East Anglia Offshore Wind

VATTENFALL

SCOTTISHPOWER RENEWABLES

East Anglia THREE

Appendix 10.5

Benthic and Epibenthic Survey Statistical Power Analysis

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10.5 BENTHIC AND EPIBENTHIC SURVEY STATISTICAL POWER ANALYSIS

1. This appendix contains a report written by APEM providing a statistical power analysis to determine how many samples would be required for the East Anglia THREE benthic surveys in order to provide sufficient statistical power.

Scottish Power Renewables

East Anglia Benthic and Epibenthic Survey Statistical Analysis

FINAL REPORT

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CONTENTS

1 INTRODUCTION

Scottish Power Renewables (SPR), in partnership with Vattenfall Wind Power, (VWP), has been awarded the rights to develop up to 7,200MW of wind driven electrical power off the East Anglian coast, within an area known as the East Anglia Zone. Together these companies have formed the joint venture East Anglia Offshore Wind (EAOW) Ltd.

The current round of development within the EAOW Zone focuses on East Anglia THREE and FOUR and the associated cable corridor, shown in Figure 1-1. A large benthic and epibenthic characterisation survey of the whole Zone was carried out between September 2010 and January 2011 by Marine Ecological Surveys Ltd (MESL, 2011), during which surveys were conducted across the extent of East Anglia THREE and FOUR, as well as sections of the cable corridor.

APEM were commissioned by EAOW to assess whether further sampling was required to inform the ecological baseline for the development of East Anglia THREE and FOUR and the cable corridor, or whether data from the 2010 surveys were sufficient to provide a statistically robust spatial characterisation of the benthic and epibenthic ecology of the site.

