# Environmental Monitoring at the Maren Wave Power Test Site off the Island of Runde, Western Norway: Planning and Design

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## Abstract

This paper provides a general description of the environmental monitoring programme currently ongoing at Vattenfall's/Tussa's wave power test site "Maren", on the Norwegian west coast. The purpose of the environmental monitoring is twofold: (i) to monitor the potential impact of the Maren installation on the environment, thereby fulfilling the consent requirements of the Norwegian authorities, (ii) more generally, to gain experiences about the design and management of an environmental monitoring programme and test a variety of monitoring methodologies and equipment. The primary environmental parameters assessed in the monitoring programme include fish, benthos and seabird communities. Observations on marine mammals are included marginally and underwater noise measurements are scheduled to be included at a later stage. The rationale for choosing the specific components of the monitoring programme is elucidated in the context of site specific environmental features, as well as project-specific technical characteristics. Generally, the monitoring strategy follows a modified so-called BACI (Before-After, Control-Impact) design, i.e. takes place before and after deployment of the wave power devices and during operation over a period of approximately 3 years.

A communication plan accompanies the programme and is considered an essential prerequisite for transparency and public acceptance of the programme.



**Keywords:** environmental monitoring, wave power, test site, marine ecological communities, Maren

## 1 The Maren project

Off the Norwegian west coast, close to the island of Runde, a test site for wave power has been established during 2008/2009 (**Figure 1**). The project is entitled 'Maren' (MARine ENergy) and represents a cooperation between the Swedish energy utility Vattenfall AB and the Norwegian energy utility Tussa AS. It is undertaken in close co-operation with Seabased AB, the developer and supplier of the wave energy system, and with Runde Environmental Centre (REC), advising on, guiding and executing the environmental monitoring programme of the project. The Maren project is managed by Vattenfall.

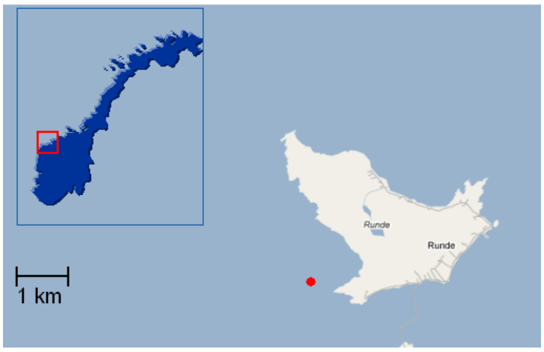


**Figure 1:** Location of the Maren wave power test site, off the island of Runde, marked with a red circle

At the test site, two full-scale wave energy converters (i.e. 20 kW each) and a submarine switchgear are to be installed in August 2009.

A submarine power cable will connect the converters to the 22 kV grid (managed by Tussa AS) on the neighbouring island of Remøy. The test site is situated approximately 400 m off the island of Runde (62º 23,3070' N 05º 35,5332' E), at approximately 50 m water depth on gravel substratum with interspersed rock and some sand.

Each wave energy converter consists of a steel buoy floating on the water surface (one discus- and one thorus shaped model is used), connected to a linear generator via wire. The generator is placed in a steel cylindrical housing with a concrete foundation placed on the sea floor. As the buoy moves with the waves, the vertical motion is transferred to the linear generator and electricity is generated [1],[2]. A picture of the system and its dimensions is given in **Figure 2**.

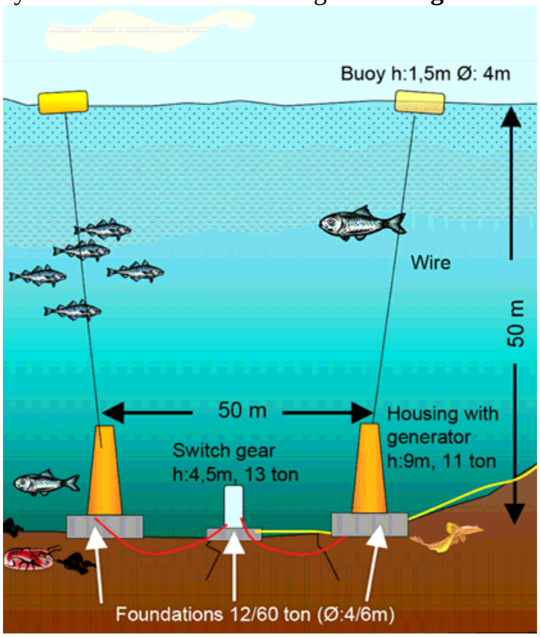


**Figure 2:** Artists impression of the Maren wave power test site (courtesy of Lars Golmen, REC)

The wave energy system will be tested over a period of approximately two years. The main purpose for in-situ testing is to gain knowledge about technical functionality, reliability and maintenance requirements of the entire Seabased$^{TM}$ system at a high wave energy location. Additionally, it provides Vattenfall, Tussa and REC with a good opportunity to gain knowledge and experience with regard to environmental monitoring of wave power systems, a field which is expected to be increasingly important in the future as wave power gets closer to commercialisation, but which to date has been studied rarely under real conditions as the technology is still in its infancy.

