Power analyses for the visual monitoring scheme at the Billia Croo site

Prepared for the Sea Mammal Research Unit (SMRU) Ltd.

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Summary of results

- Power analyses were conducted on fauna observation data collected at the Billia Croo site for the period 13/03/2009 to 14/03/2010.
- The power analyses were based on simulations, and investigated the ability of the current monitoring scheme to detect various sized reductions in the underlying abundances of Cetaceans, Seals and Birds.
- The power to detect changes in animal abundances was found to be generally low for the current monitoring scheme and historical data. Reductions in underlying animal abundances of 10%, or less, are effectively undetectable over a 6 month monitoring window.
- *For birds*: speculative impacts producing reductions of 50% in the underlying abundance, with 3+ months of post-impact monitoring, are almost certainly detected with 3 months of monitoring after the impact. After 3-months of current visual monitoring, a 50% reduction in birds is detectable with an approximate probability of 0.93.
- *For seals*: for speculative impacts producing reductions of 50% in the underlying abundance, 6 months of post-impact monitoring gives good power of detection. After 6-months of current visual monitoring, a 50% reduction in seals is detectable with an approximate probability of 0.7.
- *For cetaceans*: for speculative impacts producing reductions of even 50% in the underlying abundance, 6-months of post-impact monitoring gives only moderate power of detection. Such reductions are unlikely to be detected with only 3 months visual monitoring after the impact. After 6-months of current visual monitoring, this 50% reduction in cetaceans is detectable with an approximate probability of 0.45.
- The power to detect changes is expected to increase with a longer time-series of data.

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1 Report overview

This document briefly presents the results for the first statistical power analyses of animal sightings data for the Billia Croo site. These observations were collected over the period 13/03/2009 to 14/03/2010 in the manner detailed in the *Data Collection Protocol* (SMRU Ltd, 2008).

The principal goal of the analyses presented here is to investigate the statistical power of the current observation scheme, and subsequent statistical modelling. In this context, *power* is the ability to detect shifts in the underlying abundance of obvious marine fauna.

This report covers the following:

- A description of the data-cleaning and manipulation required to put the observations in a form suitable for analysis.
- Subsequent recommendations for improvements to the data entry process.
- A description of the simulation method that underpins the power analyses.
- The results of simulation studies investigating the power for three groups of marine animals: Cetaceans, Seals and Birds.
- A discussion of these results.

2 Data

The data provided by SMRU Ltd. consisted of a MS Access data-base with a user-friendly interface for data entry. From this data-base records for the following were extracted:

- The start and finish times of watches.
- Marine mammal observations.
- Bird observations.
- Environmental conditions during watch periods.

Naturally only observations are recorded. Periods of observer effort that resulted in no observations are integral to analysis of the data and must be inferred. The majority of the preliminary data-manipulation is directed towards including this 'no-observation' information.

2.1 Cleaning and pre-treatment

All variables were examined for inconsistencies. In particular, nonsensical values and deviations from the specifications within the Data Collection Protocols (SMRU Ltd. 2008) were sought. Where possible, inconsistent data were corrected to the most logical intended value, or excluded where this was not clear.

Some examples include:

- Variable use of upper/lower case.
- Spelling errors and variable use of acronyms e.g. the following used to represent a nil observation "N ONE", "n0ne", "na", "nil", "NIL", "none", "NONE".
- Missing observations.
- Horizontal angles outwith 0°-360°.
- Mixing of the start and finish times of watches, or omission of start/finish times.

Recordings were given for both the declination and horizontal angles for each animal observation. The declination angle, in combination with the observer height (deemed to be 110m), was used to generate distances from the observation point. Coupled with bearing, an *x*, *y* coordinate was calculated for each observation.

Observations were truncated to the specified region indicated within Figure 1. All observations greater than 5km from the observation point, or with an observation angle to the East of the linear Eastern boundary, were excluded from analysis. These must be excluded, as even partial adherence to the *Data Collection Protocol* would give systematically lower effort in these regions.