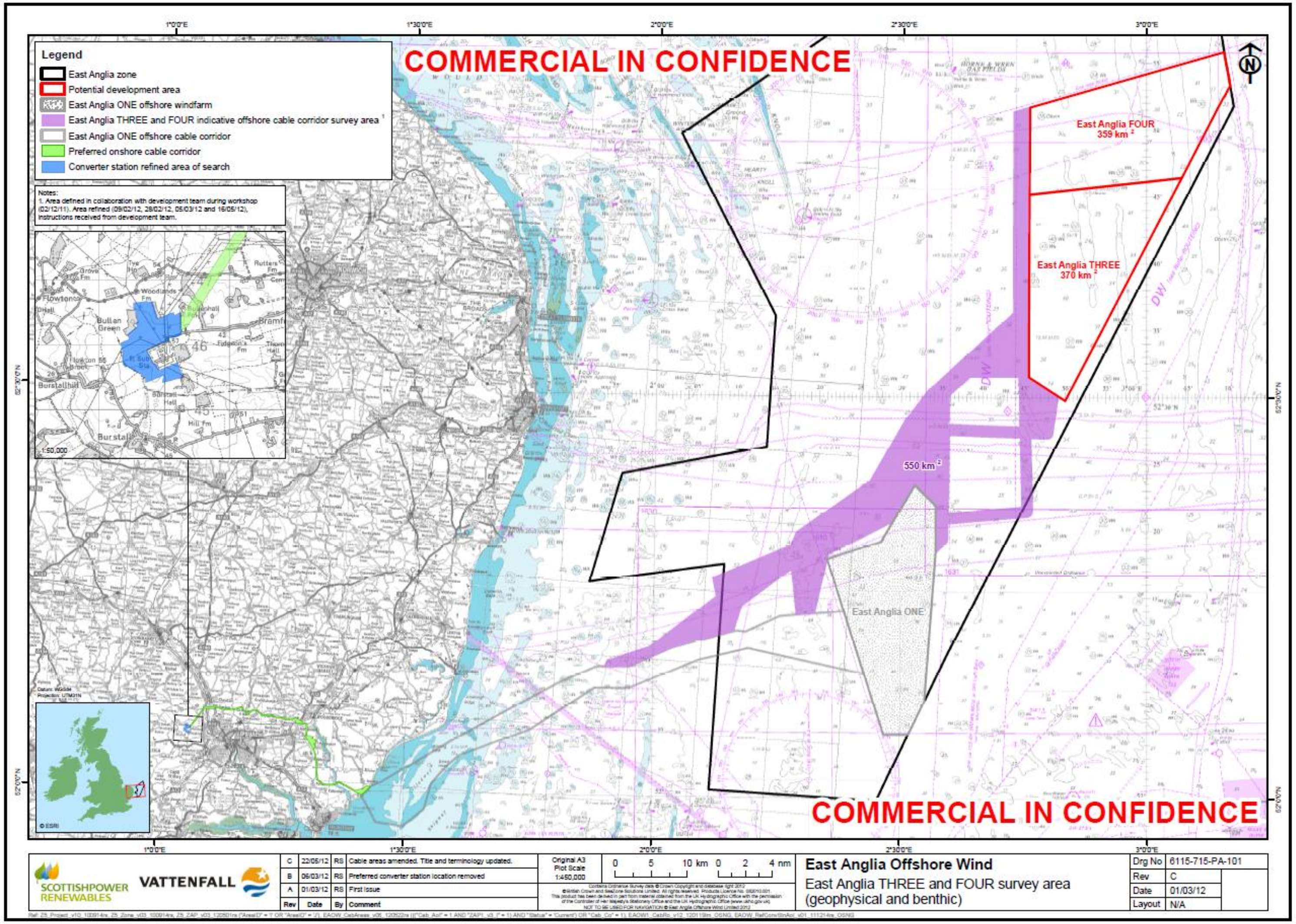


Figure 1-1 Location of East Anglia THREE and FOUR and associated cable corridor (shaded in blue)

2 POWER ANALYSIS

Biological systems are inherently variable. Variability in the spatial and temporal distribution of species within an ecosystem means that it is often difficult to separate natural variability in a measured parameter (often referred to as 'noise') from any causative effect. For example, it is difficult to ascertain whether a difference in the abundance of species observed in two populations is a result of chance, or a result of some significant underlying difference between the two populations. An important aspect in the design of any monitoring survey programme is to minimise the degree to which the natural variability within the measured data affects the statistical analysis and interpretation of the data.

There is the potential to make two kinds of error in the interpretation of statistical models. Type I errors (indicated by α) are made when the null hypothesis (H_0) is rejected when it is in fact true. Type I errors are also referred to as the significance level, or p-value. Type II errors (indicated by β) occur when H_0 is accepted when it is false (Table 2.1). Statistical Power is a measure of confidence that a statistical analysis will give us the "true" answer by limiting the risk of committing a Type II error.

Power is therefore simply 1 – β. It can be carried out *a priori*, using information gained from a pilot study or the literature to inform on the number of samples required to allow for robust statistical analyses (e.g. pre and post construction studies), or *post hoc*, to assess whether results from analysis are valid (Quinn and Keough, 2004).

Table 2.1. Summary of Type I and Type II errors

		Truth for population	
		H_0 is true	**H_0 is false**
Decision based on sample	**Accept H_0**	Correct (True positive)	Type II (False negative, β)
	Reject H_0	Type I (False positive, α)	Correct (True negative)

The two types of error are inversely relational and an increasing effort to reduce β increases the risk of encountering Type 1 error. It is therefore common practice for a compromise level for Power to be set at 0.8 (Crawley, 2011).

The formal representation of Power analysis is:

Eqn. 1.

$$Power \propto \frac{es\, \alpha \sqrt{n}}{\sigma}$$

Where:

- σ– Standard deviation. A measure of deviation within dataset. The greater the standard deviation in a data set, the greater the degree of variation of data values about the mean and the more difficult it is to measure statistical differences between populations (e.g. pre- and post-development, between geographic locations, etc).

- ***es*** – Effect size.
- ***α*** – Required significance level, or *p*-value. The desired p level is to be set at 0.05 (or 95% probability).
- ***n*** – The sample size

Any one term from Eqn. 1 can be solved when all other terms are known.

2.1 Standard Deviation

Standard deviations for epibenthic and benthic community mean values for this power analysis have been calculated from the 2010/2011 Zonal Characterisation Survey data (MESL 2011). Data with higher standard deviations (δ) have a greater degree of variability. These data require a higher degree of sampling effort (i.e. a higher number of samples, n) to detect a significant effect of a given size than data with low variation values.

2.2 Effect Size

Effect size is the level of change we are able to detect. It is calculated thus:

Eqn. 2 (Coe, 2002)

$$es = \frac{mean\ of\ survey\ A - mean\ of\ survey\ B}{\sigma}$$

and can be summarised as standardised mean difference.

In this study we are attempting to understand if a suitable number of samples have been taken as part of the Zonal Characterisation Survey to correctly detect a response to development of East Anglia THREE and FOUR and the Cable corridor in subsequent post-construction surveys. The effect size required that is representative of a true shift in the benthic and epibenthic communities however, is unknown. This is a common issue with many Power Analyses and to satisfactorily deal with this Cohen (1988) proposed the use of effect sizes of 0.8, 0.5 and 0.2 to represent a high, medium and small effect size. These effect sizes reflect degrees of change based on standard deviations (e.g. 0.2 = two standard deviations from the mean of survey A). This study has also investigated the use of a range of *es* (see Section 4.2).

Power Analysis calculations were based on calculations of Shannon Diversity and Simpson's Index at each survey site for benthic and epibenthic fauna. For ease of interpretation, this study will present *es* as percentage change. Although this is not common practice for power analysis it has been possible to convert *es* to an Estimated Detectable Percentage Change (EDPC) by partially solving Eqn. 2. Data from the Zonal Characterisation Survey were assessed and the standard deviation within different survey areas was calculated. This information was used to calculate the EDPC values for a range of effect sizes.

