MUIR MHÒR
OFFSHORE WIND FARM

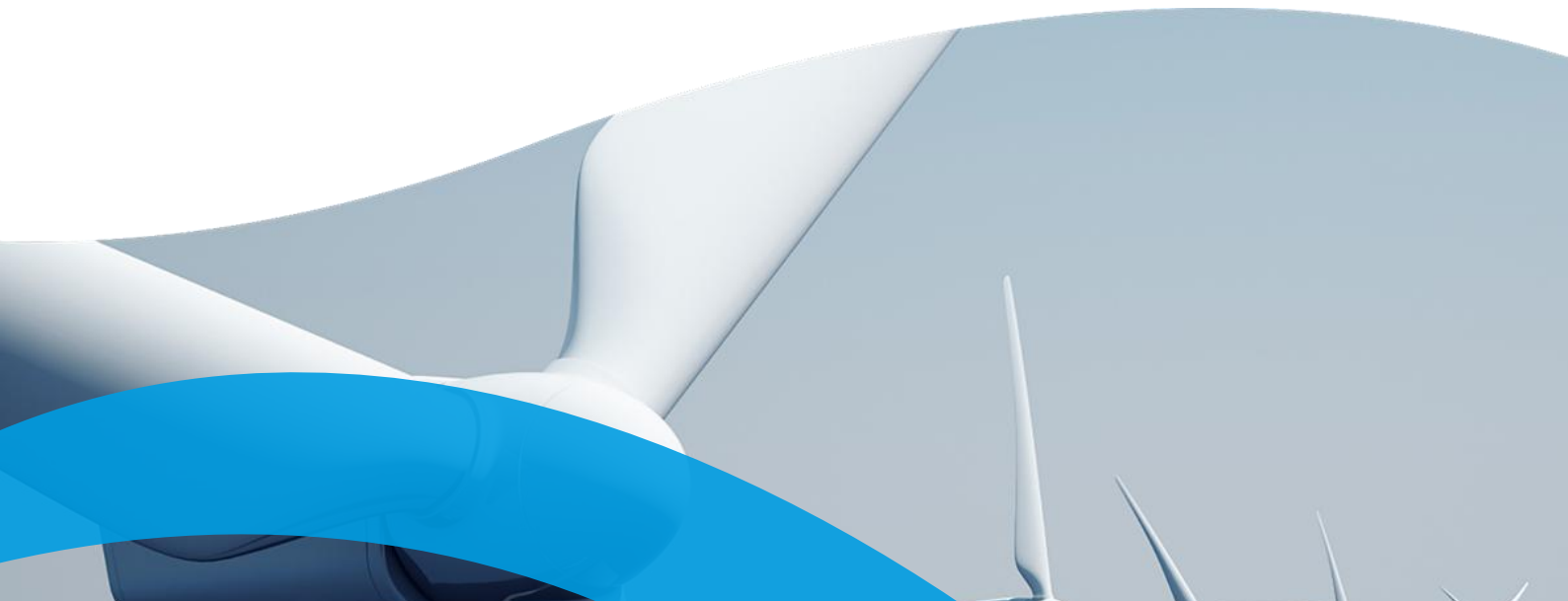
A joint venture between Fred. Olsen Seawind & Vattenfall

Additional Information Report

Muir Mhòr Offshore Wind Farm

Additional Environmental Information Report

Appendix 2: Additional Information on SeabORD



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1. ADDITIONAL INFORMATION ON SEABORD

1.1.1. During consultation with NatureScot (consultation meeting 18/06/2025) the alternative approaches to seaboard were discussed, a summary of these discussions are provided in this Appendix.

1.1. NOTES POSITIVE VALUES FROM SEABORD

1.1.2. There are a number of reasons why SeabORD can predict positive effects of wind farm developments upon seabirds (summarised in Table 3-2 in Searle *et al.*, 2018). In this case, since the development is close to the edge of the foraging range for many SPA-species combinations and a constant prey distribution was assumed, these are likely due to displacement of the foraging locations of simulated individuals to locations closer to the colony, resulting in reduced energetic costs associated with foraging trips, and possibly also due to reduced competition effects among individuals remaining within the wind farm footprint when other birds had been displaced. We do also note that there were no instances where positive impacts were predicted in which the confidence intervals did not span 0, such that rather than suggesting positive impacts of the wind farm development, these results could be considered as indicating no discernible difference among the scenarios. This was reflected in the Application by taking 0 rather than the positive impact, through to the impact assessment, as agreed with NatureScot during consultation.

