess of 12 m during storm periods. While the hourly maximum velocity in the water column typically varies between 0.2 - 1 m/s, it reaches about 1.5 m/s during storms. When the tidal variability is removed (by using a 25-hour low-pass filter), the depth-averaged currents vary between 0.1 - 0.5 m/s, occasionally reaching values above 0.6 m/s.

2.2 Sediment habitat

The deeper trenches present in the area are filled with soft sediment. The hypothesis behind monitoring the soft sediment community is that any change in productivity caused by the wind farm at shallower depth (Wilhelmsson and Malm, 2008), would lead to a subsequently changed flux of organic carbon to the surrounding sediments. Changes in hydrodynamics of the area from *e.g.* the presence of turbine foundations, could also lead to changes in organic carbon flux (Broström, 2008). We use the well-described method for monitoring of the infauna fraction of the soft sediment community using a 0.1 m^2 van Veen grab (Norsk Standard, 2005). In addition, samples for sediment characteristics and organic content are also collected. Biological samples are collected on a 1 mm round hole diameter sieve, fixed in formaldehyde, subsequently rinsed in sea water and preserved in ethanol. During the first year of baseline data collection a number of the randomized sample stations were found to be dominated by sediment and gravel too coarse for the van Veen grab to close properly and new replacement positions had to be selected and new samples taken. The feasibility of the method in areas with chaotic bathymetry and large hydrodynamic forces is limited by the heterogeneity of the seabed characteristics. In rum seas, large vessels can normally be used to withstand bad weather. Large vessels also allow for access to powerful winches, deck space, storage space, repair workshops, ventilated areas and cabins. With narrow channels, limited depths and hence, limited possibilities to manoeuvre large vessels, smaller and less optimal boats have to be used in combination with the use of various support facilities on shore.

2.3 Rocky seabed

Traditional benthic sampling techniques are not applicable on hard substrates. The use of SCUBA-based monitoring methods, are also limited by cost and safety issues in this highly energetic offshore area (e.g. Sisson *et al.,* 2002). We used a video-based approach, with data collection as video imagery (Sheehan *et al.,* 2010). Two types of platforms can be used to collect the data, either a towed platform or a remotely operated vehicle (ROV) that allow for a better compensatory manoeuvrability in high energy situations (Sheehan *et al.,* 2010). A work class ROV was used for data collection at Havsul I. The system was equipped with powerful xenon lights (total power 600 Watt), colour HD camera (resolution 1920*1020 pixels) and two laser-line pointers. Video data was collected in transects with an average length of approximately 200 m. To optimize the video footage for mosaic construction, the camera was oriented vertically, and the ROV altitude was kept as constant as possible. This was done as good as possible although the studied area is very hydrologically active, and some variations of the camera altitude and angle to the sea floor along the transects are unavoidable. An optimal ROV altitude is dictated by optimality of the seafloor illumination. A too low ROV altitude leads to image saturation and a too high altitude give strong distortions of colours due to wavelength-dependent light absorption.

Data taken from a moving camera is difficult to analyse using simple computer algorithms. Therefore, video mosaics were created for the analysis using the software developed at the Center of Coastal and Ocean Mapping (Rzhanov *et al.,* 2004). Combining overlapping frames into a single picture let us consider all the collected data in the analysis (no frame containing unique visual information were omitted). At the same time we avoid over-counting of features present in several video frames since they appear only once in a mosaic picture. To construct mosaics of manageable size, all videos were segmented into 30 sec clips, each corresponding to approximately 10 m of transect.