As only one survey has been carried out the standard deviation used is derived solely from survey A (MESL, 2011, method derived from Coe, 2002). Therefore,

Eqn. 3

$$EDPC = \frac{\sigma(survey\ A)es}{mean(survey\ A)} \text{ x } \frac{100}{1}$$

2.3 Detection Level

Although no industry standard *es* or EDCP has been made available for marine benthic and epibenthic communities, when undertaking ornithological Impact Assessments for windfarm developments an ability to detect a halving or doubling of population size (*i.e.* 50% change) is used as the threshold level for determining the accuracy of a survey. This approach was used to assess the accuracy of bird counts during initial ornithological investigations for the London Array (APEM, 2010). The 50% level of population change is also commonly used when designing surveys for fish species of conservation interest in UK rivers (Bohlin *et al.*, 1990), (e.g. Lamprey, APEM, 2011a), as well as other species of high commercial/recreational value (e.g. brown trout, APEM, 2003). The Power analysis approach is taken from survey design methodology proposed by Elliott (1993) for quadrat (*i.e.* spatially constrained) sampling for pond invertebrates.

We therefore propose that an EDCP level of greater or less than 50% is a valid ecological level at which to conduct benthic and epibenthic surveys. A unique aspect to this project however, is the use of diversity metrics to estimate the variance required for power analysis to detect changes to benthic and epibenthic marine communities. This is necessary given the complex community structure of benthic and epibenthic marine ecosystems. As discussed, the 50% EDCP threshold is used as a benchmark level of detectable change in population sizes of bird and fish species. Therefore a 50% change in diversity, as measured by Shannon or Simpson, does not necessarily indicate a 50% change in the total invertebrate abundance. Similarly it may not indicate a 50% loss of the number of taxa present. In essence, a 50% effect will show a change to the specific index value which is based on complex alterations to the community composition and patterns of dominance within the community in question, i.e. a combination of change to species number and abundance. This is because increases in abundance and the number of taxa are not linearly related to increases in Shannon or Simpson. The relationship between population number and changes to that population is however, linear. Furthermore, index values are usually functionally constrained by maximum values, 0-approximately 1 for Simpson and 0 – 3.4 for Simpson (these upper limits can be breached on occasion) while, within sensible limits, population numbers are not. Changes in population number and changes to community diversity metric values cannot therefore be directly compared as they respond differently to change. Consequently, although we have presented this analysis based on this 50%

threshold, it should be recognised that this is not a simple halving of the community in question.

2.4 Sample Number.

The Estimated Sample Number (ESN) required to reach a Power = 0.8 (the ESN) can be estimated where *es* and σ are known.

3 METHOD

As the full extents of East Anglia THREE and FOUR were surveyed for benthic and epibenthic surveys during the Zonal Characterisation Survey (MESL, 2011), GIS was used to identify which of the stations sampled fell within those areas. Subsequently we derived Shannon (H') and Simpson (S) diversity indices for East Anglia THREE and FOUR followed by overall mean and standard deviations of these indices to allow conversion of *es* to EDPC (see Section 2.2) and undertake power analysis. This analysis allowed us to determine whether further sampling effort was required to characterise the benthic and epibenthic assemblages present.

As certain sections of the cable corridor are located within the navigational channel at the centre of the Zone, a full suite of stations encompassing the entire corridor was not available. Based on the overall density of stations/km^2 (0.13km^2 for benthic stations and 0.01km^2 for epibenthic stations) carried out in the 2010 survey (MESL 2011), it was therefore estimated that 71 benthic stations and 6 epibenthic stations would have had to be surveyed to provide complete coverage of the corridor.

To derive means and standard deviations for the cable corridor, 71 and 6 sites respectively were chosen at random and the Shannon (H') and Simpson (S) diversity indices calculated. These indices incorporate information on the number and abundance of species and the relative abundance of species in an assemblage (termed evenness). These measures are routinely employed to characterise ecological communities. These indices were used to derive the necessary descriptive statistics for the cable corridor. We felt a randomised approach to derive the necessary information was valid as the entire Zone was characterised by high levels of homogeneity, both in terms of ecological communities and substrate (MESL, 2011). This approach using randomly assigned, but relevant, data is also described in Quinn and Keough (2004).

Power analyses tailored towards t-tests were carried out using R (www.R.project,org), based on the proposed null hypothesis that there will be no difference in community diversity between the communities sampled during the 2010 survey (MESL 2011) and potential survey(s) carried out post-development.

4 RESULTS

4.1 Descriptive Statistics

The descriptive statistics (Table 4.1) demonstrate the low levels of variance in ecological diversity within the relevant areas, and is supportive of the Zonal Characterisation results (MESL, 2011). Table 4.1 demonstrates the relatively higher variance in Shannon diversity index when compared with the Simpson index. This may result in a higher ESN for Shannon to reach the critical Power threshold (0.8) when compared with Simpson. The table also shows the number of stations surveyed in 2010/2011 present within East Anglia THREE and FOUR, and the sample number used for cable corridor assessments.

