Towards a Joint Monitoring Programme for the North Sea and the Celtic Sea (JMP NS/CS)

CASE STUDY BENTHOS

May 2015

EUROPEAN COMMISSION
DIRECTORATE-GENERAL
ENVIRONMENT
Directorate D - Water, Marine Environment & Chemicals

Co-funded by the European Union - DG Environment
Grant Agreement No. 07.0335/2013/659567/SUB/C2
Programme New Knowledge for an integrated management of human activity in the sea (ENV/PP 2012/SEA)

<u>This report can be cited as follows</u>:

Van Hoey Gert, Steven Degraer, Marie Vanden Berghe, Francisco Marco-Rius, Joey O'Connor, Silvana Birchenough, Henning Reiss, Johan Craeymeersch, Julia Wischnewski, Lisette Enserink, 2015. *The benthos case study in the JMP project: The way to a coordinated monitoring program for the benthic marine ecosystem.* Document produced as part of the EU project: 'Towards a Joint Monitoring Programme for the North Sea and Celtic Sea' (Ref: ENV/PP 2012/SEA). 26 pp.

<u>Authors & contributors</u>:

Van Hoey Gert, Steven Degraer, Marie Vanden Berghe, Francisco Marco-Rius, Joey O'Connor, Silvana Birchenough, Henning Reiss, Johan Craeymeersch, Julia Wischnewski, Lisette Enserink.

<u>Acknowledgements:</u>

We also like to thank all people involved in the JMP NS/CS project or participating in the project meetings for their contributions and discussion on the project outcome.

<u>The JMP NS/CS project partners are as follows:</u> RWS (NL), RBINS (BE), MSS (UK/Scot), DTU Aqua (DK), IMARES (NL), CEFAS (UK/Eng), TI (GE), JNCC (UK/Eng), ILVO (BE), AU DCE (DK), IFREMER (FR), MI (IE), SLU (SE), SMHI (SE), SwAM (SE), IMR (NO), BfN (GE), BSH (GE).

Table of Contents

The benthos case study in the JMP project: The way to a coordinated monitoring program for the benthic marine ecosystem.

1. Introduction

The benthic ecosystem plays an important ecological function within the marine ecosystem (Braeckman et al., 2010; Stief, 2013) and is a good indicator for temporal and chronic disturbances (Dauer, 1993). Benthos is therefore one of the ecosystem components considered for the evaluation of the status of the marine ecosystem under different nature directives, such as the Marine Strategy Framework Directive (MSFD) (see Descriptors 1 and 6). Within the MSFD, three aspects regarding the benthic ecosystem are taken into account: (1) benthic species distribution/occurrence (e.g. biogenic reefs, benthic species of conservation importance); (2) benthic habitat distribution; and (3) benthic habitat condition. The assessment of distribution of species itself can be based on field data and/or modelling (Reis et al., 2015). The evaluation of benthic habitat distribution needs to be based on habitat mapping/modelling approaches, which can be determined by underwater acoustics (Galparsoro et al., 2013). Benthic habitat condition can be assessed by means of multi-metric or multi-variate indicators (Van Hoey et al., 2013), which were mainly developed in the purpose of the Water Framework Directive (WFD) (Borja et al., 2007). A wide variety of benthic indicators for marine systems exists (for a most recent overview see: http://www.devotes-project.eu/devotool/). All those indicators require the collection of species presence/absence and abundance and/or biomass data, which can be collected on various ways (cores, grabs, dredges, video, …). Benthic species-abundance data, collected in one or another way, is the fundament of most indicators related to the evaluation of the benthic ecosystem.

For the MSFD monitoring, with emphasis on large assessment areas, leads this to very high requirements for the monitoring design. The aim of the MSFD monitoring program is to detect a trend or the non-compliance with a threshold value, leading to a well-defined policy action (good environmental status or not). Therefore, the monitoring need to be executed in an appropriate way and many aspects determine such design (Hayward et al., 2015). First, to have confidence in the assessment (policy action needed or not) carried out, appropriate numbers of samples in each strata are required, which are determined by the power and effect size required to be captured and the natural variability of the characteristics (e.g. species richness, abundance) of the habitat in question. Second, a stratified (habitat) monitoring design is required to undertake a proper assessment of benthic habitat condition under the MSFD (Van Hoey et al., 2010). This stratification of the area need to be known, and can be based on various approaches (Galparsoro et al., 2012). The benthic characteristics within a stratum can be very variable, which set other requirements for the monitoring (e.g. sample effort) in heterogeneous versus homogeneous habitat types. This stratification in the North Sea region is well known (Rees et al., 2007; Reiss et al., 2010). Third, an appropriate sampling technique (grab, corer, video, …) needs to be defined and the data needs to be collected and analysed based on agreed protocols. A lot of literature exists that focuses on those aspects of benthic monitoring (Kingston & Riddle, 1989; Lampadariou et al., 2005; Degraer et al., 2007;). Fourth, the determination of the temporal aspect of the monitoring, due to the fact that in temperate regions the benthic characteristics shows clear seasonal and year-to year patterns (Van Hoey et al., 2007; Kröncke et al., 2011). The temporal aspect is important, but can be decided on once a spatial monitoring strategy is worked out. This spatial monitoring strategy can be repeated in the necessary time intervals (every year, every 3 or 6 years [1 MSFD assessment cycle]).

Currently, there is no common assessment or monitoring strategy and standard operating protocol (SOP) for collecting these type of data within the North Sea region. The main benthic monitoring activities are in relation to impact assessment of human activities. The collection of seabed samples requires the use of a vessel and laboratory analysis of faunal samples to determine and count species. Therefore, the collection of benthic fauna is time consuming and labour intensive (Kingston & Riddle, 1989). Because of the relative high costs (especially for offshore sampling), the benthic monitoring should be executed in a time- and cost effective way and collected in the most appropriate way to meet the monitoring objectives. The ways proposed for saving money in benthic monitoring is to use presence/absence instead of abundance (Bates et al., 2007), another is related to the taxonomic sufficiency, *i.e*. the use of high taxonomic levels (e.g. family instead of species (Warwick, 1988; Dauvin et al., 2003), and the use of different methods (type of sampler, mesh size used by sieving) (Lampadariou et al., 2005; Degraer et al., 2007). These methods can reduce the costs today, but imply a ‘short termism’ and could be costly in coming years (Borja et al., 2013). Recently, the application of genetic tools (Environmental DNA, meta-bar coding) pop-up to monitor and assess benthic diversity in a more cost effective way (Aylagas et al. 2014), but cannot replace the regular assessment entirely.

Therefore, an efficient monitoring program for benthic habitat condition on a large scale has to be looked for. This requires a policy that goes beyond member states’ territorial borders. That such attempts can be successful is proven by the North Sea Benthos project actions of the ICES Benthos Ecology Working Group of 1986 and 2000 (Heip *et al*., 1992; Künitzer *et al*., 1992; Rees et al., 2007) and can be in a modified way serve as an example of coordinated monitoring in function of the assessment of the benthic ecosystem on a large scale. This aspect is worked out within the project ‘Towards a Joint Monitoring Program for the North Sea and Celtic Sea’ and results were outlined in this report.

The aim of this report is to reflect on the conditions for an appropriate, efficient regional benthic monitoring program that delivers the necessary data for various indicator types assessing benthic habitat community condition under the MSFD on a large scale (*e.g*. North Sea).