## 2 The environment at Runde and the consent application

The wave climate off Runde is energetic (~40-50 kW/m) and the region is considered to have high potential for future wave power development in Norway [3]. The marine environment around Runde is well known for its high productivity and biological diversity. On the interface of two oceans (North Sea to the south and Norwegian Sea to the North), and two major current systems (Norwegian Coastal Current and North Atlantic Current, i.e. gulf stream), with a highly variable topography and narrow continental shelf, the coastal marine environment is characterised as an important spawning area for fish (especially the Norwegian spring spawning herring) and houses the most southerly seabird colony in Norway on the northwestern cliffs of Runde – to name just two prominent ecological feature. Hence, the seas off Runde are among the most important fishing grounds in Norway. In addition, small scale fishing takes place in close vicinity to Runde, and other resource uses include kelp trawling and fish aquaculture (the latter in the fjords east of Runde). Primarily because of the seabird colonies, but more generally because of its unique natural environment both on land and in the ocean, Runde has been a popular tourist destination for bird watchers, divers and other nature enthusiasts for many decades [4].

### Site selection

The actual Maren test site was chosen on the basis of a number of criteria, including i) high wave energy, ii) minimum interference with ship traffic, iii) minimum interference with fishing (see **Figure 3**), and iv) minimum interference with fish spawning areas. In addition, water depth (~50m), bottom topography (uniform horizontal) and seabed substratum type (mainly gravel and sand) had to be amenable to deployment of the generators. In the process of ranking these criteria, an initial five potential areas were evaluated, before, eventually, 'Måganeset' was chosen as the most appropriate site, i.e. with the best match of selected criteria [5], [6].

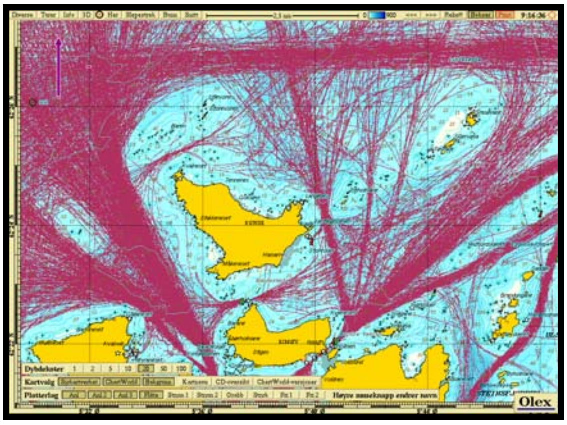

**Figure 3:** OLEX data showing the trajectories of fishing boats as one important piece of information determining the final site selection for Maren [5]

**Consent application, process and permission**

The permit application was delivered to the Norwegian authorities, 'Norges Vassdrags- og Energidirektorat' (NVE) in May 2008 and a consultation process was undertaken. In general, the reception of the application was very positive, and only some minor comments were received. Seven months after sending in the application, in December 2008, the consent was given by NVE. The operational permit is valid for five years, i.e. until January 1, 2014. The permit states a number of conditions with regard to the environment. i) A plan for the environmental monitoring is to be delivered to NVE before deployment of the devices and monitoring results are to be delivered to NVE at the end of the Maren project. ii) If items of archeological interest are discovered, all installation work must immediately be stopped and the Bergen Maritime Museum must be informed. iii) Marking of the buoys must be undertaken according to guidelines and legislation. iv) An agreement must be made with the local kelp trawlers that no trawling will be undertaken in the cable area during the test period [7].

## 3 The environmental monitoring programme – overall description

The environmental monitoring at the Maren test site will focus on three groups of ecological communities that, both by the scientific experts involved in the process and by the Norwegian authorities involved in the consent process, were deemed the most likely to respond to an installation of this particular size and location: Fish, benthos (bottom-dwelling flora and fauna) and birds will be investigated systematically and in detail, while marine mammals will be investigated qualitatively in association with the bird study.