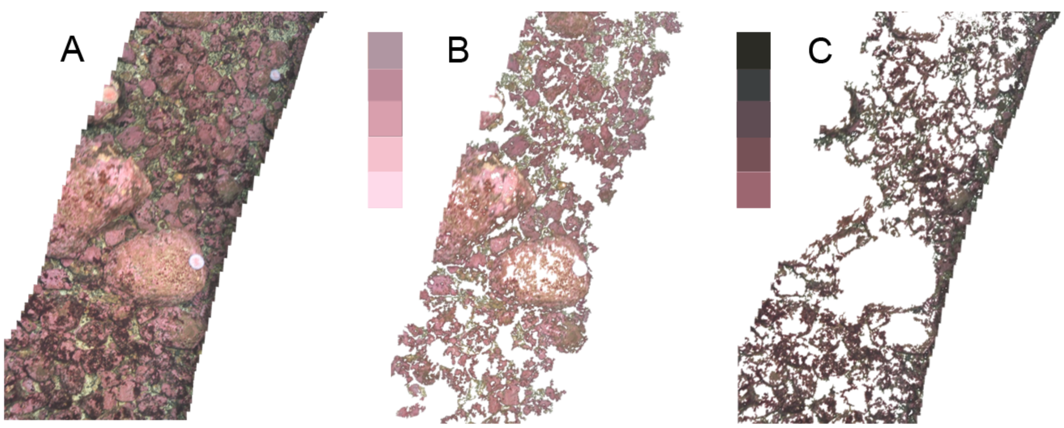

Figure 3. Example of the bottom video mosaic. Two preliminary named biological features are extracted from the initial mosaic using selected training colours (shown in the left to the layers). The coverage is calculated as a proportion of pixel count. A) Initial mosaic. B) *Lithotamnium* sp. C) Crust forming algae.

Estimated visual features included counting of mega-benthos diversity and abundance, and estimates of coverage for different algae species. While manual count of mega-benthos species could be done reliably (e.g. Jones *et al.,* 2006), coverage estimation proved to be more challenging since benthic micro-habitat types in the area are extremely patchy and diverse. Use of the video mosaic method for manually counting mega-benthos was faster, less tiresome and more accurate since it was easier to handle the still pictures than the raw video allowing the operator to zoom in and out, scrolling in any direction.

For the computer-aided coverage estimation we used a colour-based approach. For each feature, a set of training colours was chosen, and features were assigned a value (a micro-habitat) on the basis of this set (Fig. 3). This allowed for fast and reproducible extraction of features from mosaics. Once appropriate training sets have been selected, there is no need for an expert to do the rest of the analysis. The quality of the result is at this stage operator-independent and after minimal training any technician can process the data. The final results depend on the training sets of colours and could vary. To evaluate possible errors, three mosaics were selected for testing. For each feature in each of the chosen mosaics, an expert picked seven different training colour sets. To compare the method with manual analysis, the same video segments were analyzed manually using point-based feature selection (Carleton and Done, 1995). Comparison of the results obtained with different training colours and between computer-aided and manual analyses, proved that deviations due to different choice of training colour sets are minimal (less than 5%, and for some features less than 2%) and results are comparable with manual analysis performed by an expert in marine benthic ecology (Fig. 4).