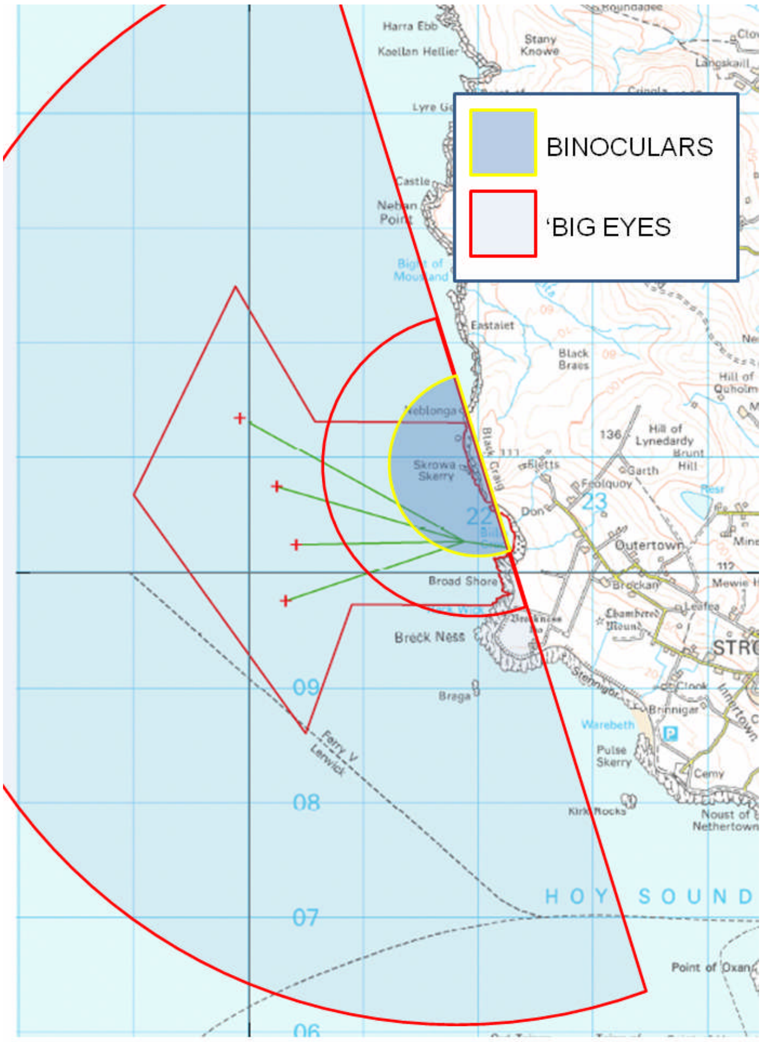

Figure 1: the Billia Croo survey region (SMRU Ltd. 2008).

All observations were further allocated onto a grid with $1km^2$ resolution – this allows easy inclusion of the "no-observed-animals" information, both spatially and temporally. The result of this filtering is displayed in Figure 2 - Figure 4.

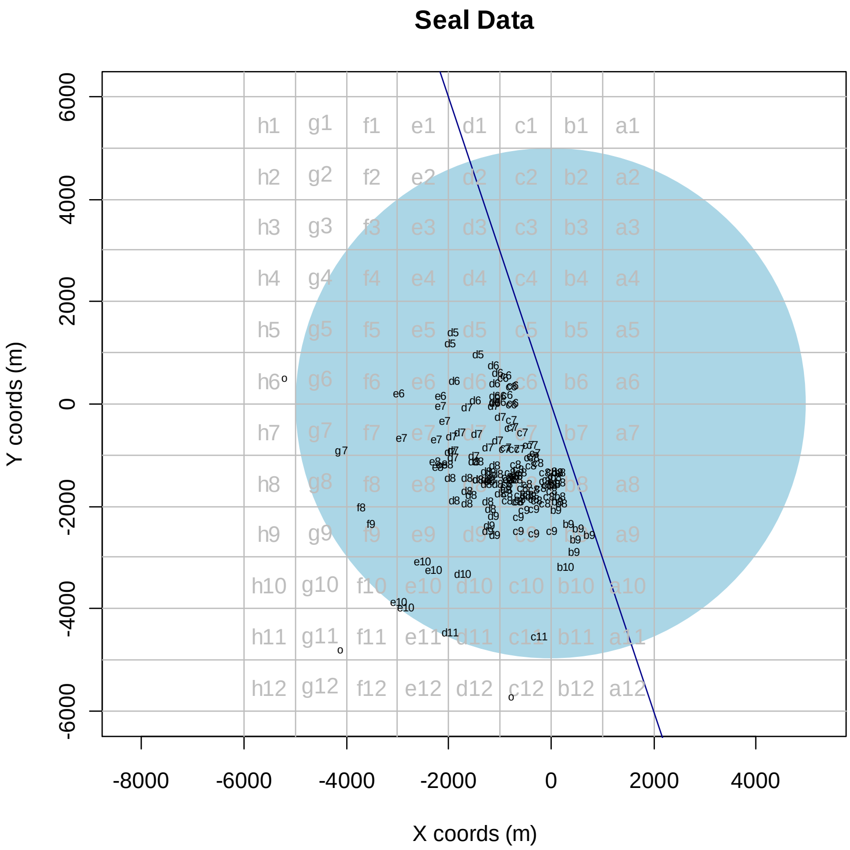

Figure 2: Locations of observations for the Seal data. The observer station is located at the origin (0,0). The blue circle indicates a 5km radius about the observer and the blue diagonal line the Easter boundary of the survey region. Excluded observations are indicated by the symbol 'o', other observations are indicated by their allocated grid-codes. Further observations exist beyond the plotting region.