With regard to structural components of the system, environmental monitoring focuses on the wave energy converters (WEC) and the switch gear. Effects associated with the underwater cable are not part of this investigation. For each of the ecological communities under question (fish, benthos and birds), an individual sub-programme has been established (details in chapter 4), however, the sub-programmes are highly integrated, especially with regard to timing of field investigations. Underwater noise measurements are scheduled to be integrated at a later stage.

As far as possible and practical, the general monitoring strategy follows a so-called BACI (Before-After, Control-Impact) design [8], with control-impact comparisons modified to a gradient analysis in a number of cases (see below). Hence, studies will be performed before, and after the deployment and during operation of the wave energy system, i.e. over a period of approximately three years, given a two-year test period. The purpose of the environmental monitoring is twofold: (i) to monitor the potential impact of the Maren installation on the environment, thereby fulfilling the consent requirements of the Norwegian authorities, (ii) more generally, to gain experiences about the design and management of an environmental monitoring programme and test a variety of monitoring methodologies and equipment. Despite its small scale (both spatial and temporal), and consequently the expectation that Maren will have little or no impact on the ecological communities investigated [6], the design of the environmental monitoring plan is used as a model for future, possibly larger wave power sites.

The potential ecological effects suggested to occur at the Maren test site are related to the following environmental aspects: i) Physical presence of the devices could lead to a) an attraction of organisms and locally increased diversity (artificial reef effect) or b) might disturb and scare away organisms. ii) Underwater noise propagation which could either a) attract or b) scare certain marine organisms.

Within the programme, standardized methodology for environmental impact assessments is applied as far as possible. However, to date only few wave power devices of the current type have been employed, making the current application for the Maren project both unique and exemplary. An important part of the programme is to continually evaluate and develop the monitoring processes.

**Planning, execution and evaluation**

The planning phase of the program was concluded in March 2009 and followed the commonly used strategy for environmental monitoring programs developed by Vos et al [9], see **Figure 4**, which is recommended by the Swedish Environmental Agency [10].

As stressed by Vos et al, the strategy is not as strictly top-down as **Figure 4** shows, but is characterised by feedback loops between the stages of the process. The design of the monitoring is an iterative process, where all the stages are run through repeatedly, increasing specification at each time [9].

Other than the overall purpose and its ideal execution, the actual version of the environmental monitoring programme is also framed by various external constraints. Some of the most important constraints for the Maren environmental monitoring programme are listed in Table 1.

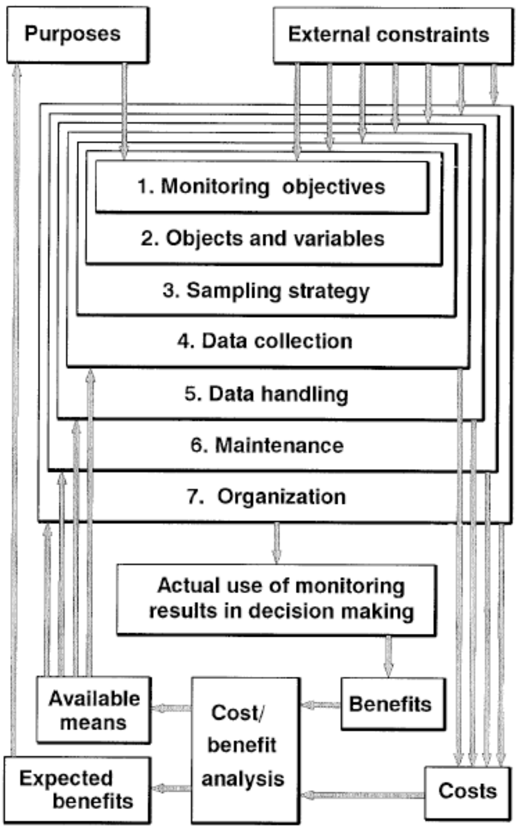


**Figure 4:** Schematic representation of the framework for the design and evaluation of environmental monitoring programmes [9]

