Inch Cape Offshore Wind Farm

New Energy for Scotland

Offshore Environmental Statement:

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Annex 14A.1: Strip Width Acoustic Analysis for Harbour Porpoise

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14A.1 Strip Width Acoustic Analysis for Harbour Porpoise

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14A.1.1 Introduction

A value for g(0), the proportion of animals on the trackline that are detected, is necessary if line transect surveys are to be used to provide absolute abundance estimates. One approach to obtaining this value uses a mark recapture methodology (Borchers et al., 1998). In this method, detections made by one detection platform are considered to set up “trials” for a second independent platform. If the second platform detects the same animal (often termed a “duplicate” detection) then the trial is scored as a success, and if the animal is not detected by the second platform it is scored as a failure. g(0) is then determined from the proportion of all “trials” that were successful. (Note, these trials are judged on a case by case basis. Comparisons of the overall detection rates of the two observers are not used.) When both platforms are visual, as has often been the case in the past, it can be difficult to attain independence in detection. Usually the two observer teams are placed at different heights and one may be instructed to search ahead of the other (and are provided with powerful binoculars to encourage this) so that “trials” can be initiated beyond the normal field of view of the second platform. In the study described in this report, the visual detection team and the acoustic system provide the two independent platforms. Detections made by the visual team initiate trials to determine acoustic g(0), while detections made acoustically initiate the trials to measure visual g(0). The use of two different detection methods (visual and acoustic) addresses some of the concerns about independence. However, because the hydrophone is towed behind the vessel (~200 m behind in this case) and sightings are made ahead or abeam of the boat, detections will be separated in time and duplicates may be more difficult to determine. There also may be factors, such as the orientation of the animal and the stage within the diving cycle (e.g. it is only animals that surface within a certain distance ahead of the vessel that are seen), that affect the independence of visual and acoustic detections. These factors could contribute to either greater or fewer than the expected number of duplicates than would be recorded under complete independence.

14A.1.2 Initiating Trials to Estimate g(0)

Sightings and associated information were recorded in the field, while acoustic data were analysed independently ashore after the survey and without any reference to the visual dataset.

“Trials” were established in the dataset by comparing the two sets of detections to identify unambiguous instances where detections by one method could be used to test the performance of the other. To avoid false positives from situations where another animal or group present in the area could be confused with the one used to initiate the trial, trials were only considered on occasions when no detections were made by the trial method for three minutes either side of the trial detection. This involved excluding data from this analysis but should not have introduced any bias.

14A.1.3 Effects of Vessel and Number of Observers

The dataset used for this analysis was not homogenous and to control for differences that might have a significant effect, data were stratified for analysis. Data were collected from two adjacent sites. On one, Neart na Gaoithe (NnG), the visual team comprised two seabird observers and a scribe who observed from the dead ahead to 90 degrees on one side of the vessel only (the side affording best visual conditions being chosen). On the second site, Inch Cape, a marine mammal observer was added to the visual team and this marine mammal observer scanned both sides of the trackline. The same type of acoustic equipment was used on both sites throughout and the same vessel was used on both sites. However, a change in survey vessel was made at the beginning of 2011, roughly half way through the NnG survey period and five months into the Inch Cape surveys. Changes in vessels and differences in visual observer methodologies across the two sites may have affected either acoustic or visual detection efficiency. Thus data have been stratified and effects of these factors investigated.

Vessels are likely to vary in the levels of underwater noise they generate. Noise measurements showed that the Eileen May (used in the latter part of the surveys) was noisier than the Fleur de Lys (used in the earlier part of the surveys). As this could affect acoustic detection efficiency, the data were initially stratified by vessel (Fleur de Lys, Eileen May). Vessel noise could affect detection rate in two ways. Masking and interference effects will directly degrade the acoustic system’s ability to detect signals. It might be expected that this effect will be most pronounced for the quieter signals from animals at greater ranges and might thus influence strip width rather than reduce the detection probability for animals at close distances. The second way that noise could affect detection rate would be though its influence on porpoise behaviour. If porpoises respond to the vessel by moving away then it is possible they may be oriented away from the hydrophone making them less likely to be detected due to the directional nature of their vocalisations.