Table 4.1. Descriptive statistics for Power analysis and es conversion

Study	Metric	Area	*n*	mean	σ
Benthic	Shannon	EA FOUR	49	2.19	0.34
	Shannon	EA THREE	48	2.06	0.4
	Shannon	Cable	71	2.15	0.5
	Simpson	EA FOUR	49	0.84	0.11
	Simpson	EA THREE	48	0.8	0.14
	Simpson	Cable	71	0.85	0.13
Epibenthic	Shannon	EA FOUR	6	1.69	0.34
	Shannon	EA THREE	4	1.56	0.31
	Shannon	Cable	6	1.6	0.11
	Simpson	EA FOUR	6	0.74	0.12
	Simpson	EA THREE	4	0.68	0.12
	Simpson	Cable	6	0.71	0.07

4.2 Effect Size

Table 4.2 shows the percentage changes (as Estimated Detectable Percentage Change, EDPC) in Shannon Diversity (H') and Simpson's Index (S) values that represent a range of effect sizes (*es*). The results show that this relationship is variable between Areas and between diversity index measured. The *es* values commonly adopted in ecological investigations (i.e. 0.2, 0.5 and 0.8, Cohen 1988) all represent changes in diversity index values of less than 20% (Table 4.2). The EDPC values at these effect sizes are all lower than would be considered required as part of an Impact Assessment, on the basis that a 50% change in a diversity index would be accepted by the statutory authority.

Table 4.2. The relationship between Effect Size and Estimated Detectable Percentage Change for each area and metric. Green boxes indicate percentage change values for target detectable effect sizes of 0.2, 0.5 and 0.8 (small, medium and large, respectively). Orange boxes represent breaches of the 50% change level.

Effect Size	BENTHIC						EPIBENTHIC					
	Shannon EA FOUR	Shannon EA THREE	Simpson EA FOUR	Simpson EA THREE	Shannon Cable	Simpson Cable	Shannon EA FOUR	Shannon EA THREE	Simpson EA FOUR	Simpson EA THREE	Shannon Cable	Simpson Cable
	% change	% change	% change	% change	% change	% change	% change	% change	% change	% change	% change	% change
0.1	1.55	1.94	1.31	1.75	2.33	1.53	2.01	1.99	1.62	1.76	0.69	0.99
0.2	3.11	3.88	2.62	3.50	4.65	3.06	4.02	3.97	3.24	3.53	1.38	1.97
0.3	4.66	5.83	3.93	5.25	6.98	4.59	6.04	5.96	4.86	5.29	2.06	2.96
0.4	6.21	7.77	5.24	7.00	9.30	6.12	8.05	7.95	6.49	7.06	2.75	3.94
0.5	7.76	9.71	6.55	8.75	11.63	7.65	10.06	9.94	8.11	8.82	3.44	4.93
0.6	9.32	11.65	7.86	10.50	13.95	9.18	12.07	11.92	9.73	10.59	4.13	5.92
0.7	10.87	13.59	9.17	12.25	16.28	10.71	14.08	13.91	11.35	12.35	4.81	6.90
0.8	12.42	15.53	10.48	14.00	18.60	12.24	16.09	15.90	12.97	14.12	5.50	7.89
0.9	13.97	17.48	11.79	15.75	20.93	13.76	18.11	17.88	14.59	15.88	6.19	8.87
1	15.53	19.42	13.10	17.50	23.26	15.29	20.12	19.87	16.22	17.65	6.88	9.86
1.5	23.29	29.13	19.64	26.25	34.88	22.94	30.18	29.81	24.32	26.47	10.31	14.79
2	31.05	38.83	26.19	35.00	46.51	30.59	40.24	39.74	32.43	35.29	13.75	19.72
2.5	38.81	48.54	32.74	43.75	58.14	38.24	50.30	49.68	40.54	44.12	17.19	24.65
3	46.58	58.25	39.29	52.50	69.77	45.88	60.36	59.62	48.65	52.94	20.63	29.58
3.5	54.34	67.96	45.83	61.25	81.40	53.53	70.41	69.55	56.76	61.76	24.06	34.51