| Constraint type | Issue | Issue adressed |
|---|---|---|
| Ecological | Relevant temporal and spatial scales for species investigated are larger than impact scales | Can not be adressed in this programme |
| Ecological | Small site meaning that small changes are anticipated | Investigation scales match anticipated impact scales |
| Technical | Limited availability of methods | Adapt mathods from related projects as far as possible. Test new methodologies. |
| Socio-political | Multiple stakeholders in the area (potential interference with navigation and shipping) limits the investigations | Consultation with stakeholders, modifications of field studies |
| Methodological | Lack of appropriate control sites | Use of gradient analysis approach |
| Methodological | Short time available to perform before-impact studies | Could potentially consider investigations after the removal of the wave energy system |
| Legal / Methodological | Permission needed from authorities for deploying marking floats for bird monitoring (surface delimitations of a monitoring grid) | Application written and sent to authorities |
| Statistical | Impossibility to meet the assumptions for a particular test | Use a variety of statistical mathods for stronger backup of results |
| Physical | Weather conditions can be tough (wave climate, visability) | Choose relatively calm days for field studies |
| Physical | 50m water depth limits the accessibility of site, meaning that investigations with divers can not be performed | Use of remote analysis via ROV |
| Physical | Distance from land (400m) has impact on the possibilities of performing bird observations from land | Good visibility needed, clear days chosen for field studies |
| Financial | Limited available means | Limitation of the scope of the activities (numbers of field samples, equipment etc) |

**Table 1.** External constraints affecting the design of the monitoring

During the first year of environmental study at the Maren test site, focus will be placed on testing and evaluating the strategies and methodologies of the programme. After the first monitoring period, evaluation of the processes and the results will take place and adjustments to the studies will be undertaken in order to plan for the next years of investigations. Methodologies within the programme will be adjusted according to initial experiences, and results will be communicated to a wider audience as transparency is considered an essential prerequisite for public acceptance of the project.

## Organisation

The overall project management for the Maren project is carried out by Vattenfall AB and Tussa AS. Whereas coordination of the environmental monitoring programme rests with Vattenfall, scientific advising and execution of the programme is the responsibility of researchers at REC. In addition, external scientific review is providing by researchers at Vattenfall AB, the University of Uppsala and the Norwegian Institute for Nature Research (NINA).

# 4 Environmental monitoring programme – detailed description of the sub-programmes

## Benthos

### The benthic environment at Runde and Maren test site

With few exceptions, the substratum surrounding the island of Runde is rocky, with slopes extending from the steep cliffs on the island into the ocean down to a plateau at approximately 100m water depth. During preliminary investigations for the purpose of site selection, the benthic environment at the Maren test site Måganeset was video-documented using ROV: The seabed at the test site is flat (<5% inclination) and the substratum consists of small pebbles and rocks (up to 10cm diameter), interspersed with sandy areas characterized by sand ripples, i.e. wave action from the surface is evident. The flora is dominated by rock-encrusting coralline red algae, lacking upright vegetation. Macrofauna on rocks consists predominantly of sessile species, especially calcareous tube-constructing polychaetes. On sandy patches, hydroid colonies (single stalks 10-15cm high) provide evidence for a high-current environment (**Figure 5**) [5].

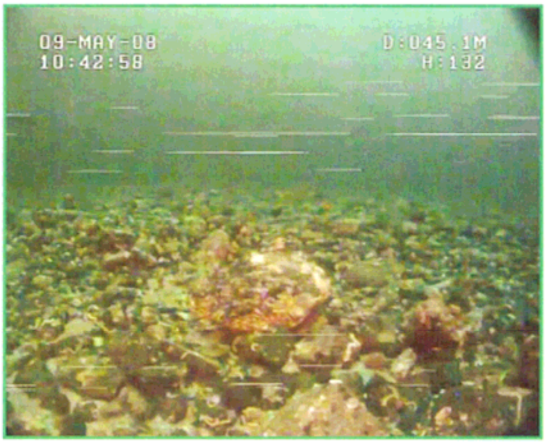


**Figure 5:** Video-still image showing bottom conditions at the Maren site (May, 2008)

### Objectives and sampling design

As (i) the substratum at the site is rocky, (ii) Maren devices will be located close to shore (~400metres), and (iii) the scale of the installation is very small, no qualitative changes to the surrounding benthos are expected by the installation of Maren. If any, some kind of an 'artificial reef' effect is anticipated from Maren by the deployed structures increasing habitat and structural heterogeneity for the existing species community, thus enhancing abundance of individuals and possibly species in the immediate vicinity of the installations.

Our hypothesis is that over time (approximately 1-2 years) species will be associated with the structures, which do not relate to them directly, but indirectly; hence further enhancing an artificial reef effect of Maren. Still images will allow us to suggest indirect community links (secondary consumption / habitat utilization). Standard remote sensing techniques (underwater video and still imagery) are used to measure abundance variables of macrobenthos, both on and surrounding the structures [11]-[13].