The two survey areas were surveyed with different observer combinations. On NnG there was a bird observer team which searched to one side of the vessel, whereas for Inch Cape the visual team also included a marine mammal observer searching both sides of the vessel. We assumed that, for visual sightings, the differences in detection efficiency between these two observer combinations would be considerably greater than any effect of vessel noise. Hence separate estimates of visual g(0) were generated for Inch Cape and NnG . Sample sizes were too small to be able to stratify by both vessel and Development Areas at the same time, and so data were pooled across the two vessels for the purposes of estimating g(0) for visual sightings.

Acoustic detection events were classified by the analyst as being either “certain porpoise” or “likely porpoise” based in part on the acoustic characteristics of the clicks. These two categories were also investigated for any difference in the proportions of acoustic detections detected visually.

14A.1.3.1 Methods for g(0) Estimation

g(0) was estimated using the method of Buckland *et al* (1993) where g(0) for method *A* is given by

$$g_A(0) = \frac{n_{AB} w_B}{n_B w_{AB}}$$

(1)

Where n_{AB} is the number of duplicates detected by both methods, n_B is the number of trials (i.e. successful trials) based on detections by method *B*, w_{AB} is the strip width of the duplicated data and w_B is the strip width of the trial data for method B.

The delta method was used to estimate overall variance in density, $\widehat{D}$ using the formula from Buckland (1993)

$$\widehat{var}(\widehat{D}) = \widehat{D}^2 \left\{ \frac{\widehat{var}(n)}{n^2} + \frac{\widehat{var}[\hat{f}(0)]}{[\hat{f}(0)]^2} + \frac{\widehat{var}[\hat{E}(s)]}{[\hat{E}(s)]^2} + \frac{\widehat{var}[\widehat{g(0)}]}{[\widehat{g(0)}]^2} \right\}$$

(2)

Where estimated strip half width is ${}^{1}/_{f(0)}$ and E(s) is the mean estimated school size (or cluster size for acoustic detections which was the average number of sightings within a minute for minutes with at least one sighting).

14A.1.4 Comparing Acoustic Events Classified as Porpoise Certain or Porpoise Likely

Table 14A.1.1 gives the number of acoustic trials detected visually for those classified as ‘certain’ or ‘likely’ porpoise based on the acoustic data. The visual detection rate for ‘certain’ acoustic detections was significantly higher than for ‘likely’ acoustic detections or tracks (Chi-squared, p=0.003). Therefore only ‘certain’ tracks were used to initiate trials for estimating visual g(0). There is some evidence from the strip widths that detections classified as ‘likely’ tended to be further away from the trackline, with strip width for ‘likely’ tracks 36% larger than for ‘certain’ tracks. However this does not fully explain the differences in visual detection rate.

Table 14A.1.1: Number of Porpoise Acoustic Detections Classified as 'Certain' or 'Likely' Used for Trials, and the Proportion of These Detected Visually

	Porpoise 'certain' (Events and Tracks)	Porpoise 'likely' (Events and Tracks)
Total acoustic trials	184	225
Detected visually	19	7
Proportion detected	0.10	0.03

Table 14A.1.2: Estimated Strip Widths for Acoustic Detections Classified as Certain or Likely

	ESHW (m)	CV	N
Porpoise Certain	266	0.073	236
Porpoise Likely	361	0.038	282

14A.1.5 Allowable Timing Error

Duplicates were identified by matching the time a sighting was expected to come abeam of the hydrophone with the actual time abeam for the closest acoustic detection. The expected time abeam of the visually observed porpoise to the hydrophones could be calculated for each sighting by adding the distance of the sighting ahead of the vessel (derived from visual observers' estimation of range and bearing for each sighting) to the distance that the hydrophone the was towed behind the observers (210 m) and dividing by the speed of the vessel (which was known at any time).

Some level of error in this time must be expected however. The main contributions to this error are likely to come from inaccuracies in recording the time of visual detections, inaccuracies in visual estimates of range and bearing and the effects of animal movement between the time of the sightings and the acoustic detection.