4.3 Benthic Power Analysis

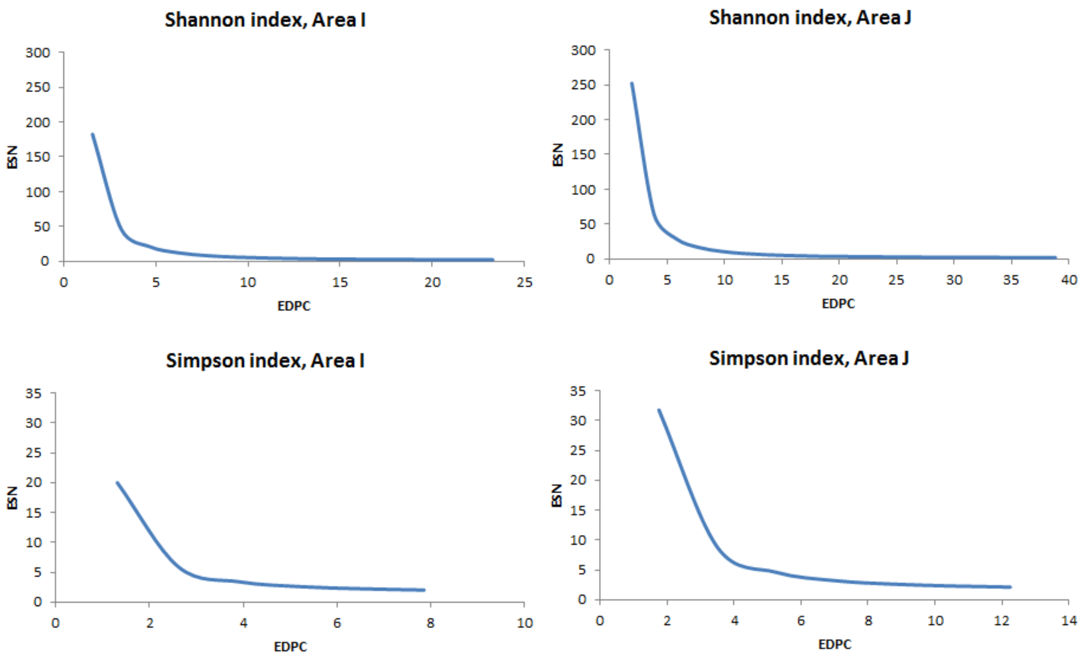
4.3.1 East Anglia THREE and FOUR.

Table 4.3 presents the Power inherent from the 2010 surveys (MESL 2011) for benthic surveys from East Anglia THREE and FOUR.

Table 4.3. Results from power analysis for East Anglia THREE and FOUR.

Effect Size	EA FOUR (n = 49)		EA THREE (n = 48)	
	Power H'	Power S	Power H'	Power S
0.2	0.82	1	0.67	0.99
0.5	0.99	1	0.99	1
0.8	1	1	1	1

The results show that only one test, for Shannon (H') at an effect size of 0.2 (East Anglia THREE), fails to reach the required Power level (0.8). At an *es* of 0.8[1] = 15% detectable change (Table 4.2) for the Shannon metric in East Anglia THREE however, the 0.8 level (effect size) is more than adequate to detect change at less than the required 50% level. This is true for all benthic surveys from East Anglia THREE and FOUR and therefore we can state that the sample numbers are sufficient, and that an *es* of 0.8 as a benchmark is also suitable for determining whether the number of sites sampled in 2010 was suitable to characterise the site and allow a future detection of change.



[1] Please note; 0.8 is the critical threshold for **statistical Power**, and care should be taken to avoid confusion between this value and the **effect size** of 0.8

Figure 4.1. Relationship between estimated sample number and percentage change in metric for benthic data.

Figure 4.1 further illustrates this point, demonstrating that the survey effort undertaken in East Anglia THREE and FOUR can detect change well below the 50% level for each metric and Area. This is evident from the decay and stop in the line at an ESN of approximately 2 before reaching an EDPC of 50% (as it is based on the variability of data between samples, Power analysis cannot predict a sample size less than 2).

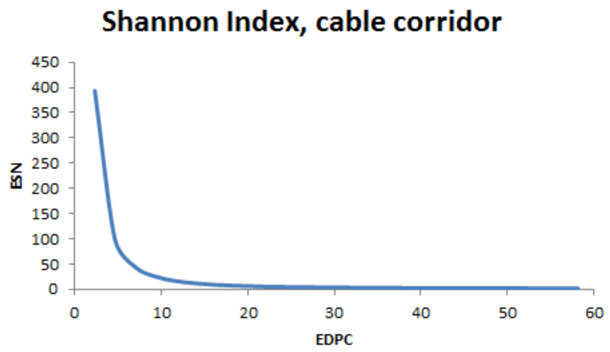
4.3.2 Cable Corridor

Table 4.4 presents the Power inherent from the 2010 surveys (MESL 2011) for benthic surveys from the cable corridor.

Table 4.4 Results from Power analysis for Cable Corridor

Effect Size	**2011 density (n = 71)**	
	Power H'	**Power S**
0.2	0.66 (99)	1
0.5	0.99	1
0.8	1	1

As with the Shannon metric from East Anglia THREE, the Power of a comparison using Shannon at an effect size of 0.2 is lower than a Power of 0.8. The 0.8 *es* however, equates to an estimated detection level of 18% (Table 4.2). As the 0.8 *es* for Simpson is also well below the 50% threshold (see Table 4.2), we can state that a survey effort of 71 stations is sufficient to characterise the site and allow a future detection of change. Figure 4.2, below, further highlights that a survey effort based on 71 sites within the cable area can detect change well below the 50% level for each metric and area.