Time scales are chosen in relation to the life and reproduction span of most benthic species (1-3 years), as well as to the succession period of benthic communities (several years) and the duration of the project (~3 years).

The main objectives of benthic studies within the monitoring programme are hence to i) assess whether Maren installations cause changes to the surrounding benthic species community (species abundance and composition of macroflora and -fauna) and ii) assess the effect of Maren structures on colonisation with marine species on the structures themselves.

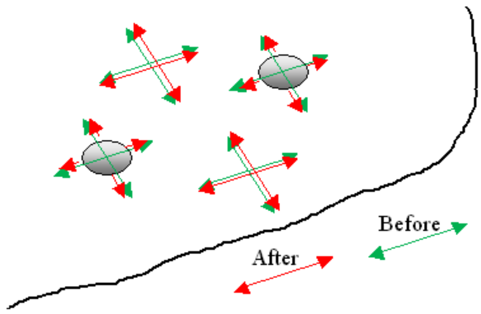


**Figure 6**: Videotransects for assessment of changes in the surrounding benthos of Maren – impact sites (Maren foundations) are indicated by grey circles, control sites are chosen in the vicinity. The red and green arrows show the transects before and after installation.

Objective (i) is measured through quantitative assessment of the macrobenthos (flora and fauna) by video transects within a 20m radius around the installations and around control areas nearby (Figure 6.). The monitoring follows a BACI design [8] i.e. one sampling event before the impact (Maren deployment) and several thereafter annually.

Objective (ii) is investigated via periodic quantitative visual assessment of benthic communities (abundance and composition) in 0.25m$^2$ still image samples by ROV-mounted camera on different structure components (**Figure 7**). The sampling design will be stratified random with 3(4) samples taken per structure component of each WEC (i.e. foundation horizontal, foundation vertical, cylinder, buoy) as well as on the switchgear.

Direct effects measurable as colonization of the structures themselves (generators and switchgear) are considered secondary, in that they affect a part of the environment that is temporary (i.e. generators and switchgear and associated colonizing communities will be removed after 3-4 years). However, we expect indirect effects from benthic colonization of the generators, such as attraction of fauna to the structures (e.g. crustaceans and fish which hide among colonizing vegetation or feed on associated fauna).

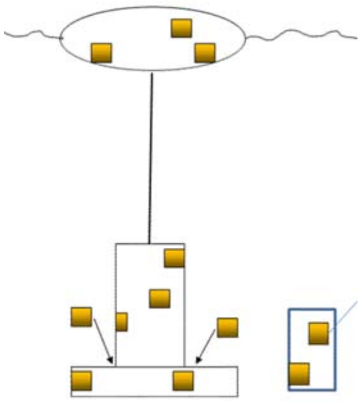

**Figure 7:** Diagram of randomly stratified sampling of benthic communities on Maren component structures. 3-4 still images of 0.25m$^2$ quadrat samples are taken per structure component by camera-mounted ROV, i.e. on foundations (vertical and horizontal surfaces), generator cylinder, buoy and switchgear.

### Holes in foundations

Following experiences with a previous project on the west coast of Sweden (the Lysekil project) using the same type of devices [14], where holes in the concrete foundations have been demonstrated to attract mobile benthic crustaceans such as crabs and lobsters through increasing structural habitat complexity [15] - [20], Maren foundations have also been designed with holes. Usage of holes by mobile benthos such as lobsters and crabs is being documented casually in the current programme – through still images during regular benthic sampling, but is not re-examined systematically.

### Fish

### Fish communities at the Maren test site

The area off and around Runde is very productive, harbouring fish stocks of national and international importance. Some of the most important species are herring (*Clupea harengus*), cod (*Gadus morhua*), saithe (*Pollachius virens*), haddock (*Melanogrammus aeglefinus*), mackerel (*Scomber scomber*) and sand eel (*Ammodytes tobianus*). Herring, cod, saithe and haddock spawn in the region in late winter or early spring (February-April), during which time these species are also fished commercially. In contrast, mackerel frequents the area during fall and is fished at that time. **Figure 8** represents a schematic picture of the vertical distribution of fish in the region.