- Timing error: On most of the surveys, visual data times were simply recorded as that of the previous whole minute. 30s was added to these times to remove bias in recorded time but a residual mean error of 30secs (maximum up to 60s) will remain even if all data were recorded accurately with synchronised clocks.
- Animal Movement: The hydrophone was towed 200 m astern of the vessel and so around 210 m behind the observers. The average forward distance to sightings estimated by observers was 134 m. Travelling at ~10 knots (5 ms^{-1}) there will be an

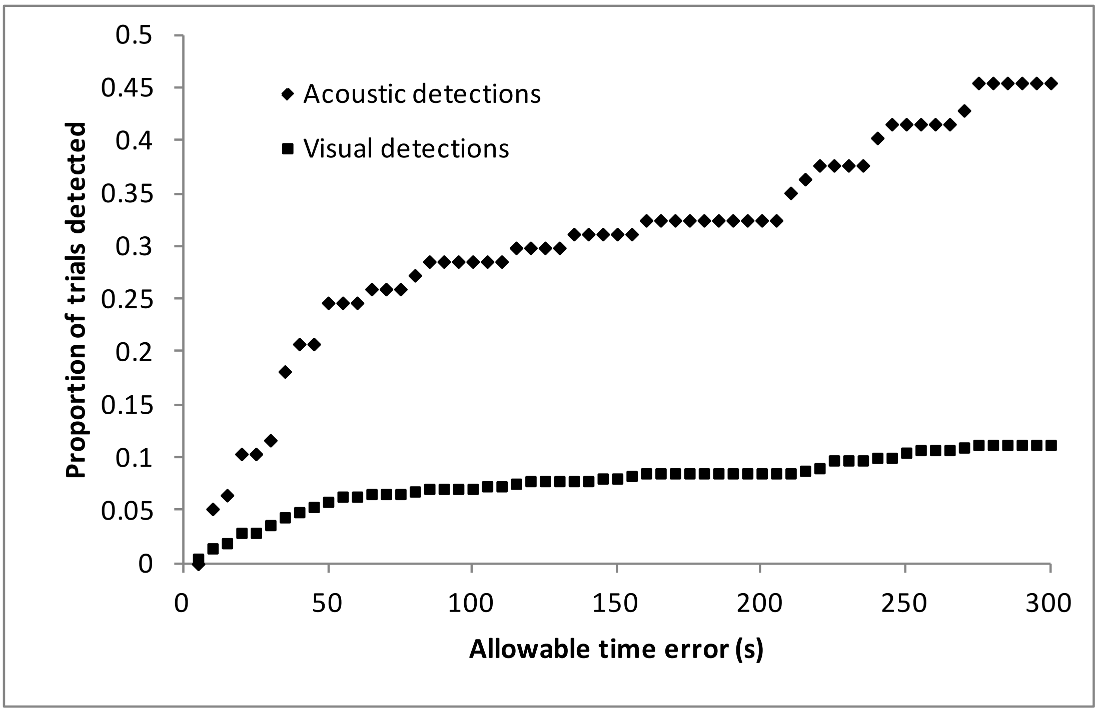
average of approximately 70s between the visual sighting and the porpoise coming abeam of the hydrophone. Thus, over this time period, movements of sighted porpoises could contribute to timing error and this will largely depend on speed and direction of movement of the animals. Data from porpoise tracks collected during the SCANS II survey indicated the highest average speed for a porpoise for a roughly straight track was 2.6 ms^{-1} over 85 seconds and average speed for apparently reliable tracks of over a minute was 1.5 ms^{-1} (n=12, SD = 0.7).

Only 21/368 sightings were more than 300 m forward of the vessel. In an extreme case of a porpoise swimming at 2.5 ms^{-1} sighted at a distance ahead of 500 m, its time coming abeam would be delayed by 100s if it was travelling in the same direction as the vessel, or would be advanced by 33s if swimming in the opposite direction to the vessel.