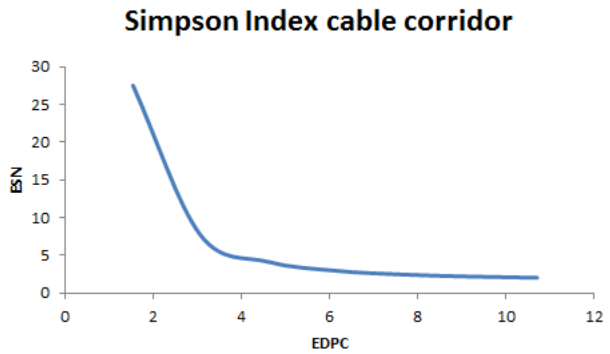


Figure 4.2. Relationship between sample size (*y*) and percentage change detection for the cable corridor for Shannon and Simpson indices for benthic assemblages.

As an estimated 271.82km^2 of the cable corridor remains to be surveyed, a further 36 stations in this area would be required to retain the 2010 survey density of 0.13 stations/km^2. This will ensure that the surveys conducted in the remaining areas are spatially consistent with previous work.

4.4 Epibenthic Power Analysis

4.4.1 East Anglia THREE and FOUR.

The results of the Power analysis, for both S and H' for East Anglia THREE and FOUR, are presented below in Table 4.5.

Table 4.5. Results from Power analysis for East Anglia THREE and FOUR.

Effect Size	EA FOUR (n = 6)		EA THREE (n = 4)	
	Power H'	Power S	Power H'	Power S'
0.2	0.15	0.8	0.11	0.57
0.5	0.63	0.99	0.48	0.99
0.8	0.95	1	0.85	1

The Power values from the highest effect size (0.8) are above the required Power threshold (also 0.8). As an *es* of 0.8 equates to values less than an EDPC of 50%, it is shown that an estimated sample size equal to that carried out during the 2010 survey is sufficiently powerful to detect change of less than 50%. Figure 4.3 also demonstrates this point and therefore that adequate stations have been surveyed.

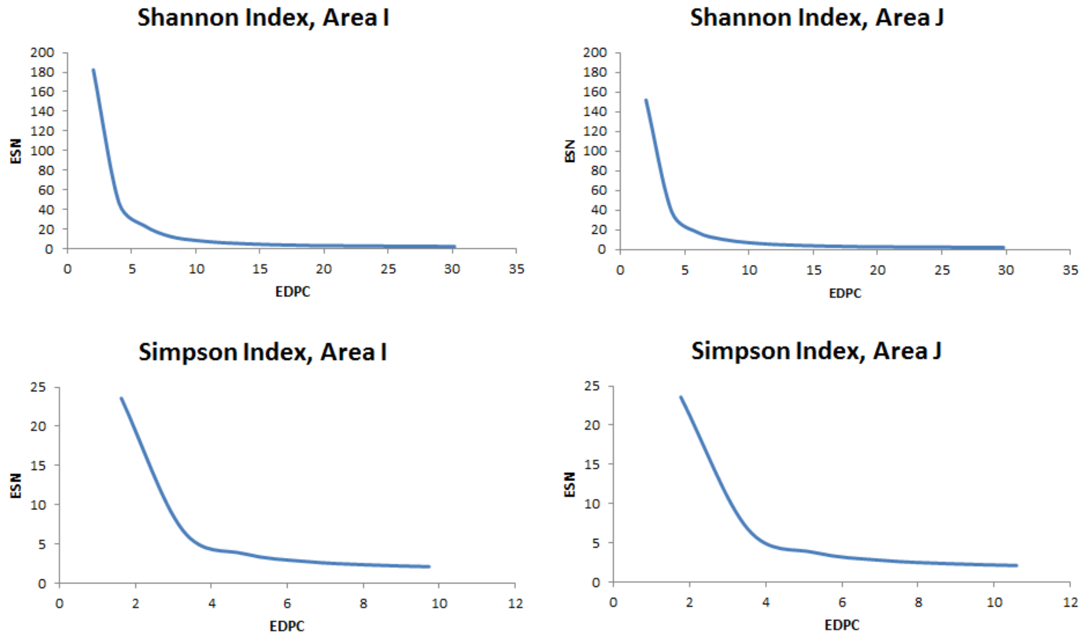


Figure 4.3. Relationship between epibenthic sample size (*y*) and percentage change detection in East Anglia THREE and FOUR for Shannon and Simpson indices.

4.4.2 Cable Corridor

Table 4.6. Results from Power analysis for estimated epibenthic surveys on the cable corridor.