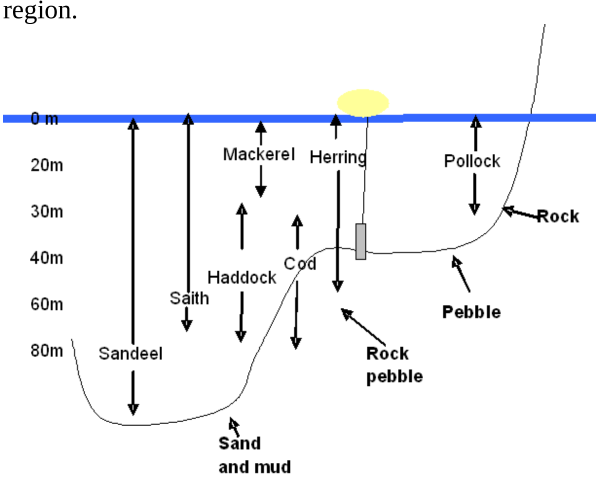


**Figure 8:** Schematic representation of the vertical distribution of the most common fish species at the Maren test site.

### Objectives and design

One of the primary foreseen effects of wave power developments on fish communities is that the structures attract fish by improving food availability and providing shelter and protection from predation, thereby increasing biological diversity locally [16]-[20]. Furthermore, solid structures can influence local hydrodynamics and light climate, influencing epibiota in the surrounding bottom area, which could have additional effects on local fish assemblages. Within the Lysekil project a variety of fish species were observed both aggregated to the foundations as well as using holes in the foundations [1],[14],[19],. On the other hand, it is also conceivable that certain fish may be disturbed by wave power devices because of noise potentially generated by them, which might cause reduced abundance of these fish in the vicinity of such devices as a consequence of avoidance behaviour.

The main objective of the fish monitoring programme at Maren is to investigate whether there is a measurable effect of the installation on fish abundance, distribution (vertical and horizontal) and behaviour (aggregation, vertical migration, etc). The assessment strategy follows a modified BACI design in that there is before- and after sampling, but the control-impact comparisons are replaced by a gradient analysis with increasing distance from the impact site because of difficulties in identifying an appropriate control area.

Fish abundance and species composition will be measured using hydro-acoustic methods, i.e. hull-mounted echo sounder (Simrad EK 60) on a vessel, and results will be shown as density maps separated by depths zones. The method is widely used for registration of fish density and assessing fish stock biomass (e.g. [21]). It has also been tested for environmental assessments of offshore wind power farms [22],[23], but, as far as we know, it will be one of the first times the methodology is employed in connection with a wave power site.

The hydro-acoustic methods will be combined with fishing trials for species identification. Additional observations from benthic ROV-studies (e.g. on fish species and fish behaviour) will complement the quantitative fish abundance data with incidental information, such as fish feeding on benthic organisms colonising the Maren devices or fish seeking shelter under the buoys.

As fish distribution is highly variable over various time scales, sampling will take place to assess diurnal variation (day vs. night) as well as seasonal variation (four sampling events per year during spring, summer, autumn, winter).

### Birds (and marine mammals)

### Seabird breeding colonies at Runde and birds and mammals at the Maren testsite

Runde is well known for housing the most southerly seabird colonies in Norway. With approximately 180,000 breeding pairs annually, these colonies are among the largest in Norway. For a variety of reasons, Runde has received international status as an 'Important Bird Area' (IBA) by BirdLife International [24]-[27]. Breeding seabirds are concentrated along the western steep cliffs of the island, with individual species grouped into separate colonies in distinct vertical and horizontal locations. The densest aggregations of nests are found alongside the southwestern cliffs of Runde, i.e. approximately 1 km of Måganeset, the Maren test site. Breeding seabirds are feeding on a variety of fish and other marine species. (**Figure 8**, **Figure 9**).

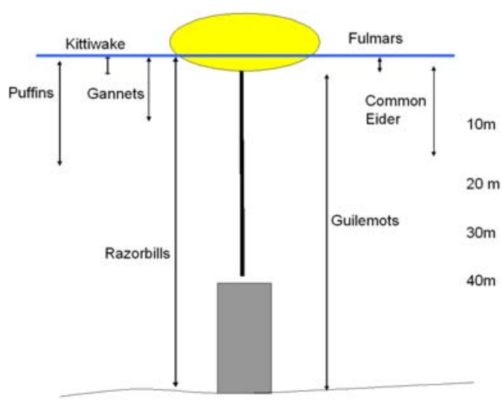


**Figure 9:** Depth Distribution for feeding for the most abundant birds on Runde

Three marine mammal species are regularly sighted in the area, i.e. may be expected to be seen occasionally at the Maren test site: Harbour Porpoise (*Phocoena phocoena*), Common Seal (*Phoca vitulina*) and Grey Seal (*Halichoerus grypus*) frequent the entire region mostly in relation to feeding activity following fish prey, and the two seal species also breed several kilometers northeast of Runde on the protected rocky outcrops of 'Grassøyane'.