Considering all the various sources of error we suggest a maximum error window of around 120s should be considered realistic.

Figure 14A.1.1 below illustrates the proportion of duplicate trails as the allowable timing error window is made larger. We would expect these plots to show the steepest slope within the time window reflecting the real timing error, as an increasing number of real duplicates are included, and for the plots to flatten off beyond that. The slope of the line remains positive as the allowable time window continues to get larger tending towards an asymptote that corresponds to the average detection rate of animals within the area. However this will be affected by clustering of animals and distances between clusters.

Figure 14A.1.1: The Proportion of Duplicate Trails as the Allowable Timing Error Window is Made Larger. Diamonds Indicate Acoustic Detections of Visual Trials. Squares Indicate Visual Sightings of Acoustic Trials



The data in Figure 14A.1.1 do not provide a very clear basis for selecting an appropriate time error window. Although there is an obvious change in slope at around 55s for the acoustic detection, this occurs at the minimum of the expected error and so cannot be considered a reliable indicator. The slope of the acoustic detections is then flat until around 200s. The flat slope within the expected error window means that it is difficult to use the data to select an appropriate error window.

To estimate g(0) and its associated variance, we assumed a uniform distribution of allowable error from 60-120s. This was considered to span the likely range of timing error but we chose a uniform distribution because we had little basis on which to choose a point estimate from within that range. We used a re-sampling procedure, bootstrapping, to generate both the point estimate and the variance. The bootstrap re-sampling was based on selecting a random selection of *n* trials with replacement from the overall set of *n* trials within the data. An allowable timing error was chosen from the uniform distribution and any trial with a corresponding detection or sighting within the allowable window was classified as a success. To incorporate the uncertainty in strip width estimates, each replicate was multiplied by the ratio of the estimated strip width for each trial method and an estimated strip width for duplicates drawn from a normal distribution with the variance associated with these estimates. Each re-sample thus provided an estimate of g(0) taking into account the various sources of uncertainty. This process was repeated for 10,000 replicates with the mean estimate of g(0) and the variance being used to generate the point estimate of g(0) and its associated confidence limits.

14A.1.6 Results

14A.1.6.1 Effects of Vessel

The quieter vessel (Fleur de Lys) did show a slightly greater acoustic strip width than the Eileen May (Figures 14A.1.2 and 14A.1.3 below), but this difference was not significant. There was also no significant difference in the proportion of successful trials between the two vessels, as described in Table 14A.1.3, (Chi-squared test, p=0.62). Given these results, it seemed reasonable to pool data from both vessels for estimating g(0) for acoustic detections.

Figure 14A.1.2: Detection Function for All Eileen May (n=307, 15 samples truncated >1000 m) (ESHW=313 m CV=0.110). The Figure Shows Output from Program Distance which selected the Bin Width and Best Fit Detection Function (red line) on the Basis of AIC. The Y Axis Shows Relative Detection Probability which has not Been Corrected for g(0)