2. Material and Method

2.1 Database

The MSFD imposes a series of key steps which have to be undertaken by Member States (MS) in order to reach a good environmental status of the marine waters by 2020. One of these key steps is to develop and implement a monitoring programme (art. 11). MS had to report on their monitoring programmes to the Commission in October 2014.

In its original version, the database tried to gather all the existing and on-going marine monitoring conducted by partners involved in the JMP project. Because MS were already working on the reporting of their national monitoring under the MSFD, the database contained a mixture of on-going and planned MSFD monitoring programmes. Unfortunately, the lack and/or incompatible information provided by some MS for 'non-MSFD monitoring' made the final product not accurately/easily searchable. The JMP consortium therefore agreed to focus only on the legal MSFD sub-programmes.

In order to get an overview of the MSFD monitoring sub-programmes in the North Sea, a searchable meta-database has been developed. The 'new' database integrates the legal sub-programme metadata reported in October 2014 as well as additional information required by the project (e.g. platform, seasonality of the sampling,…). It also contains an overview of indicators and environmental targets reported to the European Commission MS in July 2012.

2.2 Test data sets North Sea (NSBP 1986 and 2000)

Ideally, analyses on benthic data of the greater North Sea , collected on a spatial and temporal scale are needed to investigate the requirements for a North Sea wide benthos monitoring program. The following spatial datasets of the greater North Sea (Figure 1) are available for this purpose: the North Sea Benthos Survey of 1986 (NSBS 1986) (Heip *et al*., 1992; Künitzer *et al*., 1992) and the North Sea Benthos Project of 2000 (NSBP 2000) (Rees et al., 2007). These datasets, compiled by the ICES-Benthos Ecology Working Group (BEWG), are readily and publicly available, and have been scrutinised for consistency during earlier work (Rees et al., 2007). The survey of 1986 was funded, which lead to a dedicated cruise for sampling the central and southern North Sea, and to arrange for common sampling procedures. The data were supplemented by an earlier extensive grid survey of the northern part conducted by Scotland (see e.g. Eleftheriou and Basford, 1989).Sampling in the southern North Sea for NSBS 1986 was conducted in April/May, 1986, employing a 1 mm mesh sieve to extract the macrofauna. However, sampling in the northern North Sea was conducted between 1980 and 1985, using a 0.5 mm mesh sieve, as part of an earlier synoptic survey of this area by FRS (Scotland). Further details are given in Eleftheriou and Basford (1989), Heip *et al*. (1992), and Künitzer *et al*. (1992).

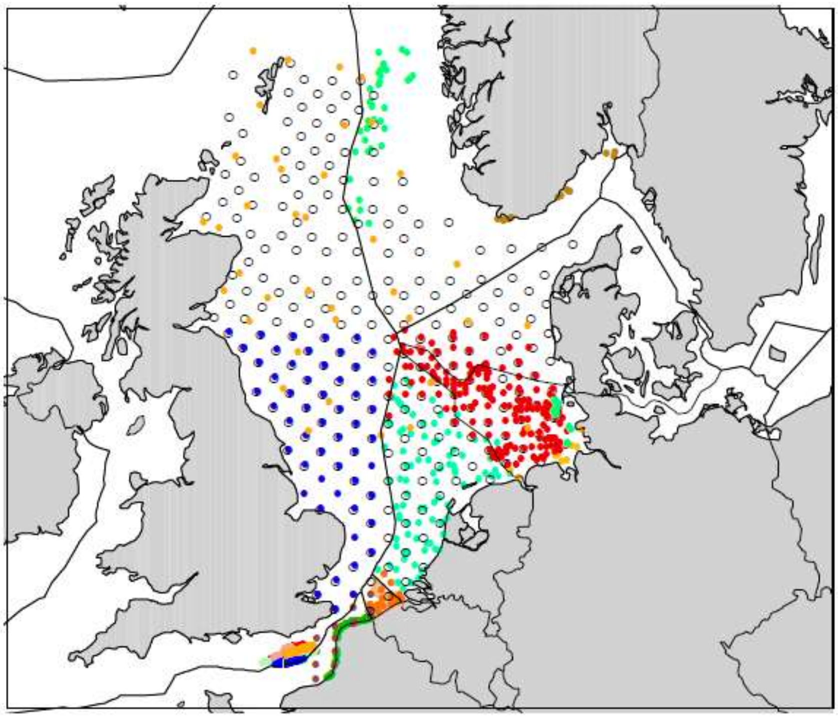

Figure 1. Location of sampling stations (1986 and 2000 surveys). The different datasets contributing to the NSBP 2000 are colour-coded. The NSBP 1986 stations are the open dots.

No comparable funding for a collaborative North Sea wide survey was available in 2000, and much of the data employed was collected for other purposes, for example, to meet national monitoring, regulatory, or research needs (Rees et al., 2007). This resulted in more uneven coverage, e.g. a concentration of stations in parts of Belgian waters and high replication at stations in Norwegian waters. Sampling occurred mainly in spring and early summer 2000 and covered almost the whole North Sea from the English Channel to about 60°N. The Norwegian dataset contained information mainly from studies around offshore oil and gas platforms. The data was collected with boxcorers, Day or Hamon grab, Van Veen grab and sieved on a 1 mm mesh sieve. Further details are given in Rees et al. (2007). Due to the higher variability in sampling procedures and the different origin of the data, much effort was committed to the harmonization of datasets on the macrobenthic infauna and associated environmental variables from different sources, which included desk-based evaluation of combined species lists and some laboratory work to resolve identification problems (Rees et al., 2007).Both dataset of species-abundance data are standardized and appropriate for the purpose of this study.

2.3 Analyses: statistical analyses and mapping

An appropriate collection of benthic species-abundance data is needed for a confident assessment of benthic habitat condition by any type of benthic indicator. The conditions for a monitoring programme that were analysed in this study are: (1) the stratification; (2) the allocation of samples; (3) sampling effort; (4) effort/power. Benthic indicators are containing different type of parameters: an abundance related, a diversity measure (e.g. species richness, Shannon diversity, …) and a species sensitive/tolerance parameter (e.g. AMBI, Borja et al., 2000). All parameters can be calculated based on a species-abundance dataset. Therefore, there will be focused in this study on the variability of those underlying parameters of the benthic indicators (species richness, abundance and AMBI) on determining appropriate conditions. This will allow us to draw conclusions regarding the monitoring needs, that are applicable to the wide set of benthic indicators.

Stratification process

The goal of stratification is dividing the survey area into suitable (spatial) subunits, which are sampled and evaluated separately. In this way, you strive to obtain more similar measurements within each of the strata, and clearer differences between different strata. This increases the certainty – or reliability – of the measurements. The stratification of benthic habitats in the North Sea region are well known (Rees et al., 2007; Reiss et al., 2010). This is of course helpful when optimizing the sampling for a single indicator. It is adapted to measure the particular parameter needed for this indicator, in our case study the species-abundance of benthos. However, the purpose of the JMP project was to work towards a joint monitoring approach, and we therefore looked for a type of stratification that would be applicable for a whole range of indicators at the same time. During a workshop with specialists for the three case studies in JMP and external experts, we decided to use strata, which are based on ecosystem characteristics. The main idea in this is that the key characteristics of the ecological sub-regions of the sea would be rather stable, compared to the indicators measured. And hence, they could be maintained over a long term and for many indicators. We decided to apply a stratification scheme, which was developed in the just finalized EU project VECTORS to be applied in a North Sea-wide ecosystem model 'Atlantis' (Hufnagl et al., unpublished data). This form of stratification is based on a combination of environmental and ecological parameters in subsections of the survey region, which remain rather constant over time. Therefore, we expected them to be suitable for long-term monitoring programmes.