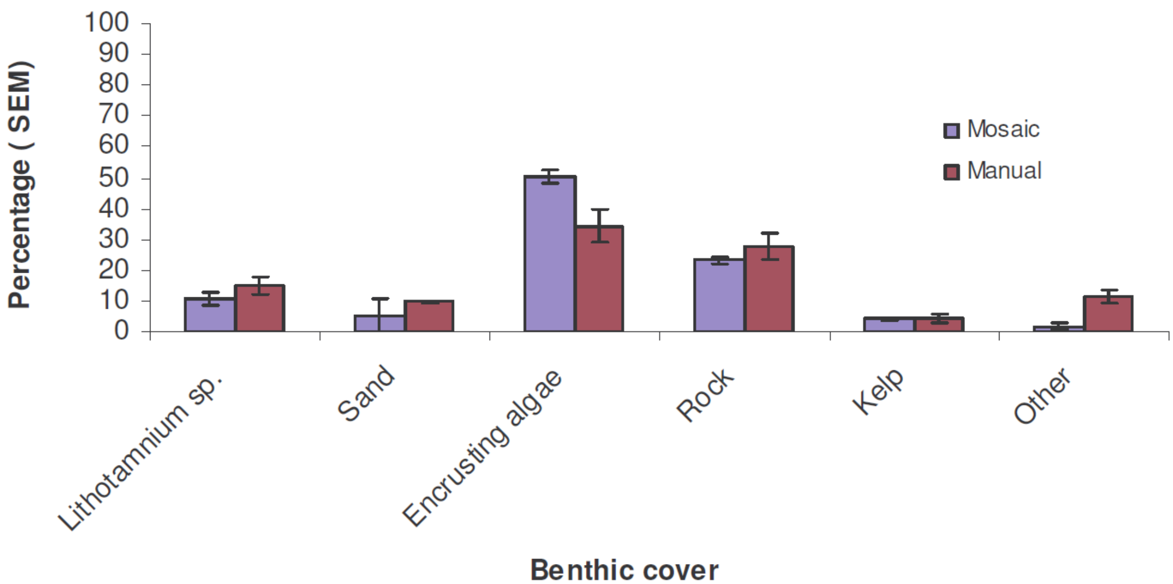

Figure 4. Comparison of moisaic-based benthic cove analyses method and a manual method for six features encountered at Havsul I.

2.4 Kelp ecosystem

The area where the wind farms Havsul I is planned overlaps with one of the most important areas for kelp harvest along the Norwegian coast. The upper 10-15 m are dominated by dense communities of kelp, mainly the species *Laminaria hyperboria* which is harvested at a regular basis in Norway (Vea and Ask, 2011). The planned wind farm with turbines and cable tranches, will likely affect the possibility to harvest kelp inside area, and thus, relax the degrading effects on the habitat from trawling. To assess the impact on the kelp forest and the associated community of plants and animals we take samples of kelp stipes with a small commercial kelp trawl (Vea and Ask, 2011). The associated community is removed from the kelp stipes and fixed in formaldehyde. Cross section samples of the stipes are taken for estimates of the kelp age structure (Kain and Jones, 1964). The diversity and abundance of associated animals is enormous with up to 80,000 individuals on one stipe, belonging to up to 238 species (Christie *et al.,* 2003). To make monitoring of this diversity and abundance feasible, a subsample of representative taxa is required. Following the work by Kongsrud (2000) we chose to sample the diversity and abundance of crustaceans and annelids in a semi-quantitative design where kelp stipes is cleared of all associated fauna. All samples from the baseline study are preserved and stored for future reference. One reason would be to re-examine the baseline samples using a broader taxon sample if diversity changes are suggested from the more restricted sample.

2.5 Fish community

The Havsul I area is normally avoided by larger commercial fishing vessels due to the shallow seas and complex and large waves. Only local fishermen conduct a restricted small-scale fishery within the area. This fishery is based on the use of passive gear and small crafts that are able to use short-term favourable weather conditions. Our monitoring of the fish community is based on the same type of gear and conducted by the same local fishermen. We use three types of bottom set gill net, bottom set long lines and crab pots. In addition, during the first year of baseline sampling we also used cod fyke-nets. This fishery had to be abandoned due to extreme catches of crabs (*Cancer pagurus*) and low catch rates of fish. The catch is identified to species level, measured and weighted on board. Admittedly, using this approach we will not be able to identify any changes in the abundance of pelagic species such as herring. Estimates of herring abundance using ship-borne acoustics are commonplace in today's management of fish stocks (e.g. Simmonds and MacLennan, 1992). So far it has only been partly successful in monitoring programs at wind farms (Bergström *et al.,* 2012a), and is not suitable for ground fish estimates at rocky banks (Starr *et al.,* 1996). Suggestions to use upwards directed bottom-set acoustics for continuous monitoring of pelagic species are considered to be too expensive (Axenrot *et al.,* 2004). In view of the high frequency loss of moored equipment in Havsul I area, we choose not to risk it and wait for this technique to be cheaper and more expandable. The use of baited underwater cameras, are also promising for non-destructive monitoring in a rocky and energetic habitat (Harvey *et al.,* 2007). Once the wind farm is constructed web-based underwater visual observatories connected to land via the wind farms control system can provide a possibility to remotely monitor changes in fish behaviour and abundance due to for instance turbine load (Glover *et al.,* 2010).