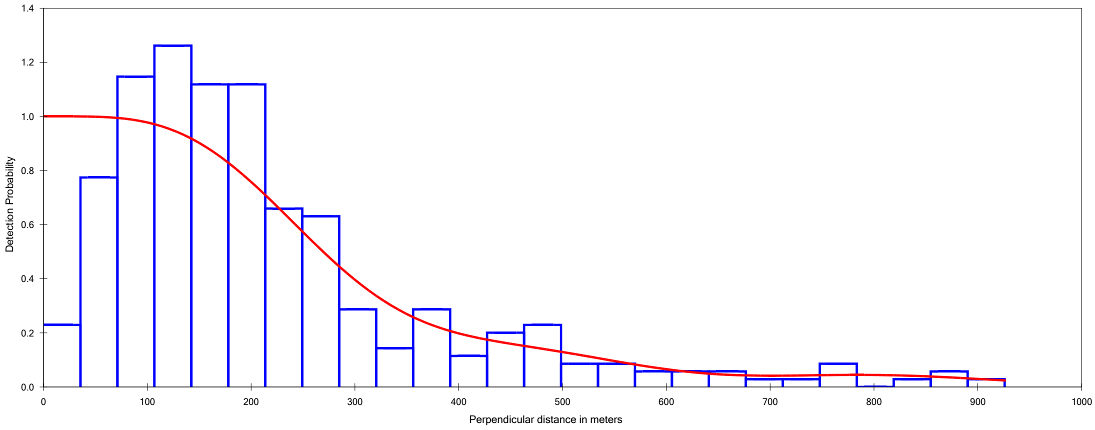


Figure 14A.1.3: Detection Function for All Fleur de Lys (n=166, 12 samples truncated >1000 m) (ESHW=339 m CV=0.050). The Figure Shows Output from Program Distance which selected the Bin Width and Best Fit Detection Function (red line) on the Basis of AIC. The Y Axis Shows Relative Detection Probability which has not Been Corrected for g(0)

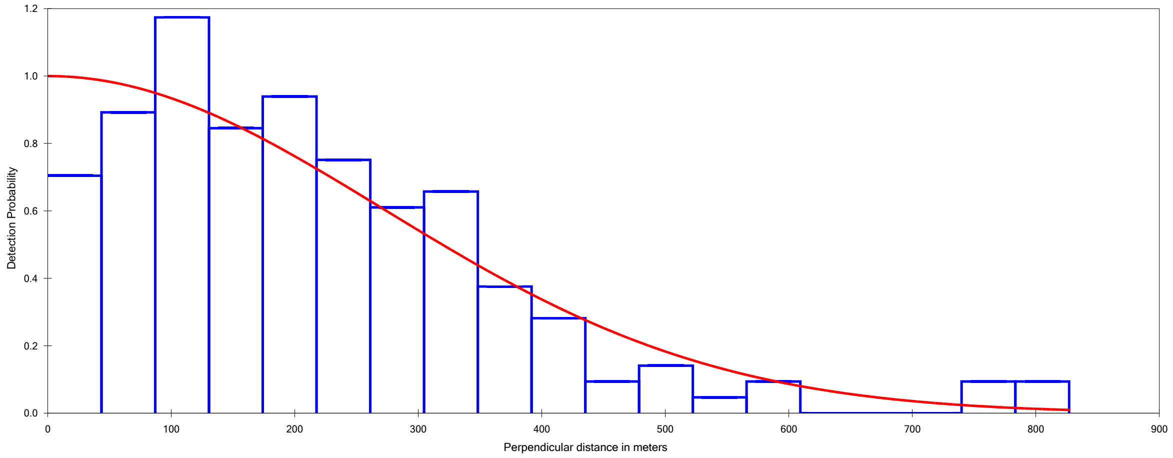


Table 14A.1.3: Number of Trials and Duplicates Trials Using Visual Sightings to Examine the Proportion of Porpoises Detected Acoustically. The Allowable Time Error was taken as +/- 90s, the Mid-point of the 60s-120s Range

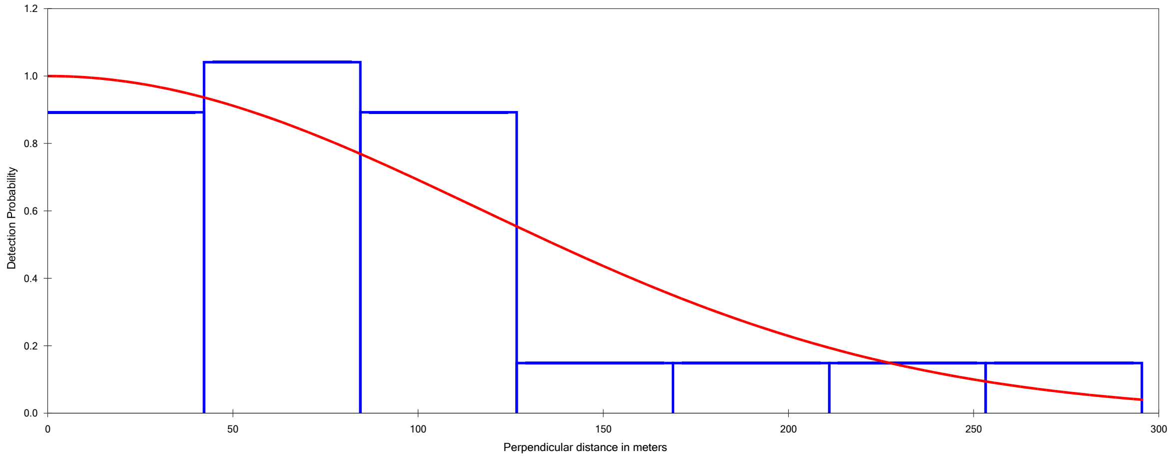
	Both vessels	Fleur de Lys	Eileen May
Visual trials	75	30	45
Trials detected acoustically	25	9	16