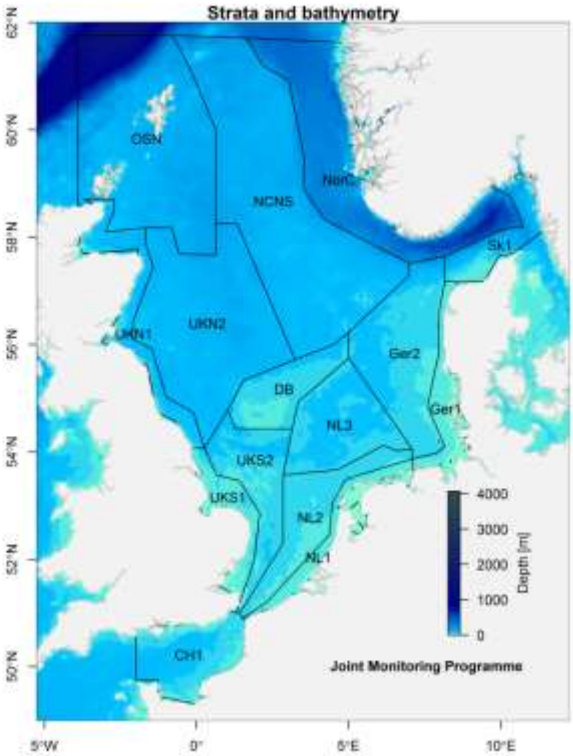

Figure 2: Strata of the ecosystem model 'Atlantis', modified for JMP to reduce the number of strata. Here overlaid with bathymetry.

Allocation principles

After definition of the most suitable strata (spatial subunits for the sampling), the most appropriate distribution of stations between these different strata has to be found. Different options exist for allocating stations to the previously defined strata. Equal allocation distribute the samples equal over the strata. Proportional allocation take into account the size of a strata, which means that larger strata get more samples assigned. The most refined approach: the so-called Neyman allocation, which derives the best distribution of samples between strata by involving both, the proportional area of the stratum, and the variability of the measured parameter in each stratum. The more variable the measured indicator, the more stations are needed to get a reliable estimate.

Breakpoint analyses for guiding total effort

With this analysis, we wanted to find a way to determine how many samples we need to increase the quality of the estimate. Based on the relation between the uncertainty of the measurement, and the number of stations sampled, an advice on sample effort can be made. Visual, you can see on those graphs that at certain sampling effort, the adding of extra samples lead to a very low decrease in uncertainty (asymptotic value). An estimate of this, is best made mathematically, which is done by a systematic method to determine the breakpoint in these curves, in order to identify the number of stations that would be needed to improve the quality of the estimate. The criterion is a considerable improvement in the certainty – or phrased inversely, a reduction in the standard deviation of the estimate. See activity E report for the details on the mathematical method.

Effort/power per strata based on 86 and 2000 comparison.

We need to know when we can be certain that a difference we observe in the data is really a change. In a related analysis, we investigated how likely would we be to detect a difference if the species abundance changed by 10, 20, or 30% over a given time period. In this case study, we have only two temporal moments (data of 86 and 2000), where we can test the power to detect certain changes between both periods, based on the common samples. We have 57 stations in common between 86 and 00. In a "normal" study we use the mean abundance (only one value per station), but here we use different abundance of different species per station, so the power of detection changes is based on different abundances (not only in the mean one). The result is a powerful and precise analysis of changes in North Sea. See activity E report for the details on the mathematical method.

3. Results

3.1 Existing monitoring programs within North Sea area

Benthos data (habitat and species) are mainly collected within the following frameworks:

- National monitoring programs, which are financed by the respective national governments (e.g. the Netherlands). Most of the MSFD programs are considering the WFD monitoring programs (Table 2).
- Compliance monitoring by industry for permits and environmental impact assessment of human activities (constructions [harbors, wind farms], aggregate extraction, dredging and dredge disposal, …) (e.g. Belgium) (Table 2).
- Institutional monitoring of long term time-series (sometimes externally financed, mostly institutionally financed). No example of this type of benthic monitoring program reported for MSFD monitoring.

These different types of monitoring program are characterized by different objectives and each have their own mix of strategies, sampling designs and protocols. Ships are used as the platform for benthic surveys, and monitoring is mostly dedicated to benthic work (e.g. benthic monitoring surveys do not usually include other data type collection). A part of the benthic monitoring is part of an integrated, multidisciplinary program (e.g. environmental monitoring of mainly biological and chemical aspects [CSAMP, ILVO Monitoring, …]).

3.2 Ideal monitoring program

Based on the 1986 and 2000 benthic monitoring survey's, the conditions for constructing an optimal sampling survey for benthos within the ecosystem strata (see material and method) can be determined.

3.2.1 Allocation of the samples

A proper determination of the strata is necessary. In this study, an ecosystem stratification is used, because it allow an application to various ecosystem components and standardize the sampling across the ecosystem (Marco et al., in prep). The variance in benthic characteristics within the strata and the allocation principle of the samples will influence the sampling effort. An appropriate choice will improve your design and increase the confidence. The most optimal design is achieved when the samples were allocated regarding the Neyman allocation principle to the 'Atlantis' strata of the North Sea for species richness (Figure 2). An equal allocation of your samples lead to a strong increase of the variance with the same sample effort, compared to proportional and Neyman allocation. This need also to be investigated for the two other benthic parameters.

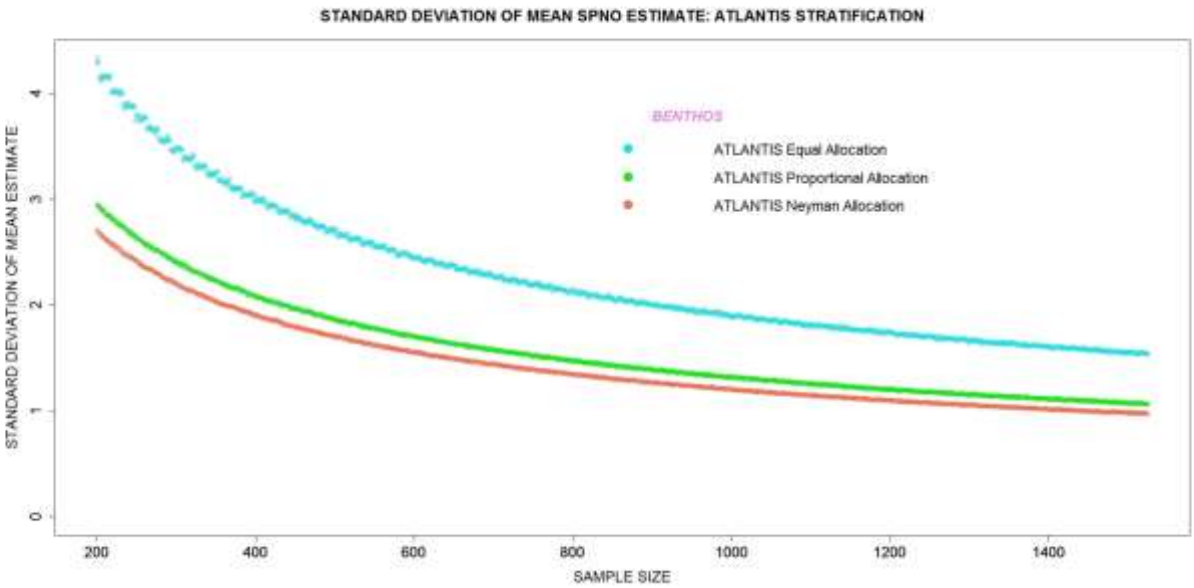

Figure 3: Standard deviation (SD) of the mean species richness (A lower SD can be considered to provide a more reliable estimate) against sample size.