1.1.3. NatureScot noted that the mortality rates predicted using SeabORD are significantly different to the total breeding season distributional response mortality predicted from the displacement matrix approach (which are provided for context within the assessment). This highlights the levels of precaution in the mortality rates used in the matrix displacement calculation when applied to this Array Area. Current methods to apportion impacts derived from the matrix approach assumes that the adult to juvenile ratio and the sabbatical to non-sabbatical bird ratio is the same regardless of the relative location of the wind farm and the colony. However, it seems logical that the sabbatical rate will be higher further offshore as sabbatical birds avoid competition with breeding birds closer to the colonies and energy expenditure costs associated with foraging so far out are high for breeding birds acting as central place foragers. It is also noted that SeabORD covers only the chick-rearing period, whereas breeding season matrices use peak (or mean peak) values as representative of a whole season. By selecting the peak values from each year of available data, larger impacts are more likely. For example, guillemot are expected to be rearing chicks around June whereas the largest densities of guillemot observed within the Array Area and associated two-kilometre buffer and therefore used in displacement matrices for the breeding season, were detected in May, July and August.

1.2. NATURESCOT PROPOSED APPROACHES TO PROVIDE SUFFICIENT SUPPLEMENTARY INFORMATION

1.2.1. NatureScot suggested three approaches to provide more context within which to understand these discrepancies (copied from NatureScot feedback document):

- The Applicant can repeat the apportioning and PVA elements of the assessment, using displacement matrix outputs to inform the predicted mortality from distributional responses for kittiwake, guillemot, razorbill and puffin;
- The Applicant can repeat the SeabORD model in MATLAB using an adjusted distance decay value to determine bird distribution, ensuring that a suitable number of birds are predicted to enter the development footprint, in consultation with NatureScot. Then as

above, the Applicant can repeat the apportioning and PVA elements of the assessment with the new SeabORD MATLAB outputs. We note that the SeabORD MATLAB version does not allow for simultaneous runs, and therefore this option may be significantly more time-consuming than the other options presented here; and

- If timescales allow, the Applicant be provided access to the SeabORD-R tool by UKCEH/Marine Directorate and re-run SeabORD, in consultation with NatureScot. Then as above, the Applicant can repeat the apportioning and PVA elements of the assessment with the new SeabORD-R outputs. We note that the SeabORD-R version allows for simultaneous runs, and therefore this option may be more efficient, depending on the tool availability timescales.

1.2.1. Option 3 was not available to the Applicant since, at the time of writing, the R-based version of the MATLAB tool had not been released. Option 2 was considered. However, further investigation into the distance decay curve applied within MATLAB SeabORD indicated that it would not be possible to create a foraging surface that would be considered suitable in terms of the proportions of birds entering the development footprint (see explanation below.)

1.2.2. Option 1 was therefore agreed with NatureScot in a meeting on 30 May 2025 as the most suitable option and was therefore carried out by the Applicant.

1.3. CONSIDERATION OF OPTION 2

1.3.1. The function used to determine distance decay within SeabORD is provided below (taken from Searle *et al.*, 2018):

$$u_i \sim \frac{(1-p)^{d_i/r}}{d_i}$$

1.3.2. Where:

- u_i is the proportion of time that birds from a specific colony spend in the i-th grid cell;
- d_i is the distance of the i-th grid cell to the colony;
- r is the foraging range of the species; and
- p is the proportion of birds expected to forage within that distance.

1.3.3. Using guillemot as an example, different parameter values were used to attempt to generate a curve capable of predicting a number of birds entering the development footprint that is roughly equivalent to densities predicted from modelling site-based digital aerial survey (DAS) data carried out at the site.

1.3.4. In order to make this comparison, it was necessary first to derive guillemot density estimates from the DAS data density predictions that would be comparable to the foraging density maps generated within SeabORD. This was under the assumption that June densities represent the chick-rearing season simulated within SeabORD, based on the phenology of this species. Model-based (MRSea) estimates for guillemot densities within the Array Area and 2 km buffer were extracted and then adjusted to remove birds expected to be juvenile (51.6% of birds are assumed to be adult based on a stable age structure – see the EIAR), sabbatical (7% of birds are assumed to be sabbatical – see the EIAR) or to derive from a population other than those included within the SeabORD run (60.7% of birds were apportioned to the Buchan Ness and Collieston Coast SPA and 36.8% of birds are apportioned to the Troup, Pennan and Lion's Heads SPA as used in the EIAR – giving a total of 97.5% of birds attributable to one or other of the SPAs included

within the Project's SeabORD analysis for guillemot. This gave final predictions of 11.37 birds per km^2 in June 2021 and 2.72 birds per km^2 in June 2022 (see Table 1.1).