Table 14A.1.4 shows that for both vessels combined, acoustic g(0), based on 75 visually initiated trials = 0.46 [CV=0.25; 95% CI = 0.27-0.71]. This is based on a half strip width for the duplicate visual trials that were subsequently detected acoustically (Figure 14A.1.4) of 144 m (CV=0.13). However, it should be noted that this strip width was based on just 23 perpendicular distances which is a rather low number for reliable estimation. The strip width for duplicates was considerably lower than for either visual or acoustic detections independently, and the potential reasons for this are explored in the discussion below.

Table 14A.1.4: Number of Trials and Duplicates for Trials Using Acoustic Detections to Examine the Proportion of Porpoises Seen by the Visual Observers. The Allowable Time Error was taken as +/-90s, the Mid-point of the 60s-120s Range

	NnG	Inch Cape
Acoustic Trials classified as Porpoise ‘certain’ only	110	74
Number of trials detected visually	7	11

Figure 14A.1.4: Detection Function for Visual Trials that were Detected Acoustically (ESHW=144, CV=0.13, n=23). The Figures Shows Output from Program Distance which selected the Bin Width and Best Fit Detection Function (red line) on the Basis of AIC. The Y Axis Shows Relative Detection Probability which has not Been Corrected for g(0)



Visual strip widths were similar with no significant difference between Inch Cape (195 m) and NnG (209 m). These are shown in Figures 14A.1.5 and 14A.1.6.

Figure 14A.1.5: Detection Function for Visual Data from Inch Cape (ESHW=195, CV=0.050, n=244). The Figures Shows Output from Program Distance Which Selected the Bin Width and Best Fit Detection Function (red line) on the Basis of AIC. The y Axis Shows Relative Detection Probability Which Has not Been Corrected for g(0)