3.2.2 Total effort

The Atlantis stratification and allocating the samples following the Neyman allocation is the best strategy. Therefore, guidance on the total sample effort needed, is based on this “curve". The analysis tries to compartmentalize the curve (between an effort of 370-1525) in parts that share “similar” quantity of variability. This means that there are three different parts in the curve: 370 to 551, between 551 and 777, and after 777. The number of breakpoints in the curve are calculated statistically. With this, we can conclude that there is not much difference doing 1525 stations (as in the 86 + 00 dataset) and doing 777 (lower part of the breakpoint). The minimal effort needed seems to be 551. This effort estimate is based on species richness and need also to be calculated for the two other benthic characteristics.

3.2.3 Design

Table 3: Overview of the amount of samples allocated to the different strata by a total effort of 551 samples.

strata	size strata	variance	Number of samples	Samples 1986-2000
UKS1	0,022	134,59	13	13
NL1	0,024	39,64	5	315
Ger1	0,024	44,48	6	63
Sk1	0,026	66,44	12	4
UKN1	0,033	106,26	25	18
DB	0,035	48,31	12	57
NL2	0,047	23,84	11	110
UKS2	0,048	44,36	21	33
CH1	0,050	44,63	23	509
NL3	0,056	20,62	13	93
Ger2	0,076	19,52	22	106
NorC	0,104	24,73	58	14
UKN2	0,131	21,75	78	66
OSN	0,142	17,16	72	36
NCNS	0,183	26,26	180	89
TOTAL			551	1526

An example of a benthic monitoring design for the North Sea is given in figure 4. Based on the breakpoint analyses, we can propose that 551 samples are a good number to evaluate changes in species richness within the North Sea. In table 3, the number of samples per strata with this total effort are shown, based on the Neyman allocation principle. It seems that the deeper areas need more effort compared to the shallower and coastal parts of the North Sea. For example, the NCNS strata need to be sampled most intensively, whereas Ger2, NL2 and DB need less effort. Strata with a rather similar size, but a higher variance in species richness need more samples (e.g. UKS1 versus NL1). For certain strata (UKS1, Sk1, NorC, UKN1), the amount of samples available for the analysis is very low (<20), which can also be the reason for the very high variance (e.g. UKS1 and UKN1). Therefore, the current sample suggestions are maybe not ideal.

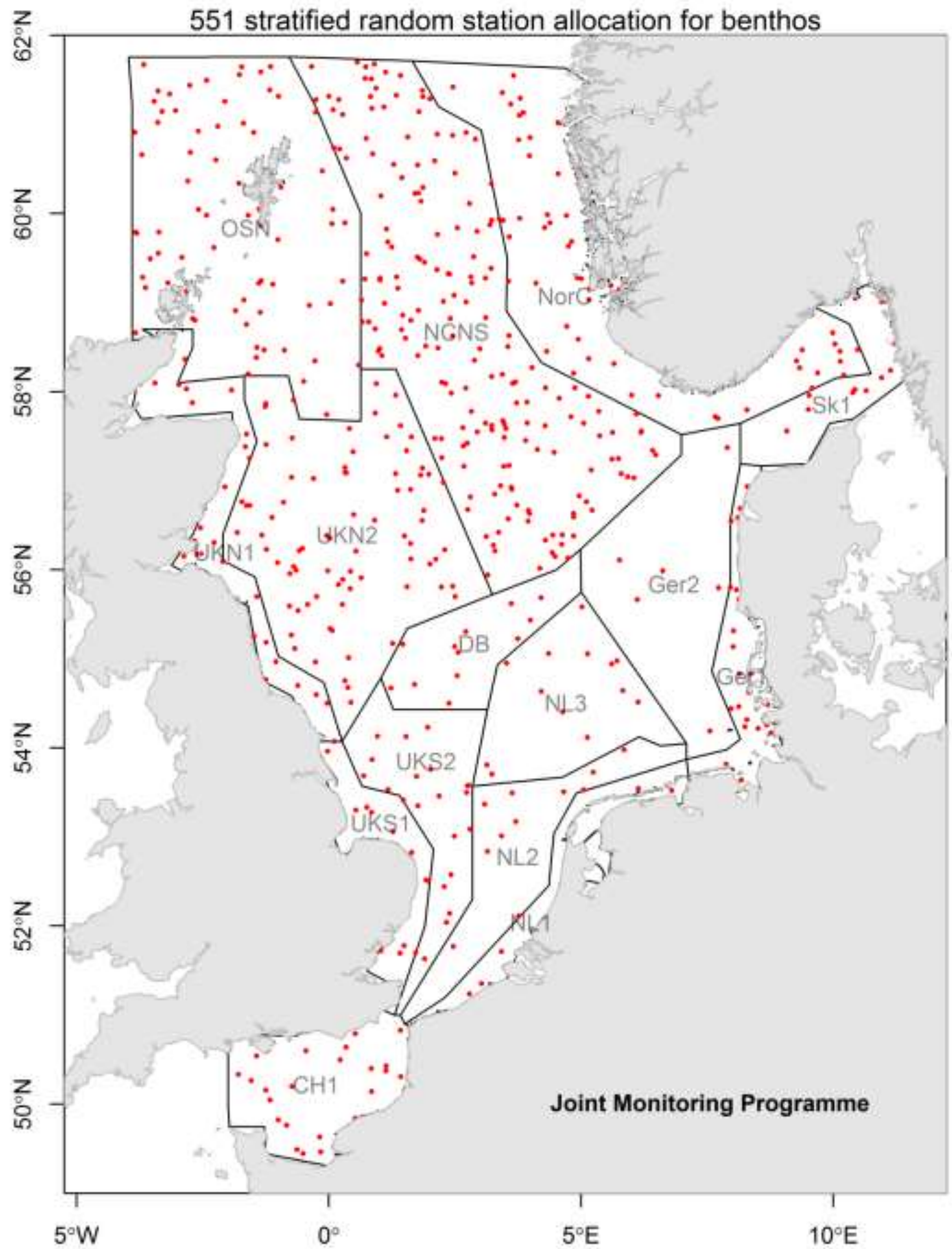

Figure 4: An example of a stratified random sampling design for benthos within the North Sea.

3.3 Effect size and power

Power- effect size obtained by the 1986 – 2000 survey to detect changes in species abundance (a set of common benthic species). The ability to detect certain changes (effects) in species abundance is very different between the investigated strata. Especially, in the coastal area's (UKS1, NL1, Ger1) too few sampling points are now available to detect certain changes (less than 20%) with a high confidence.