### Objectives and design

Generally, the impact on birds from small-scale wave power installations is not thought to be an issue of large concern [28]. The potential impacts on birds from wave power are most likely related to (i) surface structures affecting behavior of birds swimming or feeding around them, (ii) indirectly, through affecting food /habitat availability that may lead to new trophic opportunities (attraction of fish prey by structure components or bivalves colonizing structures) [20]. However, since the seabird colonies at Runde are of utmost importance, both ecologically but also as attractions to bird watchers and nature enthusiasts, effects of Maren on birds are being addressed and quantified with equal emphasis as benthos and fish.

Whereas we have included incidental observations of marine mammals within the bird monitoring programme, a systematic assessment of the potential effects of Maren on marine mammals is not included. The small scale of the test system implies that the probability for negative interaction with these marine mammals is low (e.g. through collisions or indirectly through food availability) [28]. The mammals' activity range extends over much larger spatial scales.

The objectives with the bird study are to describe seabird abundance, distribution (e.g. aggregation on or around buoys), and behaviour (e.g. resting, feeding) at the test site in a modified BACI design, during installation impact and after removal of MAREN structures and by using a gradient comparison with increasing distances from the Maren structures.

The monitoring of the test site area will be performed by scanning the area by telescope from an elevated point on land at Måganeset. Birds will be identified to species level and numbers recorded in relation to a triangular grid identifying sections of increasing distance from the Maren structures at the centre. The grid is to be marked with floats (diameter: ~0,4m). See **Figure 10** below.

[At a late stage in the planning process it was discovered that establishment of the marking floats for the bird observation grid required permission from the Norwegian Coastal Administration (NCA). The necessary application was sent to NCA in June 2009 [29]. This led to a delay of the bird sub programme as no monitoring will take place until a permission has been received. Consequently, the BACI monitoring design will be modified in that 'pre-impact' assessments have to be replaced by observations AFTER the impact has been removed.]

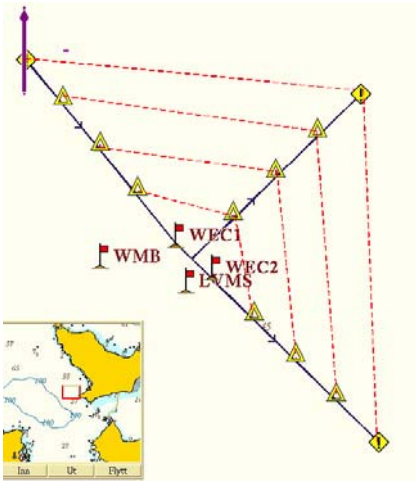


**Figure 10:** Design of the monitoring grid for seabirds. Yellow triangels and squares indicate grid marking floats and red lines delineate the imaginary sections. Red flags indicate Maren installations, i.e. wave energy converters (WEC), switch gear (LVMS) and wave measuring buoy (WMB).

On each sampling occasion, variables (bird abundance and behaviour by species) will be recorded during the same time of day (during 3 hours preferably early morning) on three subsequent days. Ideally, sampling days will be coordinated with the other monitoring components (fish and benthos) but are most dependent on weather conditions (wind / rain). Optimal visibility has high priority. Presence of marine mammal occurrence will be recorded within the bird observation grid.

As birds display different behaviour from season to season, it can be expected that any potential effect of the Maren test site are variable on the same basis. Additionally, the presence of bird species varies during different times of the year. Investigations will therefore take place during the following seasons (i) Overwintering period, (ii) Spring migrating period (iii), Hatching period (iv) Autumn migration period.

### Noise

The potential presence and propagation of underwater noise from the Seabased wave energy device have not been measured before. Underwater noise from wave power devices is an area of general concern as it may interfere with communication of many marine species, especially fish and marine mammals [28]. Fish species that are hearing specialists, e.g. herring , can detect noise from a sound source far away [30],[31]. In contrast, most hearing generalists, e.g.flat fish species, are only able to detect underwater noise a short distance from a sound source. Many marine mammals that use echo location for intra-specific communication have their most sensitive hearing in the high frequency range [31]. At the Maren test site, hearing specialists as well as hearing generalists are present, and certain marine mammals are resident in the general area [4]. Underwater noise generated by wave energy device at the Maren test site will therefore be measured and its potential effects investigated. This will, however, be planned and undertaken during a later stage in the programme.