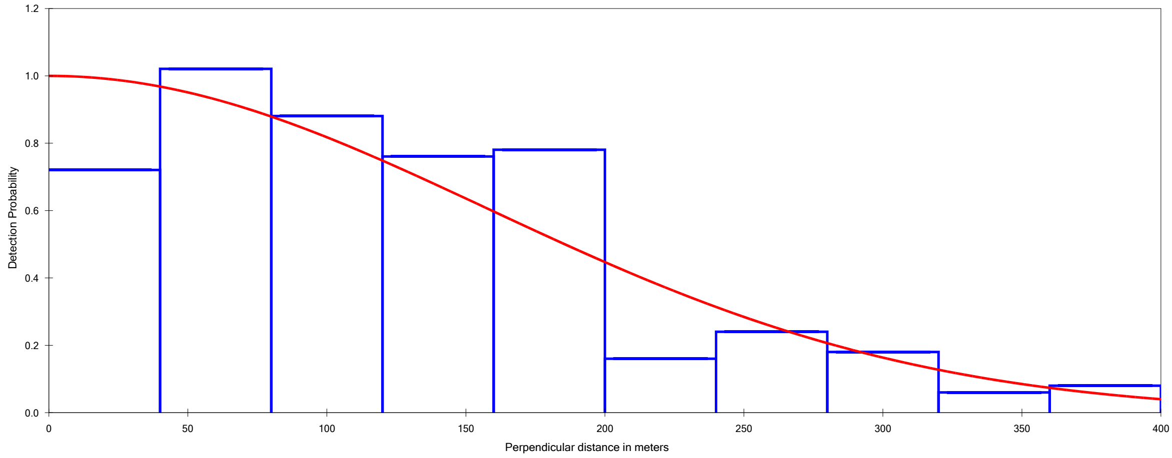
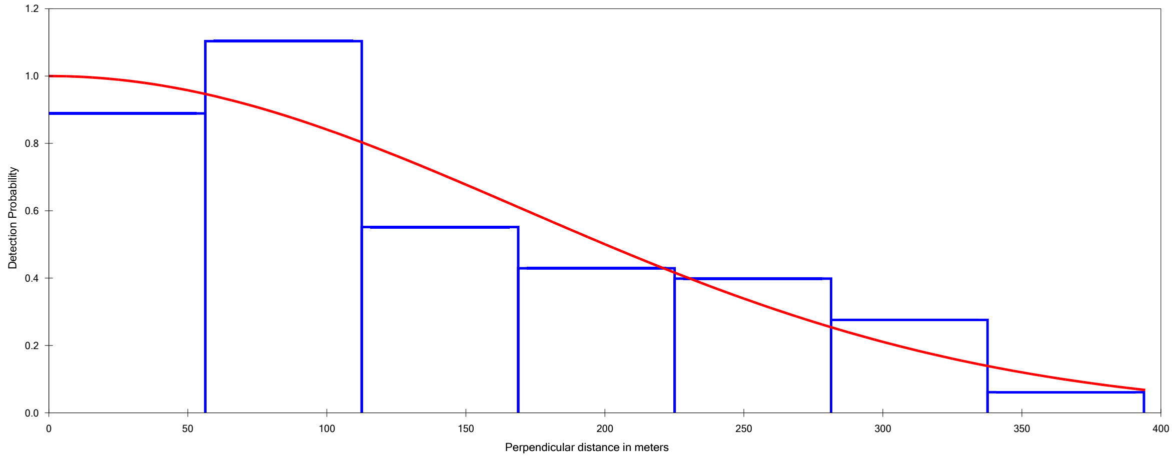


Figure 14A.1.6: Detection Function for Visual Data from NnG (ESHW=209, CV=0.072, n=121). The Figures Shows Output from Program Distance which Selected the Bin Width and Best Fit Detection Function (red line) on the Basis of AIC. The y Axis Shows Relative Detection Probability Which has not Been Corrected for g(0)



For NnG, visual g(0) based on 110 acoustically initiated trials = 0.24 [CV=0.40; 95% CI = 0.08-0.44]. In this case the number of detected trials was only seven which were insufficient to estimate a strip width for duplicates. However, several of these duplicates were from a subset of the duplicates from the visually initiated trials detected acoustically. Hence the duplicate half strip width from these trials (144 m) was used in equation 1 to estimate g(0).

For Inch Cape, visual g(0) based on 74 acoustically initiated trials = 0.32 [CV=0.31; 95% CI = 0.16-0.54]. In this case the number of detected trials was only 11 which were insufficient to estimate a strip width for duplicates. However, as for NnG, several of these duplicates were from a subset of the duplicates from the visual trials detected acoustically. Hence the duplicate strip width from these trials (144 m) was used in equation 1 to estimate g(0).

Inch Cape had a significantly greater proportion of successful trials than NnG (chi-squared, p=0.04) and a higher g(0), which is to be expected given the additional marine mammal observer looking to both sides. A point of note is that in the Inch Cape data both marine mammal and bird observers have been treated as a team (since they are all on the same platform). However, the effort was not even on both sides of the vessel as the Marine Mammal Observer scans both sides whereas the bird observers only watch to one side of the vessel.