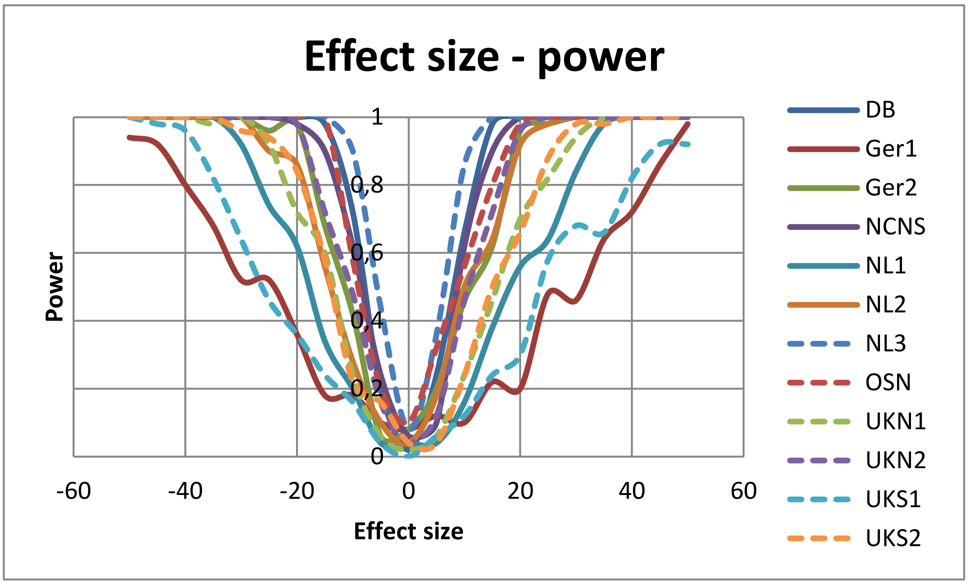

Figure 5: Relation between effect size and power for comparing changes in species abundance in certain North Sea strata.

4. Discussion

Due to the variety of benthic sampling strategies employed within the North Sea region, a regional monitoring strategy is advisable to achieve a regional assessment of benthic habitat condition. This does not need to be a completely new and independent monitoring program from the national programs currently in existence. A good example of this can be seen within the ICES BEWG work, which has undertaken a North Sea wide benthos evaluation on two occasions to date (1986 and 2000) (Heip *et al*., 1992; Künitzer *et al*., 1992; Rees et al., 2007). The first study was based on a gridded sampling design that was sampled simultaneously by different institutes. The second was based on a voluntary collection of benthic data from the year 2000 originating from national or project related monitoring programs. Both exercises have shown that a regular evaluation of the benthos on the North Sea scale can have benefits (Rees et al., 2007; Reis et al., 2009). The analysis in this paper shows that both strategies were not ideal, but a more optimal design can be delineated from it. It is obvious that such North Sea wide sampling design can be executed in cooperation with the ongoing monitoring on the member state level by multiple use of the sampled data and slightly allocating some sampling locations. In every member state, dedicated national surveys and industrial monitoring is ongoing, which can be used as building blocks to form this North Sea wide sampling design. The need for some extra sampling cannot be excluded, but will lead to higher value for money, if this serve multiple use. If some sampling locations (e.g. offshore locations) or not in the neighbourhood of ongoing monitoring areas, benthic samples can be collected by ships of opportunity to save extra ship time costs. This for example during fishery surveys, which cross the entire North Sea several times a year and experiments at the IBTS surveys show that benthic sampling can be added to a fishery survey (see activity C report).

4.1 Stratification

An ecosystem stratification process is used, which is of course ideal to align monitoring needs for different ecosystem components at the same spatial scale. The benthic habitat boundaries are in line with this North Sea ecosystem stratification, but not exact of course. This is also a general approach, which exclude certain specific, local habitats (e.g. gravel beds [Klaverbank, the Netherlands]; Muddy habitat near estuaries [e.g. *Macoma balthica* habitat near Scheldt estuary]. There are still some sedimentological differences within certain ecosystem strata if there is zoomed in on a local scale. This does not hamper the monitoring or assessment on a large scale, where the objectives are different from local monitoring.

4.2 Sampling effort

The results show very clear that the most optimal large scale benthic sampling design can be obtained by distributing your sampling effort according to a Neyman allocation principle on the Atlantis strata. For evaluating changes in species richness it seems that a set of 777 samples is appropriate to have a "similar" variance level than the 1986-2000 dataset. Of course it is under the assumption that we stratify (Atlantis) and we allocate the samples following the Neyman allocation. In inappropriate allocation of those samples will lead to an increase of the variance with 1 or more for the same effort. This means that your confidence of your assessment decrease a lot.

4.3 Current gaps and needs

In this section the gaps and needs regarding the development of a regional benthic monitoring program are outlined.

- Sample resolution is rather complex (i.e. spatial coverage + temporal aspect).

- Different assessment approaches and monitoring objectives at the national level require different data collection methods and designs (e.g. time of year), than the integrated one. As seen in table 1 and 2, there is still quite some difference in the benthic MSFD monitoring.
- Monitoring must be seasonally fixed across all programs, and all ‘common’ data needs to be collected and analysed based on agreed protocols (cf ISO 16665 norm). Still different ways of collecting benthic species-abundance data between member states, which require harmonisation (same methods) or calibration (comparison of methodological differences), despite the existence of a SOP (ISO 16665 norm).
- Coordination group required to steer direction of this monitoring. In fishery monitoring such coordination groups exist, but is lacking for environmental monitoring. A constructive network to build this up can be found in the ICES BEWG in combination with the JMP NS/CS network. This latter covers all relevant institutes (18) in 9 countries that are responsible for monitoring in the North Sea sub-region, concerning both fisheries and environmental monitoring.
- Difficult to stratify monitoring sampling where background data are limited (e.g. habitat extents and boundaries). This is not a major problem for the North Sea, which is well known. But is a gap if you apply this approach to other areas.
- Multinational dedicated funding for Joint Monitoring development, coordination and implementation is lacking and still needed. Extra costs for sampling where minimal with this approach, but additional money needed to bring it on an international level and to allow coordination.
- There is still a way to go. Nevertheless opportunities are identified to coordinate benthic monitoring and to come to a step wards process to join the monitoring effort (regional scale), with as starting point the national surveys.

4.4 Benefits and risks

Going towards a more coordinated monitoring for certain ecosystem components (e.g. benthos) on a regional scale has of course lot of benefits, but also risks were accompanied with it.

Benefits:

- Existing monitoring data/programs (national survey, industrial monitoring) can be used to increase regional data series (e.g. 1986, 2000,...). The collected data is used for different purposes , which create more value for the invested money.
- Joint co-ordination using agreed protocols.

- Improved knowledge of sampling design and techniques.
- Possible financial savings, at least a better value for the invested money
- Extra training regarding sampling, taxonomy, …
- The collected data can be used for other initiatives (modelling, habitat ground throuting, …)
- Coordination across fields (e.g. integrated monitoring and assessment)
- Existing monitoring platforms can be used to collect data.
- Integrated, regional dataset which can be stored in international data networks (e.g. Emodnet and Seadatanet), so it is widely, publicaly available data. In this way, the data is stored in a standardised way.

Risks:

- Failed collaboration (countries not adapting their local monitoring to fit the regional scheme). Member and institutional boundaries, which lead to a status quo (see activity D report)
- Duplication of effort if national and regional monitoring programmes are not joint and/or integrated optimal.
- It will need some time to reach such optimal, integrated regional benthic monitoring program.
- Accuracy dependent on protocols produced and level of harmonization and calibration.