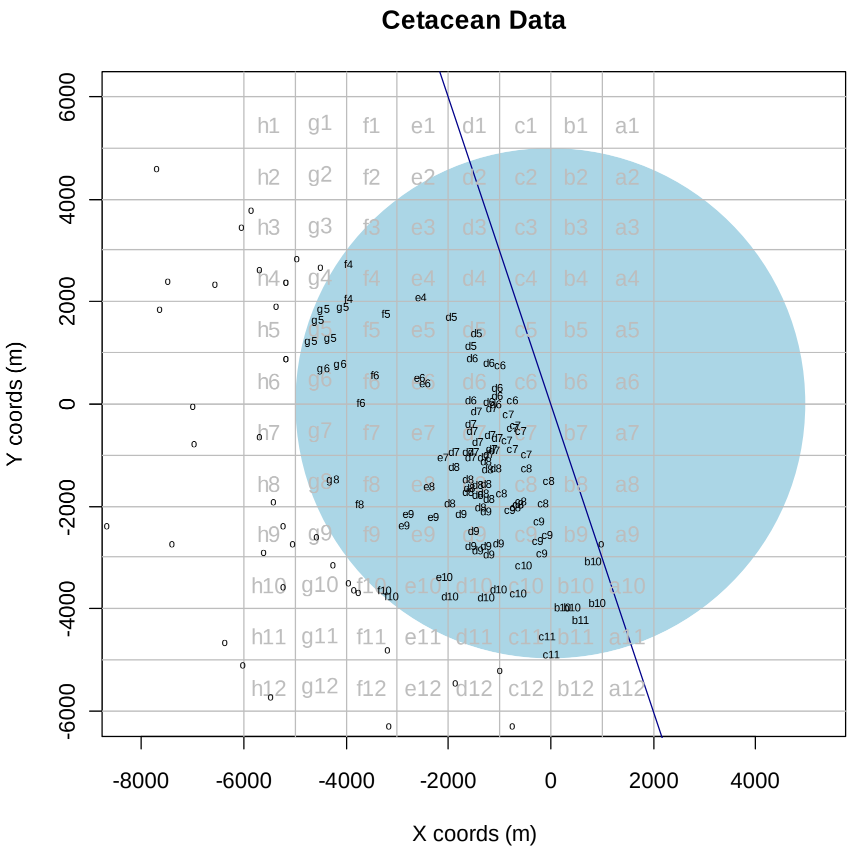

Figure 3: Locations of observations for the Cetacean data. The observer station is located at the origin (0,0). The blue circle indicates a 5km radius about the observer and the blue diagonal line the Easter boundary of the survey region. Excluded observations are indicated by their allocated grid-codes. Further observations exist beyond the plotting region.