14A.1.7 Discussion

The estimates of g(0) obtained from these studies (0.24 and 0.32) for visual observers and 0.46 for acoustic detections are comparable to other studies using similar equipment and methods from small vessels. Surveys in the southern North Sea with similar objectives using similar equipment report g(0)= 0.61 for acoustic detections (Smartwind, 2012). This is rather higher than the 0.46 estimate from this study but not significantly different when consideration is taken of the high coefficient of variance (cv). The estimate for visual observations of g(0)=0.23 in the Smartwind study is very similar to the value of 0.24 from this study for the same observer configuration (i.e. sea bird observers only). It is also similar to the overall estimate of g(0) for harbour porpoise from the SCANSII survey of 0.22, although the vessels used in SCANSII were generally larger, giving a higher observation platform. The confidence limits on all the estimates are quite large and the variance is dominated by the binomial variance associated with the number of trials and proportion of successes. These large confidence intervals could be reduced by collecting more and better data.

An additional source of uncertainty and potential bias is in the identification of duplicates. Estimation of g(0) for visual sightings or acoustic detections relies on accurately detecting duplicate animals. Identification of duplicates will be improved by accurate recording of the time of visual detections and by accurate measurement of distance and angle rather than relying on visual estimates which are generally poor (Leaper et al., 2011). At some spatial scales, porpoise distribution may be clustered with animals occurring in loose aggregations. If a different individual within an aggregation is detected by the method for which g(0) is being estimated than the individual detected for the trial, then this will contribute a false positive. False positives contribute to an overestimation of g(0). The criteria for trials applied in this study, that no porpoises should be detected by the primary method for three minutes before or after a detection initiating a trial, is an attempt to minimise the chance of false positives. However, with relatively low detection probabilities there is still a high chance that there will be animals in the area that are not detected by the method used to set up trials.

Porpoises are thought to show a level of response to vessels, and studies of observed headings suggest a tendency to orientate away from the vessel (Palka and Hammond, 2001). The intensity of the received acoustic signal from porpoises is also known to be strongly dependent on the orientation of the animal relative to the hydrophone. If animals continue to point away from the vessel as they come close to the hydrophone then this will reduce the probability of acoustic detection, whereas if they have moved away and turn to head back to their original position once the vessel has passed then they may be more likely to be detected.

Orientation, and possibly vocal output, may also be affected by the stage in the diving cycle. Porpoises are most frequently seen in the range 100-200 m ahead of the vessel when they are at the surface. This means that they will most likely be well into their diving cycle when they come closest to the hydrophone around 60 seconds later. It is possible they may be more likely to be vocalising at this stage in the dive cycle but further investigations would be needed to relate vocal behaviour to the dive cycle, including possible response to the vessel.

The strip width for duplicates was considerably lower than for either visual or acoustic detections independently. Further investigations could be carried out to see if the ratios of duplicate strip width to the strip widths from the trial methods were lower than expected. It is possible that an interaction between responsive movement and stage in the diving cycle could influence duplicate strip widths. However, the sample sizes for duplicate strip width estimation are very small and have wide confidence limits.

Some of these factors affecting detection probability could also be investigated by towing hydrophones at different lengths astern of the vessel to see if this affected g(0) estimates. A shorter tow length would reduce the time between visual sighting and acoustic detection but would increase the vessel noise on the hydrophone, resulting in lower acoustic detection probability. If two hydrophones were towed at different lengths behind the vessel they could act as two independent acoustic platforms in a similar way to two-platform visual methods. The relative detection rates should provide some information on whether animal response to vessels or stage in the diving cycle consistently affects acoustic detection probability. We also found that very few porpoises appear to be detected acoustically whilst they are ahead of the vessel. This may be due to bubbles created by the propeller blocking sound from ahead of the vessel reaching the hydrophone. It is commonly noted that vessel noise is lower directly aft of the vessel due to this effect.

Methods using visual and acoustic data for obtaining g(0) estimates for harbour porpoise from small boat surveys are still at an early stage of development and the results need to be treated with some caution. However, they do offer the chance to estimate absolute abundance which has not been possible previously from small vessels with insufficient room to have two fully independent visual observation platforms and, moreover, to achieve this without the expense of a second sighting team. Absolute abundance is critical to understanding how many animals may be affected by a development but is also essential if survey results are to be compared between areas and provides a more meaningful validation check on results than a simple index of abundance.

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