2.6 Porpoise and seal abundance

We have opted for a yearly estimation of Harbour seal (*Phoca vitulina*) abundance by air surveys in August at known haul-out sites within the area (Bjørge *et al.,* 2002). At this time the seals are moulting and have a higher and more predictable preference for being out of the water. The average ratio of seals at haul-out sites in relation to the total population size have been calculated for the moulting period at different areas along the Norwegian coast (Bjørge *et al.,* 2007). By using a correction factor of 1.35 for Møre and Romsdal the total population size can be estimated from the number of seals at haul-out sites (Bjørge *et al.,* 2007). The seals are counted from photographs taken from a light aircraft. To reduce costs and environmental impact the flights are conducted in collaboration with baseline studies for sea bird abundance.

Harbour porpoises (*Phocoena phocoena*) are the most common cetacean in many north European waters and are frequently monitored when offshore wind farms are being built to minimize the impact from this construction to the population. There are no previous data on porpoise's abundance in the Havsul area, however, data from by-catch and other studies in Norwegian waters indicate that they are common all year around with a peak in the coastal areas between July and October (Bjørge *et al.,* 2011).

The aim of this program is to acoustically monitor harbour porpoises using autonomous underwater echolocation click detectors, called C-PODS (Chelonia Limited, see www.chelonia.co.uk), to estimate their abundance and habitat use in the planned wind farm site and at a control site. The aim is also to test the hypothesis that there is no impact (negative or positive) on the abundance of porpoises due to the construction phase and operation phase of the wind farm. For the second year of baseline data collection (2012) the sensors will be deployed at the two sites only during July and August as the area is known for is challenging weather conditions during the winter months.

The monitoring program is planned for two years of baseline studies and four years of studies during the operation phase. The Havsul I region is a very challenge area to work in weatherwise and therefore, and to be able to take advantage of short weather windows, a small rib boat was used by the porpoise program. This meant that deployment and retrieval of the sensors could only be done quickly but only during reasonably good weather.

During the planning phase, care was taken to choose the sensors deployment location using data on bottom substrate and oceanographic conditions were available. For instance, to allow the recorded data to be treated separately, the sensors should be positioned at similar environmental conditions. The six deployment positions, three in each of the impact and reference areas, were therefore chosen to be of similar depth, topography and at the Havsul I site, 100 m from a planned wind turbine position. As no data existed of porpoise habitat usage or behaviour for this particular area, only one kind of habitat was chosen, *i.e.* a plateau at 30 m depth at the edge of a much deeper (> 50 m) area.

The rigs were bottom-mounted to reduce the risk of theft and impact from wave motion should it have been placed with a surface buoy. Advice on rig configurations was gathered from several scientific groups that have long experience in deployment of C-PODs in various waters. The rigs contained each a C-POD, an acoustical releasers (pop-ups) and ballast weights made up from jute bags containing 35 kg of gravel and buoys for buoyancy (Fig. 5). The choice of size and weight of the ballast was also influenced by that it had to be managed by two people in a rib boat. Each bag was tied with ropes to a shackle and a 2 mm stainless steel wire to the acoustical releasers. To provide buoyancy, two hard Nokalon trawling buoys were used, each with a lifting force of four kilo. Both the C-POD and the acoustical releasers are well known for their durability and reliability in rough conditions.