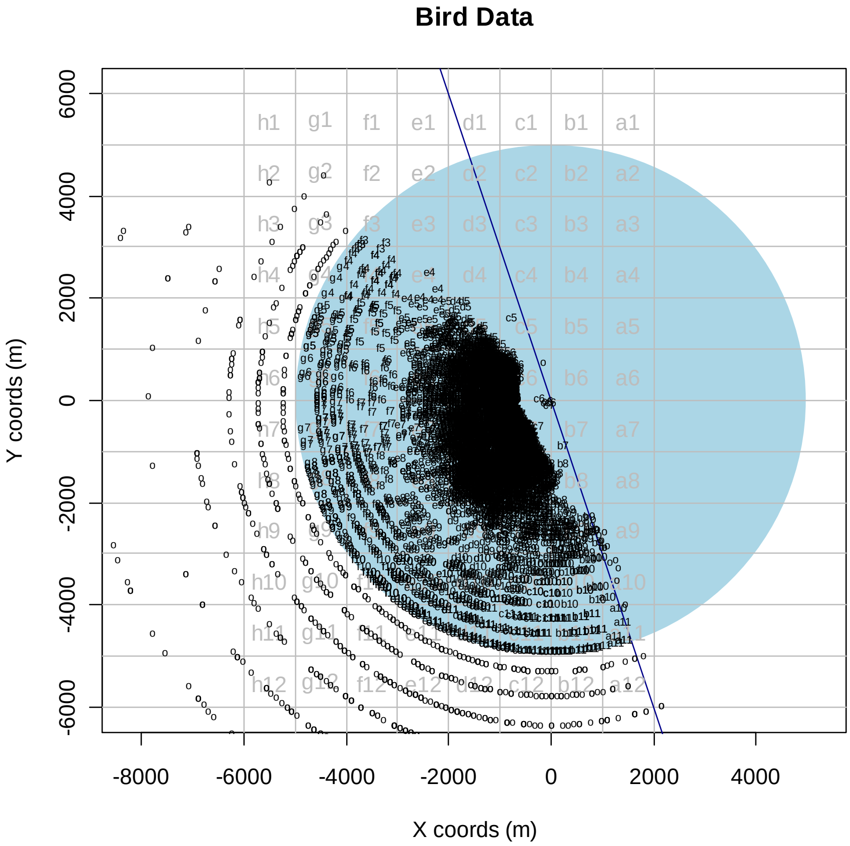

Figure 4: : Locations of observations for the Bird data. The observer station is located at the origin (0,0). The blue circle indicates a 5km radius about the observer and the blue diagonal line the Easter boundary of the survey region. Excluded observations are indicated by their allocated grid-codes. Further observations exist beyond the plotting region.

2.2 Data recommendations

Entries to the database should be further constrained. For example:

- Some angles (in degrees) are outside the 0-360 range. Similarly some declinations indicate distances of more than 60 km.
- Entries to most character fields appear to be case-insensitive, which is generally not the case at the analysis stage. Character case could be restricted.
- Equipment code is an unrestricted field.

The most important modification would be to the entry of bird observations. Currently the data-base fields permit the entry of up to three species names per observation, and an overall count for the total number of animals. The analyses requested were species-specific, (in this case only Guilliemot, Razorbill, Kittiwake, and Fulmar were considered), which requires species-specific counts. This information is currently only contained within the comments field, which requires substantive post-processing i.e. to date, the manual entry of approximately 1000 observations from examination of the comments field.

3 Power analyses

A power analysis was conducted via simulation. This is similar to the approach used in Mackenzie *et al.* (2007b, 2008a,b).

3.1 Overview of simulation process

- The model that has been developed on historical data is assumed to hold true for the future monitoring periods, but with a general reduction in relative animal abundance (e.g. attributable to an anthropogenic cause such as a marine installation).
- Simulation data is generated from this process, with noise consistent with the historical recordings.
- Various sizes of effect are simulated, and detection of a statistically significant effect is sought from the models at various post-effect time points (here 3 and 6 months). Monitoring effort at the historical rate is assumed throughout.
- The current modelling process is applied to the multiple sets of simulation data but additionally estimating for an effect.
- The inherent noise in the system will mean small effects are difficult to detect over small time-periods, but become more detectable with more data. Large effects should be detectible sooner.
- The simulation process conducted a large number of times, allows quantification of the probability of detecting an effect, for various combinations of effect sizes and periods of post-effect monitoring.

For the above process, Generalized Additive Models (GAMs) with Generalized Estimating Equations (GEEs) were fitted to the historical data. These models provide estimates of both the underlying signal and the noise expected for the system. The simulated effects (i.e. %-age reductions in the underlying animal abundances) are created by altering the underlying signal.

3.2 Cetaceans

The historical Cetacean data was modelled and simulations generated, where the underlying Cetacean abundances were depressed by 0%, 1%, 5%, 10% & 50%.

Assuming the current monitoring effort were maintained, Table 1 indicates the percentage of times that statistical analysis of the data would conclude an effect had occurred. This was performed for data collections over both 3- and 6-month windows post-impact. The simulations were run 500 times for each combination of monitoring period and effect size.

		Additional monitoring period (months)	
		3	**6**
Effect size	**0%**	6.8%	6.0%
	1%	7.6%	6.8%
	5%	8.4%	6.2%
	10%	9.6%	7.4%
	50%	26.8%	45.4%

Table 1: Power to detect % abundance reductions (Effect size) for differing lengths of post-impact monitoring.

From the table, the power to detect an underlying change increases with the longer monitoring period. Similarly the power increases with the magnitude of the effect. However, power is generally low until the effect size is 20% regardless of additional monitoring duration.

Entries for the 0% effect size indicate the percentage of times an effect would be concluded, when no such effect exists. This ought to be approximately 5%, corresponding to the expected type 1 error.

3.3 Seals

The historical Seal data was modelled and simulations generated, where the underlying Seal abundances were depressed by 0%, 1%, 5%, 10% & 50%.