## 5 Discussion and future plans

This paper gives an overview of the planning phase of the Maren environmental monitoring programme. In mid June 2009, the first field studies for fish and benthos were carried out successfully. Preliminary results suggest that both benthic and fish communities were characterised by low abundance and diversity at that time, and proposed monitoring methods were proven appropriate for the communities studied. More extensive results will be disseminated at a later stage.

In this study, only Maren site- and scale-specific issues are addressed. For this very reason, results from monitoring the Maren test site cannot be simply extrapolated to larger scale sites at other locations, where potentially different effects will require different fundamental approaches. Some of the impact investigations might, after adjustments of scale, be applicable to larger farms, such as the effects of potential noise propagation from a Seabased device. Since the type of wave energy converter is the same as at Islandsberg test site and since the size of the sites is similar we expect that we could assess transferability of results through a compairision of the two sites. In addition to evaluating the monitoring programme for the Maren project, its usefulness for future, larger-scale farms at other locations will be assessed as well. Within the planning phase of the programme, the set-up and results from environmental monitoring programmes of wind power farms as well as other sub-sea structures have been considered. In addition, experiences from other marine energy test sites have been reviewed in the planning process. However, more detailed studies of other environmental monitoring programmes, the design and results are to be undertaken during the course of the Maren project and the possibilities for future collaboration regarding environmental issues between different wave power test sites is encouraged: sharing experiences, transferring knowledge and co-ordinating research could be useful for the entire industry as well as the public and, most importantly, benefit the environment by enhancing sustainability. Joint efforts for the development of both standardised and more elaborate and methodologies for environmental assessments of wave power farms would potentially offset limitations to monitoring programmes at smaller test sites, such as financial restrictions and requirements for cost-effectiveness, as well as scale limitations. One challenge with undertaking monitoring of such a small site as the Maren test site is finding the right scope of the project and finding the balance between what effects potentially could occur and should be monitored and to what extent the monitoring could be of use for future large scale farms. An extensive monitoring program would not be motivated as there will be a limited use of the results of the program, in particular for future studies. At the same time the "learning by doing" approach is considered crucial for getting prepared for future large scale monitoring and is the reason why the monitoring should not be too simple.

Due to the fast establishment of the Maren test site, the time available for undertaking baseline studies of the environmental conditions before deployment of the plant has been restricted. Consequently, both the design of the programme and supposedly also the results, are somewhat implicated and bound by the limitations of – spatial and temporal - scale.

At the Maren test site, one of the experiences that can be extended to larger scale farms are the sequence and process of designing the programme, i.e.

1. Design of a monitoring template
2. Identify a group of specialists developing the programme in collaboration
3. Identify potential environmental components that might be affected
4. Develop monitoring strategies suitable for potential environmental effects and scale of the plant
5. Design the programme
6. Review the programme
7. Execution and reporting of the programme
8. Internal and external review
9. Public communication and transparency

## 6 Conclusions

The main conclusions of the Maren environmental monitoring programme so far are the following:

The consent process for the test site has run very smoothly and the consent was obtained within six months from submitting the application.

To date (June 25th, 2009), the planning of the environmental monitoring has been undertaken and the first field studies for fish and benthos carried out. The rest of the field studies are to be carried out during 2009-2011.

The planning phase is crucial for the monitoring programme but has been more time and resource consuming than anticipated.

It was discovered during the planning phase that a permission from the authorities was needed for the establishment of a survey field for bird and marine mammals monitoring. The permission has not yet been obtained and the process has led to a postponement of the bird monitoring activities, as well as to modification of the monitoring design for that monitoring component.

The scope of the Maren monitoring programme has been set as a result of balancing between the two objectives of the programme: monitoring of environmental effects of the test site and gaining knowledge and experience of monitoring for wave power farms.

The planning work has been undertaken as an iterative process, where several researchers have been involved and where discussions have been a crucial part.

At the Maren test site fish, benthos, birds and noise will be investigated and an individual sub-programme has been established for each area, the integration of the sub-programmes is considered to be of high importance

There is a general need for further development of methodologies for measurements of environmental effects of wave power devices. The possibilities for individual operators to develop methodologies is limited and transferability of results among different monitoring programmes is only possible if wave power technology, site characteristics and operational scales are similar.

In addition to the investigations outlined in the environmental monitoring programme, a communication plan to the media and the general public accompanies the programme and is considered an essential prerequisite for transparency and public acceptance of the programme.


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