During the first year of baseline studies, harbour porpoises were sighted in both areas on the surface during deployment indicating that porpoises do indeed inhabit both survey areas. In October of 2011, before the planned C-POD retrieval, the Havsul I region was hit by severe storms resulting in delayed recovery and causing several of the C-PODs to break loose. The most likely cause was a failure of the stainless steel wire and wire lock (Fig. 5). Local fisher-men up to 130 km from the deployment site found some of the lost sensors. Two sensors were never found and all data was lost. However, of the remaining four, two was originally deplo-yed at the Havsul I site and two at the control site, luckily allowing for a balanced analysis. A common way of analysing click detector data is to calculate Detection Positive Minutes (DPM, see *e.g.* Leeney *et al.,* 2007). This is equal to at least one porpoise echolocation train detected during one minute of the actual total

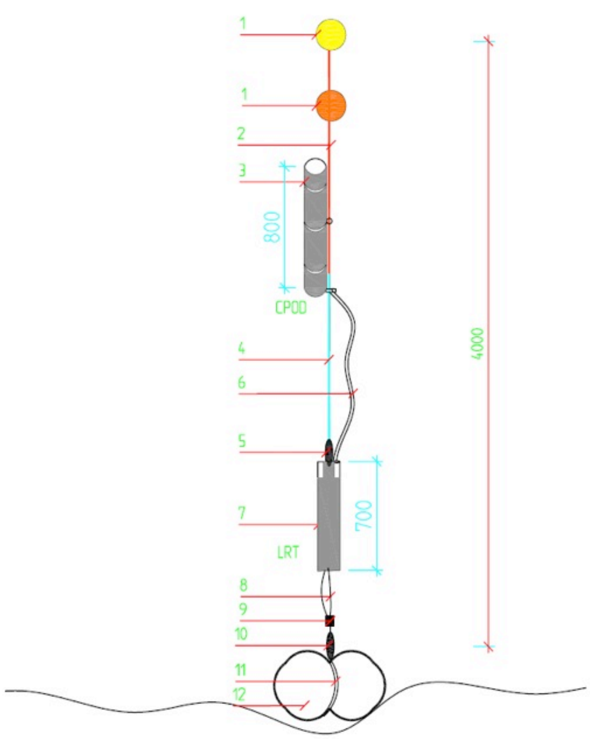

Figure 5. Sketch of C-POD sensor rig. 1) Nokalon trawling bouys, ø 20 cm, lifting force 4 kg. 2) Attachement rope (nylon), Ø=10 mm, 2 m long. 3) C-POD. 4) Attachment rope (polypropylen), Ø=20 mm, 1 m long. 5) Shackel (stainless steel), Ø=4 mm. 6) Security rope (nylon), Ø=5 mm, 1.5 m long. 7) LRT. 8) Wire (stainless steel), Ø=2 mm, 30 mm long. 9) Wirelock (stainless steel, AISI 316). 10) Shackel (galvanized), Ø=10 mm diameter with a breaking strength of 1200kg. 11) Barlast rope (nylon), Ø=10 mm, 2 m long. 12) Barlast weight, jute bag with 35 kg of stones and gravel.

logging time. In the analysis, only data recorded while the C-PODs were at the mooring site was used, although clicks were recorded also while some sensors were afloat on the surface after being torn of the ballast. The preliminary analysis of the first year's data showed a considerable amount of porpoise activity, however, relatively unevenly distributed between sensors. Although looking at the two areas, the overall estimation of porpoise presence in both the Havsul I area and control area was similar, indicating an even usage of the area as a whole.

For the second baseline year, the rig will be modified according to the lesson learned during the first year. The deployments will be conducted covering a period from July 2012 to September 2012, trying to avoid the more extreme storms in the autumn. Final analyses, with data also from the second year of baseline investigations, will include an extensive assessment of porpoise habitat use as well as an estimate on the possible impact of the weather on the results.

3 CONCLUSIONS

There are multiple and complex challenges associated with environmental monitoring at installations in an energetic marine environment. This environment is a facetted mix of habitats with very different characteristics. The expected impacts on these habitats are often not understood. These harsh coastal environments have been avoided also by historic environmentalists, which have caused a lack of baseline data. Any work conducted today is very weather dependant. The practical use of permanent and long-term installations such as bottom mounted instruments or oceanographic buoy's is limited due to the higher than normal frequency of extreme weather events. Monitoring methods need to be adjusted to a small boat since shallow seas and narrow channels hinder the operations using larger research vessels. Plan any fieldwork with a generously sized weather factor. A combination of methods is required to cover possible effects on the different habitats.

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