Effect Size	Cable Corridor (n = 6)	
	Power H'	Power S
0.2	0.39	0.97
0.5	0.98	1
0.8	0.99	1

As with all previous assessments presented during this study, Table 4.6 demonstrates an effect size of 0.8 relates to a sufficiently high statistical Power. Table 4.2 establishes that this level of effect also relates to an EDPC of less than 50% for both Shannon and Simpson indices for the epibenthic cable corridor. Again this is confirmed for both indices by a plot of ESN and EDPC (Figure 4.4).

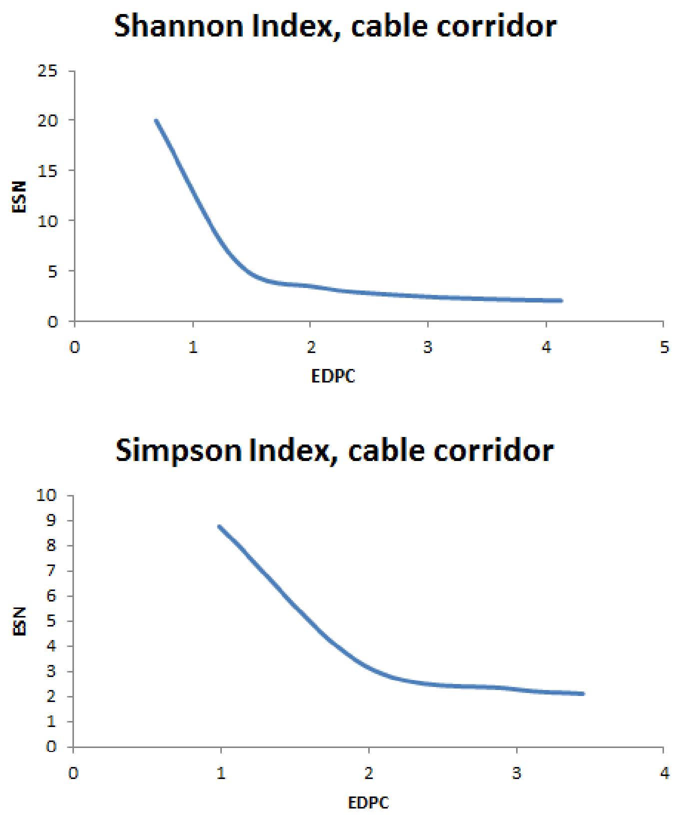


Figure 4.4. Relationship between epibenthic sample size (*y*) and percentage change detection in the cable corridor for Shannon and Simpson indices.

As part of the cable corridor remains unsurveyed an estimated 3 additional stations are required to provide the necessary coverage for robust statistical analysis and to reach the requisite sample size of 6 stations throughout the entire cable area. This is in line with the 2010 study density (MESL, 2011) of 0.01 epibenthic stations per km^2. It is recommended that 6 stations are surveyed throughout the cable corridor as a whole to avoid any temporal variation in data collected in different parts of the corridor.

5 DISCUSSION

5.1 Implications of Variance

It is evident that the low spatial variance in diversity exhibited by the benthic and epibenthic community in the Zone (MESL 2011) would have major implications for the Power analysis. It is the variance around the mean that is the main driver for the estimated sample number and, as in this case where that variance is low, Power analysis informs us that a very high statistical Power is possible with a relatively small number of samples. This is most evident in the plots of ESN against EDCP which show that the lower limit of sample size that can be estimated from a Power analysis (n = 2) is reached before an EDCP of 50% is reached. This low community variation has positive implications for the EIA, as any changes in the community structure should be easily detected.

Although the relationship between detectable change and sample number shows very high Power, we cannot, however, assume that any post impact survey will show the same low levels of variance. Increasing levels of variation in future may compromise Power and therefore a conservative approach is advised. This is because increasing variation in spatial patterns of diversity is one potential outcome of development. Nevertheless, we have shown that the current survey protocol will detect change well below the proposed 50% (doubling or halving of diversity) that is deemed appropriate for many biological communities, we can assign high confidence that it will highlight any changes in the communities present in East Anglia THREE and FOUR and the cable corridor (once adequately surveyed).

The levels of variance found also have implications beyond this study. The low EDPC/high effect size relationship has resulted in a high effect size being selected as suitable for this study; that is an *es* of 0.8 consistently relates to a percentage change substantially below the 50% threshold. It is important however, to note that an effect size of 0.8 may not be applicable to Power analysis conducted for other benthic surveys, as they may demonstrate considerably greater spatial variation in diversity than found here. Indeed, the use of an effect size of 0.8 for other studies may potentially compromise those studies to the extent that major change is not perceived, or that an unmanageable number of samples are required. In the absence of regulator guidance, we therefore recommend the tailored approach retaining the 50% detectable change level to Power Analysis for similar studies.

5.2 Benthic Surveys

It is clear from the high Power and low EDCP values shown that the number of benthic stations sampled in undertaken in East Anglia THREE and FOUR are adequate to assess any change in community structure. Indeed the level of change detectable is quite low (estimated as low as 10% for Simpson metrics in East Anglia THREE).