4.5 CONCLUSION

A regional coordinate benthic monitoring program is needed and can be reached in an efficient way. This requires some changes in attitude on institute and member state level. A regional coordination platform is needed to facilitate this process of coordinating the program. If everyone (institutes, member states) contribute to such regional benthic monitoring program, a lot of efficiency and value for money in relation to the assessment of benthic habitat condition can be obtained.

Successful implementation of this joint or 'coordinated' monitoring will result in improved coordination and efficiency of programs for marine monitoring and assessment. Such program can be built based on the individual institutional and member states monitoring programs, but with a good shared understanding of the scope of their individual programs. This enables us to respond more effectively to pressures affecting the benthic ecosystem on a wider scale.

Therefore, an efficient monitoring program for benthic habitat condition on large scale has to be looked for in coordinating and harmonizing the ongoing benthic monitoring, rather than developing a new one.

5. References

Aylagas et al. 2014. Environmental status assessment using DNA metabarcoding: towards a genetics based marine biotic index (gAMBI

Borja, A., Josefson, A.B., Miles, A., Muxika, I., Olsgard, F., Phillips, G., Rodriguez, J.G., Rygg, B., 2007. An approach to the intercalibration of benthic ecological status assessment in the North Atlantic ecoregion, according to the European Water Framework Directive. Marine Pollution Bulletin 55, 42–52.

Borja, A.; Elliot, M, 2013. Marine monitoring during an economic crisis: The cure is worse than the disease. Marine Pollution Bulletin 68, 1-3.

Braeckman, U., Provoost, P., Gribsholt, B., Van Gansbeke, D., Soetaert, K., Middelburg, J.J., Vincx, M., Vanaverbeke, J., 2010. Role of macrofauna functional traits and density in biogeochemical fluxes and bioturbation. Marine Ecology Progress Series 399: 173-186.

Degraer, S., Moulaert, I., Van Hoey, G., Vincx, M., 2007. Sieving alive or after fixation: Effects of sieving procedure on macrobenthic diversity, density and community structure. Helgoland Marine Research 61, 143-152

Eleftheriou, A., and Basford, D. J. 1989. The macrobenthic infauna of the offshore northern North Sea. Journal of the Marine Biological Association of the UK, 69: 123–143.

Galparsoro, I., Connor, D.W., Borja, A., Aish, A., Amorim, P., Bajjouk, T., Chambers, C., et al. 2012. Using EUNIS habitat classification for benthic mapping in European seas: present concerns and future needs. Marine Pollution Bulletin, 64: 2630–2638.

Galparsoro, I., Borja, A., Kostylev, V.E., Rodriguez, J.G., Pascual, M., Muxika, I., 2013. A process-driven sedimentary habitat modelling approach, explaining seafloor integrity and biodiversity assessment within the European Marine Strategy Framework Directive. Estuarine Coastal and Shelf Science, 131, 194-205

Heip, C., Basford, D., Craeymeersch, J. A., Dewarumez, J. M., Dörjes, J., de Wilde, P., Duineveld, G., Eleftheriou, A., Herman, P. M. J., Niermann, U., Kingston, P., Künitzer, A., Rachor, E., Rumohr, H., Soetaert, K., and Soltwedel, T. 1992. Trends in biomass, density and diversity of North Sea macrofauna. ICES Journal of Marine Science, 49(1): 13–22.

Kingston, P.F. & Riddle, M.J., 1989. Cost effectiveness of Benthic faunal monitoring. Marine Pollution Bulletin, 20 (10), 490-496

Kröncke, I., Reiss, H., Eggleton, J.D., Aldridge, J., Bergman, M.J.N., Cochrane, S., Craeymeersch, J.A., Degraer, S., Desroy, N., Dewarumez, J.-M., Duineveld, G.C.A., Essink, K., Hillewaert, H., Lavaleye, M.S.S., Andreas Moll, Stefan Nehringl, Richard Newell, Eivind Oug, Thomas Pohlmann, Eike Rachor, Mike Robertson, Heye Rumohr, Michaela Schratzberger, Rebecca Smith, Edward Vanden Berghe, Jan van Dalfsen, Gert van Hoey, Magda Vincx, Wouter Willems, Hubert L. Rees, 2011. Changes in North Sea macrofauna communities and species distribution between 1986 and 2000. Estuarine, Coastal and Shelf Science 94, 1-15

Künitzer, A., Basford, D., Craeymeersch, J. A., Dewarumez, J. M., Dörjes, J., Duineveld, G. C. A., Eleftheriou, A., Heip, C., Herman, P., Kingston, P., Niermann, U., Rachor, E., Rumohr, H., and de Wilde, P. A. J. 1992. The benthic infauna of the North Sea: species distribution and assemblages. ICES Journal of Marine Science, 49(2): 127–143.

Lampadariou, N., Karakassis, I., Pearson, T.H., 2005. Cost/benefit analysis of a benthic monitoring programme of organic benthic enrichment using different sampling and analysis methods. Marine Pollution Bulletin 50, 1606-1618.

Rees, H. L., Eggleton, J. D., Rachor, E., and Vanden Berghe, E. (Eds). 2007. Structure and dynamics of the North Sea benthos. ICES Cooperative Research Report No. 288. 258 pp.

Reiss, Henning, Degraer, S. Duineveld, GCA, Kroncke, I., Aldridge, J., Craeymeersch, J.A., Eggleton, J.D., Hillewaert, H., Lavaleye, MSS, Moll, A., Pohlmann, T., Rachor, E., Robertson, M., Vanden Berghe, E., Van Hoey, G., Rees, H.L, 2010. Spatial patterns of infauna, epifauna, and demersal fish communities in the North Sea. ICES Journal of Marine Science 67(2), 278-293.

Reiss, H., Birchenough, S., Borja, A., Buhl-Mortensen, L., Craeymeersch, J., Dannheim, J., Darr, A., Galparsoro, I., Gogina, M., Neumann, H., Populus, J., Rengstorf, A.M., Valle, M., Van Hoey, G., Zettler, M.L., Degraer, S., 2015. Benthos distribution modelling and its relevance for marine ecosystem management. ICES Journal of Marine Science 72(2), 297-315.

Van Hoey, G., Vincx, M., Degraer, S., 2007. Temporal variability in the Abra alba community determined by global and local events. Journal of Sea Research 58, 144-155

Van Hoey, Gert; Borja, Angel; Birchenough, Silvana; Degraer, Steven; Fleischer, Dirk; Kerckhof, Francis; Magni, Paolo; Buhl-Mortensen, Lene; Muxika, Iñigo; Reiss, Henning; Schröder, Alexander; Zettler, Michael, 2010. The use of benthic indicators in Europe: from the Water Framework Directive to the Marine Strategy Framework Directive. Marine Pollution Bulletin 60: 2187-2196

Van Hoey, Gert; David Cabana Permuy; Magda Vincx ; Kris Hostens, 2013. An Ecological Quality Status assessment procedure for soft-sediment benthic habitats: Weighing alternative approaches. Ecological Indicators 25, 266-278

Stief, P., 2013. Stimulation of microbial nitrogen cycling in aquatic ecosystems by benthic macrofauna: mechanisms and environmental implications. Biogeosciences, 10(12), 7829-7846