Assuming the current monitoring effort were maintained, Table 2 indicates the percentage of times that statistical analysis of the data would conclude an effect had occurred. This was performed for data collections over both 3- and 6-month windows post-impact. The simulations were run 500 times for each combination of monitoring period and effect size.

		Additional monitoring period (months)	
		3	**6**
Effect size	**0%**	4.0%	3.6%
	1%	4.6%	4.6%
	5%	5.6%	6.0%
	10%	7.3%	6.0%
	50%	43.0%	71.8%

Table 2: Power to detect % abundance reductions (Effect size) for differing lengths of post-impact monitoring.

From the table, the power to detect an underlying change increases with the longer monitoring period. Similarly the power increases with the magnitude of the effect. However, power is generally low until the effect size is 20% regardless of additional monitoring duration.

Entries for the 0% effect size indicate the percentage of times an effect would be concluded, when no such effect exists. This ought to be approximately 5%, corresponding to the expected type 1 error.

3.4 Birds

The historical Bird data was modelled and simulations generated, where the underlying Bird abundances were depressed by 0%, 1%, 5%, 10% & 50%. The species considered here were Guilliemot, Razorbill, Kittiwake, and Fulmar grouped together. The reductions indicated are not species specific and apply to the grouped counts as a whole.

Assuming the current monitoring effort were maintained, Table 3 indicates the percentage of times that statistical analysis of the data would conclude an effect had occurred. This was performed for data collections over both 3- and 6-month windows post-impact. The simulations were run 500 times for each combination of monitoring period and effect size.

		Additional monitoring period (months)	
		3	6
Effect size	0%	4.0%	5.3%
	1%	4.7%	7.0%
	5%	6.7%	8.0%
	10%	8.7%	13.3%
	50%	93.3%	99.3%

Table 3: Power to detect % abundance reductions (Effect size) for differing lengths of post-impact monitoring.

From the table, the power to detect an underlying change increases with the longer monitoring period. Similarly the power increases with the magnitude of the effect. However, power is generally low until the effect size is 20% regardless of additional monitoring duration.

Entries for the 0% effect size indicate the percentage of times an effect would be concluded, when no such effect exists. This ought to be approximately 5%, corresponding to the expected type 1 error.

4 Discussion

All the results presented here are based on the detection of changes in *relative* animal abundance. There is certainly variable detection probability with respect to distance from the observer. As this is unquantifiable with the current data, estimates of genuine animal abundance are not possible. This has no particular consequence to the power of the monitoring scheme.

The power of the current monitoring scheme, at this point, is found to be generally low for all species considered. This is a consequence of large natural variability and relatively little data to identify any underlying patterns in abundance.

Birds currently offer the best power for the detection of changes in relative animal abundance. The results here suggest the current monitoring scheme would almost certainly (93.3%-99.3%) detect a genuine 50% reduction in the relative abundance of birds, given 3-6 month window of data collection.

Seal observations would offer a reasonable chance of detecting a genuine 50% decrease in relative abundance after 6 months of data collection under the current scheme. However, Cetacean observations offer a poor chance of detecting even large changes in relative abundance after 6 months of the current monitoring scheme - only a 45.4% chance of detecting a 50% decrease in relative abundance.

The poor power for the Seal and Cetacean data is not unexpected given even a brief exploration of the data – sightings for these are relatively uncommon. For example, observers were active for more than 1000 hours, but Cetaceans were only observed within 89 of these. Even large reductions in the relative abundance of cetaceans, exhibited in lower numbers of sightings, would be indistinguishable from the base-line in the short-term. Bird sightings, in contrast, were recorded in >80% of observer hours and underlying reductions are more rapidly determined.

The power can be expected to improve as greater base-line data is collected. As greater amounts of the natural variability can be explained (e.g. by annual or tidal cycles), deviations from the existing underlying patterns are more detectible.

5 References

Mackenzie, M. L., Donovan, C. R. & Pawley, M. (2007a) Modelling relative marine mammal sighting rates for the Strangford Narrows. *DMP Statistical Solutions UK Ltd. report to SMRU Ltd. August 2007.*

Mackenzie, M. L., Donovan, C. R. & Pawley, M. (2007b) Analysis of Bird Data for the Fall of Warness Area: A Draft Report for SRMU Limited. *DMP Statistical Solutions UK Ltd. report to SMRU Ltd. August 2007.*

Mackenzie, M. L., Donovan, C. R. & Pawley, M. (2008a) Detecting changes in relative animal abundance using Strangford Narrows visual observations. *DMP Statistical Solutions UK Ltd. report to SMRU Ltd. August 2008.*

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