Assuming that the homogenous ecological diversity recorded across the Zone also applies to the unsurveyed areas, then it is assumed that the cable corridor will demonstrate similar high Power/low EDCP levels based on the variance from the randomly selected sites used. As shown in Section 4.3.2, a further 36 benthic stations will be required in the unsurveyed areas to ensure a consistent survey effort of 0.13 stations per km^2. It should be noted however, that by surveying only these outstanding 36 stations, temporal inconsistencies could affect the cable corridor assessment and it would be prudent to discuss this temporal issue and the need for future surveys with the regulator.

5.3 Epibenthic Surveys

As found for the benthic surveys, the epibenthic characterisation effort for East Anglia THREE and FOUR is sufficient to assess any impacts to the epibenthic ecology of that area. It should be noted that this analysis is in relation to benthic invertebrate taxa only and does not include fish species, for which there was dedicated survey effort.

Similarly, as discussed in Section 5.2, assuming that the homogeneity recorded within the surveyed sites also applies in the unsurveyed areas, the epibenthic cable corridor community surveys should demonstrate similar high Power/low EDPC levels. As shown in Section 4.4.2 a further 3 benthic stations will be required in the unsurveyed areas to ensure a consistent survey effort of 0.01 stations per km^2. Due to the small number of sample stations that are required throughout the cable corridor as a whole however, (6 stations are required to achieve statistical Power and maintain consistency with the previously sampling density), APEM recommended surveying 6 stations throughout the entire cable corridor which will result in all epibenthic samples from the cable corridor being gathered within the same sample season.

5.4 Spatial v Temporal variation.

This report is tailored towards a short term, pre- and post-construction study to assess potential effects of development using analyses which compare the (pre- and post-impact) mean and variation of assemblage diversity metrics for each of the relevant areas. Nonetheless, the extremely high Power suggests that the survey effort will be suitable for a longer term monitoring program.

It is important to note however, that short term changes in climactic or physical oceanic conditions may provoke a change in ecology which could falsely be attributed to development (for example, following a severe storm event). APEM recommends therefore that consideration is given to the development of longer term monitoring, and if this is not possible due to cost or other considerations, monitoring of local marine conditions is undertaken to exclude the potential effect of other causal factors in the event of major change being discovered.

6 RECOMMENDATIONS

1. No further survey work is necessary to inform the baseline characterisation for East Anglia THREE and FOUR for both benthic and epibenthic communities, as the results of the Power analysis indicate that the number of samples already collected are more than sufficient to confidently assess greater than a 50% change in diversity index values with a high statistical Power.
2. To provide a spatially and statistically sound baseline from which to measure potential impacts of the project, unsurveyed areas from the cable corridor should be sampled, and to provide temporal consistency, consideration should be given to resampling the entire cable corridor.
3. Sampling design should be carried out using the same grid approach as that employed for the 2011 Zonal characterisation survey.
4. A reduction in sample number for future benthic surveys is possible, however due consideration of potential impacts and dialogue with the regulators is required.

7 REFERENCES

APEM. 2003. Electric fishing sampling methodologies for salmonids. APEM Scientific Report ERT 724.

APEM. 2010. London Array offshore wind farm: Aerial survey methods, data collection and statistical analysis. APEM Scientific Report LAL 410955, APEM Ltd.

APEM. 2011a. Lamprey monitoring on the River Dee Special Area of Conservation. APEM Scientific Report 411656, APEM Ltd.

Bohlin, T., Heggberget, T.G. & Strange, C. 1990. Electric fishing for sampling and stock assessment. In: Cowx, I. & Lamarque, P. (eds.) Fishing with electricity, Applications in Freshwater Fishery Management. Blackwell Scientific Publications, Oxford, pp 112-139.

Coe, R. 2002. *It's Effect Size, Stupid: What effect size is and why it is important*. Proceedings of the Annual Conference of the British Educational Research Association. University of Exeter.

Cohen, J. 1988. *Statistical Power Analysis for the Behavioural Sciences*. 2nd Ed. Lawrence Hilbaum, Hillsdale, NJ.

Crawley, M.J. 2011. *The R Book*. 9th Ed. John Wiley & Sons, Chichester.

Elliott, J.M. 1993. Some methods for the statistical analysis of samples of benthic invertebrates. 4th Edition. Freshwater Biological Association, No. 25, Ambleside.

Marine Ecological Surveys Ltd. 2011. East Anglia offshore windfarm zonal environmental appraisal: Benthic biological characterisation report. *Report prepared by Marine Ecological Services (MES) for East Anglia Offshore Wind.*

Quinn, P. & Keough, M.J. 2003. *Experimental Design and Data Analysis for Biologists*. 2nd Ed. University Press, Cambridge, UK.

Appendix 10.5 Ends Here