Table 1. Ad hoc info collected during JMP project

	Name	frequency	# samples	coverage	Goal/purpose	method	Linked to MSFD indicator
BE	Environmental monitoring ILVO	Every 3y, 2y or annually depending on the area	190 - 270	Monitoring in the framework of a specific human	Environmental state and impacts Pressures Human activities causing the pressures	Sampling with a Van Veen grab (0.1m²) follows the ISO standard (ISO 16665:2005(E))	BE_ET10: Benthic ecosystem quality index (BEQI)
NL	Bestandsopname van Ensis en Spisula in de Noordzeekustzone	Yearly	unknown	Kustzone Nederland en Voordelta	Environmental state and impacts	Unknown	Unknown
	Monitoring of bodemfauna Noordzee	Every 3 years	Unknown	Noordzee, NCP. 100 locaties verdeeld over Doggersbank, Oestergronden, Zuidelijk offshore gebied, kustzone. Voor NCP betreft het de habitat typen: H1110, H1110C, H1140A, H1140B, H1170	Environmental state and impacts	Unknown	Unknown
	Monitoring schelpdierbestanden	Unknown	Unknown	Voordelta, Waddenzee, kustzone	Environmental state and impacts	Unknown	Unknown
DE	MacroZooB - Shellfish Banks	Yearly	unknown	Eulittoral zone - Sublittoral zone	Environmental state and impacts	Unknown	Unknown
DK	Monitoring of zoobenthos	Yearly	unknown	North Sea - Wadden Sea - Skagerrak - Kattegat	Unknown	Unknown	Unknown
FR	RESOMAR-BENTHOS	Parameter dependent	Unknown	Côtes françaises (Manche-Mer du Nord, Mers Celtiques, Golfe de Gascogne, Méditerranée)	Environmental state and impacts	Méthodes (bennes, dragues, carottiers, suceuse) et plans d'échantillonnages (série spatiale et/ou temporelle) variables selon les suivis.	Unknown
SE	Mjukbottenl	Yearly	70	Coastal waters, territorial	Environmental	https://www.havochvatten.se/	Unknown

	evande makrofauna – Soft-bottom macrofauna			waters and EEZ. Costal sites are included with the aim to monitor recipients while offshore sites are included with the aim to monitor large-scale changes in the benthic fauna	state and impacts	download/18.64f5b3211343cffddb28000401/1348912813195/Mjukbottenlevande+makrofauna%2C+trend-+och+omr%C3%A5des%C3%B6vervakning.pdf	
UK	NO INFO ON BENTIC PROGRAMS						

Table 2. Official MSFD monitoring programs for benthos (D1-D6)

	ID	frequency	# samples	coverage	Goal/purpose	method	Linked to indicator	Habitat type
BE	ANSBE-D1-4-6-Seabed-SP6	• Every 3 years • Every 2 years • Yearly	190-270	Monitoring in the framework of a specific human pressure : sand extraction area, dredge disposal sites, Windfarm zone and some reference area • Territorial waters • EEZ (or similar) • Continental shelf (beyond EEZ)	• Environmental state and impacts • Pressures • Human activities causing the pressures	Sampling with a Van Veen grab ($0.1m^2$) follows the ISO standard (ISO 16665:2005(E))		
	ANSBE-D1-4-6-Seabed-SP9	• Every 2 years • Yearly	12	One area in zone 3 of the Marine Spatial Plan (no impact of fisheries), one area in zone 4 of the MSP (low impact of fisheries) and one area in outside these zones (regular impact fisheries). The selection is based on the current knowledge on the appearance of gravel beds, the pressure we can expect in the area • Territorial Waters • EEZ (or similar)	• Environmental state and impacts • Pressures	Hammon grab http://www.belspo.be/belspo/organisation/publ/pub_ostc/EV/rappEV45_en.pdf		
NL	ANSNL-D1346-Sub10-Benthos	• Every 3 year • Yearly	MWTL Benthos: Benthos is monitored on approximately 514 locations. This number is excluding the monitoring that is being carried out in order to determine the effectiveness of	The Habitats Directive and MSFD are both intended to ensure protection of the sea-floor habitat. The monitoring therefore focuses on the information requirement that follows from both directives Before sea-floor protection measures come into effect,	• Environmental state and impacts • Pressures • Effectiveness of measures	The regular survey networks that will be used are: The Rijkswaterstaat MWTL benthos measurement network [A], supplemented with information from the WOT (statutory research tasks from the Ministry of Economic Affairs) for Fisheries (shellfish surveys		

			seafloor protection measures. See table 7 on page 84 of the Marine Strategy part II. WOT Shellfish monitoring: The Dutch part of the “Noordzeekustzone” is monitored on the presence of shellfish. Along the coast approximately 855 locations are monitored each year. Supplementary area monitoring: On top of the 514 locations from the MWTL, at least another 95 locations are monitored. For the Voordelta the number of extra locations has not yet been determined. See table 7 on page 84 of the Marine Strategy part II.	the baseline situation of the areas protected under the MSFD and HD (baseline measurement) is determined. Sampling is focused on the designated areas protected under the HD and on the MSFD areas of search for sea floor protection. Within those, both areas under protective measures and relevant reference areas that are not under protective measures are covered. Within each of these areas, the measurement locations are randomly distributed. With the exception of the ‘medium-deep mixed sand’ of the Southern Bight, the ‘common habitats’ reported in the MSFD Initial Assessment are thus also covered at EUNIS level 3. For this reason, the Southern Bight is sampled – additionally – in the same way as the protected areas. • Coastal waters (WFD) • Territorial waters • EEZ (or similar)		section [B]) [A] MWTL Meetplan 2015 (will be available at http://www.helpdeskwater.nl/ onderwerpen/monitoring/gegevensinwinning/). [B] WOT 05-406-008 - http://www.wageningenur.nl/nl/project/Monitoring-schelpdierbestanden.htm. Most recent report, including methodology: http://edepot.wur.nl/278820. Table 7 of the Marine Strategy Part II (Par. 9.2.1, Page 84) gives an overview of the number and distribution of sampling locations, as well as the monitoring method and sampled habitat types.			
UK	ANSUK_D 0146_01_intertidal_sediments_sub	• Every 3 years • 3 monthly	England and Wales 535 sites in total in UKDMOS (including sub-tidal), roughly 50% in North Sea area Scotland 13 sites	ALL COUNTRIES WFD Benthic invertebrate monitoring programme defined for the benthic invertebrate quality element of WFD, split out for this reporting between the	• Environmental state and impacts	• England and Wales: http://www.wfduk.org/sites/default/files/Media/Characterisation%20of%20the%20water%20environment/Biological%20Method%			

				subtidal and intertidal sediment sub-programmes • Transitional waters (WFD) • Coastal waters (WFD)		20Statements/TraC%20Benthic%20Invert%20IQI%20UKTAG%20Method%20Statement.pdf • Northern Ireland Benthic sampling: ○ http://oceannet.org/documents/prot0392_10074_analysis.pdf ○ http://www.cefas.co.uk/media/183499/green-book-tables.pdf ○ http://jncc.defra.gov.uk/PDF/MMH-Pg%203-9.pdf		
	ANSUK_D0146_03_subtidal_sediments_sub	• Every 3 years • 3 monthly	England and Wales 160 sites in total in UKDMOS, roughly 50% in North Sea area. Scotland 100 sites	ALL COUNTRIES WFD Benthic invertebrate monitoring programme defined for the benthic invertebrate quality element of WFD, split out for this reporting between the subtidal and intertidal sediment sub-programmes • Transitional waters (WFD) • Coastal waters (WFD)	• Environmental state and impacts	• ENGLAND AND WALES: http://www.wfduk.org/sites/default/files/Media/Characterisation%20of%20the%20water%20environment/Biological%20Method%20Statements/TraC%20Benthic%20Invert%20IQI%20UKTAG%20Method%20Statement.pdf • SCOTLAND: http://www.cefas.co.uk/media/183509/green-book-appendices.pdf		
	ANSUK_D0146_06_1_SAC_England_sub	Natural England survey packages have different temporal frequencies. Most are expected to occur between every 4 years and every 12 years. The frequency	There are 21 sites, with a minimum of 175 stations per annum monitored on average in this region. These sites are spread over a six year rolling programme of	The geographic scope of the sub-programme thus reflects the distribution of SACs in England • Transitional waters (WFD)	• Environmental state and impacts	• Common Standards Monitoring Guidance for Vegetated Coastal Shingle Habitats: http://www.jncc.gov.uk/pdf/CSM_coastal_shingle.pdf • Marine Monitoring		

		and density of sampling is a function of feature vulnerability (i.e. risk of deterioration and / or damage).	monitoring	• Coastal waters (WFD) • Territorial waters		Handbook: Marine and Estuarine Habitats Monitoring: http://www.jncc.gov.uk/page-2430 • Common Standards Monitoring Guidance for Saltmarsh Habitats: http://www.jncc.gov.uk/pdf/CSM_coastal_saltmarsh.pdf • EA WFD methodologies: www.wfduk.org			
	ANSUK_D0146_06_2_SAC_Scotland_sub	• Every 6 years • Every 3 years • Every 2 years • Yearly	SNH survey packages have different temporal frequencies. Most occur annually, but some are expected to occur only every 12 years. The density of sampling is as indicated focused on risk areas.	The geographic scope of the sub-programme thus reflects the distribution of SACs in Scotland • Transitional waters (WFD) • Coastal waters (WFD) • Territorial waters	• Environmental state and impacts	• Surveying Sea Caves: http://www.snh.org.uk/pdfs/publications/commissioned_reports/Berwickshire_North%20Northumberland_littoral_sublittoral_caves.pdf 4.1 http://www.jncc.gov.uk/PDF/CSM_marine_sea_caves.pdfhttp://www.jncc.gov.uk/page-2430 • Recording Biotopes in Sea Caves - http://www.jncc.gov.uk/page-2430 5.1 http://www.jncc.gov.uk/PDF/CSM_marine_sea_caves.pdf • Surveying Sea Caves and Rocky Reefs - http://www.snh.org.uk/publications/on-line/commissionedreport/F02AA409b.asp, http://www.snh.org.uk/pdfs/publications/commissioned_reports/F02AA409b_			

						A1.pdf http://www.jncc.gov.uk/page-2430 • Site Condition Monitoring Protocols [Papa Stour cSAC] ERT (Scotland) Ltd. (2005). Site Condition Monitoring: surveys of marine rocky environments in the Papa Stour cSAC July-August 2003. Scottish Natural Heritage Commissioned Report No. 102 (ROAME No. F02AA409b).) Site Condition Monitoring Protocols [Moray Firth SAC] (Evans, P.G.H. and Hammond, P.S., 2004. Ground and aerial monitoring for Carmarthen Bay SPA - Banks A.N. Bolt D. Bullock I.D. Collier M.P. Fairney N.P. Hasler C. Haycock B. Maclean I.M.D. Roberts N.P. Sanderson W.G. Schofield R.A. Smith L. Swan J.M. Taylor R.H.A. and Whitehead S. 2007. Ground and aerial monitoring for Carmarthen Bay SPA. Marine Monitoring Report No. 48. Countryside Council for Wales 91 pp.		
	ANSUK_D0146_07_MECN_sub	• Yearly • 6 monthly	100	MECN contains coastal and shelf-wide data sets. The original project covered four geographical areas – the North Sea, the English	• Environmental state and impacts • Pressures	• Data Protocol for Liverpool Bay Coastal Observatory - http://www.hydromod.de/ferrybox/Public_results/FerryBox_Reports__R-2-		

		• 3 monthly • Monthly • 2 weekly		Channel, the Irish Sea and the Tiree Passage. • Coastal waters (WFD) • Territorial waters • EEZ (or similar)		0/FerryBox_D-2-1__System_description__R_2-0.pdf • Data protocol for MarCLIM http://www.mba.ac.uk/marclim/pdf/Sampling_protocols.pdf • Data protocol for time series are historic internal documents, but see methods outlined in recent publications: • http://dx.doi.org/10.1016/j.seares.2010.09.006 http://www.int-res.com/articles/meps2010/423/m423p069.pdfb		
DE	ANSDE_Sub_007	• Yearly		Gemäß Verpflichtungen WRRL, MSRL, OSPAR, BLMP/BLANO (Bund/Länder-Messprogramm / Bund/Länder-Ausschuss Nord- und Ostsee) • Coastal waters (WFD) • Territorial waters • EEZ (or similar)	• Environmental state and impacts • Pressures	• MP_055: Tiefengrenzen, Dichte, Biomasse, Artenzahl, Ausdehnung (m^2) • Hardbottom Makrozoobenthos-MP_057: Erfassung per Rahmen, zumeist nicht-destruktiv, auf Helgoland auch Fauna in Laminaria-Haftkrallen sowie in Schill, Fauna in Muschelbänken • Softbottom Makrozoobenthos-MP_062: Per Greifer oder Stechkasten werden Sedimentproben genommen und deren Fauna > 1mm herausgesiebt und bestimmt, Dredge		

	ANSDE_Sub_122	• Yearly	5-20	Gemäß Verpflichtungen WRRL, MSRL, OSPAR, BLMP/BLANO (Bund/Länder-Messprogramm / Bund/Länder-Ausschuss Nord- und Ostsee) • Coastal waters (WFD) • Territorial waters • EEZ (or similar)	• Environmental state and impacts • Pressures	• Softbottom Makrozoobenthos - MP_062: Per Greifer oder Stechkasten werden Sedimentproben genommen und deren Fauna > 1mm herausgesiebt und bestimmt, Dredge		
	ANSDE_Sub_044	• Yearly	5-20	Gemäß Verpflichtungen WRRL, MSRL, OSPAR, BLMP/BLANO (Bund/Länder-Messprogramm / Bund/Länder-Ausschuss Nord- und Ostsee) • Coastal waters (WFD) • Territorial waters • EEZ (or similar)	• Environmental state and impacts • Pressures	• Softbottom Makrozoobenthos - MP_062 : Per Greifer oder Stechkasten werden Sedimentproben genommen und deren Fauna > 1mm herausgesiebt und bestimmt, Dredge		
DK	ANSDK-D06-04_abundance_softbottomfauna			The program including rationale for the geographic scope can be found here: http://naturstyrelsen.dk/naturbeskyttelse/national-naturbeskyttelse/overvaagning-af-vand-og-natur/novana-program • Coastal waters (WFD) • Territorial waters • EEZ • Beyond MS Marine Waters	• Environmental state and impacts			
FR	Not reported yet!							

SE	ANSSE-BENT-D165-Bottenfauna	• yearly	70 samples/year	• Coastal waters (WFD) • Territorial waters • EEZ	• Environmental state and impacts	Nationell undersökningstyp för provtagning av mjukbottenfauna - https://www.havochvatten.se/download/18.64f5b3211343cffddb28000401/1348912813195/Mjukbottenlevande+makrofauna,+trend-+och+omr%C3%A5des%C3%B6vervakning.pdf		