Table 1.1 Determination of Density of Adults in the Array Area plus 2 km Buffer Area

Density of Birds in Flight and on sea in the Array Area + 2 km Buffer (birds/km^2)				
Month	**Total Density (birds/km^2)**	**Removing Non-adults (48.4%)**	**Removing Sabbatical Birds (7%)**	**Removing non-SPA birds (2.5%)**
Jun-21	24.31	12.54	11.67	11.37
Jun-22	5.82	3.00	2.79	2.72

1.3.5. The distance decay function applied within SeabORD was then parameterised using different values of *p* and *r* to create normalised foraging distributions over a 1/120 degree grid (as used by SeabORD) across the sea area within the bounding box applied within the EIAR assessment during guillemot SeabORD runs. This provides a surface the value of each cell represents the probability of a bird selecting that cell to forage within. Note that while SeabORD uses distance by sea to apply the distance decay curve, Euclidian distances were used in this case to reduce computing time. This is not expected to make a significant difference to conclusions drawn from this investigation.

1.3.6. An assumption was made that 50% of breeding adult birds from each colony would be on the sea at any time during the chick-rearing period, similar to assumptions made within SeabORD itself. The density of birds expected to be foraging within the Array Area plus 2 km buffer (ignoring that some birds will be travelling between the colony and foraging locations at any given point in time) was therefore calculated to be 50% of the adult breeding population size multiplied by the sum of the values within the grid cells falling within the Array plus a 2 km buffer.

1.3.7. The detailed steps followed for this analysis are provided below for transparency:

- Create a grid matching that applied within SeabORD – 1/120 degree cell size, within the bounding box defined in the assessment, clipped to remove land area;
- Extract the mid-points of each cell and calculate the Euclidean distances from these to each of the two colonies used in the SeabORD analysis;
- Use the distance decay curves to calculate the relative foraging distribution surface for each of the two colonies and scale each of these surfaces to add up to 1;
- Multiply each surface by half of the corresponding population size assuming 50% of the breeding adult birds are foraging according to the distribution at any time, to give the number of birds expected to be foraging within each cell (when not accounting for birds travelling between the colony and their foraging location*);
- Sum the number of birds predicted to be foraging within cells falling within the Array Area plus 2 km for each population and sum these to get the total number of birds within the area; and
- Divide by the area to calculate the density of birds per km^2.

1.3.8. *Since the Project is at the edge of the foraging range for guillemot, the resulting density will likely be an over rather than an under-estimate of birds at the site during the actual SeabORD modelling, since few birds will travel through the site to get to foraging sites beyond it, but birds will need to travel a long distance to arrive at the site.

RESULTS

1.3.9. The results of the trials carried out using different parameter values for *p* and *r* are presented below. The analysis demonstrates that whilst changing parameters does result in increased or decreased density estimates as would be expected, the function asymptotes to a maximum density prediction within the site of around 0.86 birds/km^2 (Table 18) which is far below the 2.72/11.37 birds/km^2 predicted by apportioning densities derived from site-based digital aerial surveys. It was therefore recommended by NatureScot that option 1 should be presented in additional information in preference to pursuing further application of SeabORD. Figure 1.1 – Figure 1.4 also show this relationship visually for both varying *r* (Figure 1.1 and Figure 1.2) and *p* (Figure 1.3 and Figure 1.4) for the Troup Head, Pennan and Lion's Heads SPA.

Table 1.2 Density of Birds per km^2 Predicted to be Foraging within the Array Area Using Different Parameterisations of the Distance Decay Curve Implemented within SeabORD

	Proportion in Foraging Range			
Foraging Range (km)	0.8	0.9	0.95	0.99
95	0.509	0.37	0.257	0.1
950	0.83	0.817	0.802	0.768
9500	0.858	0.857	0.855	0.852
95000	0.861	0.861	0.86	0.86
950000	0.861	0.861	0.861	0.861

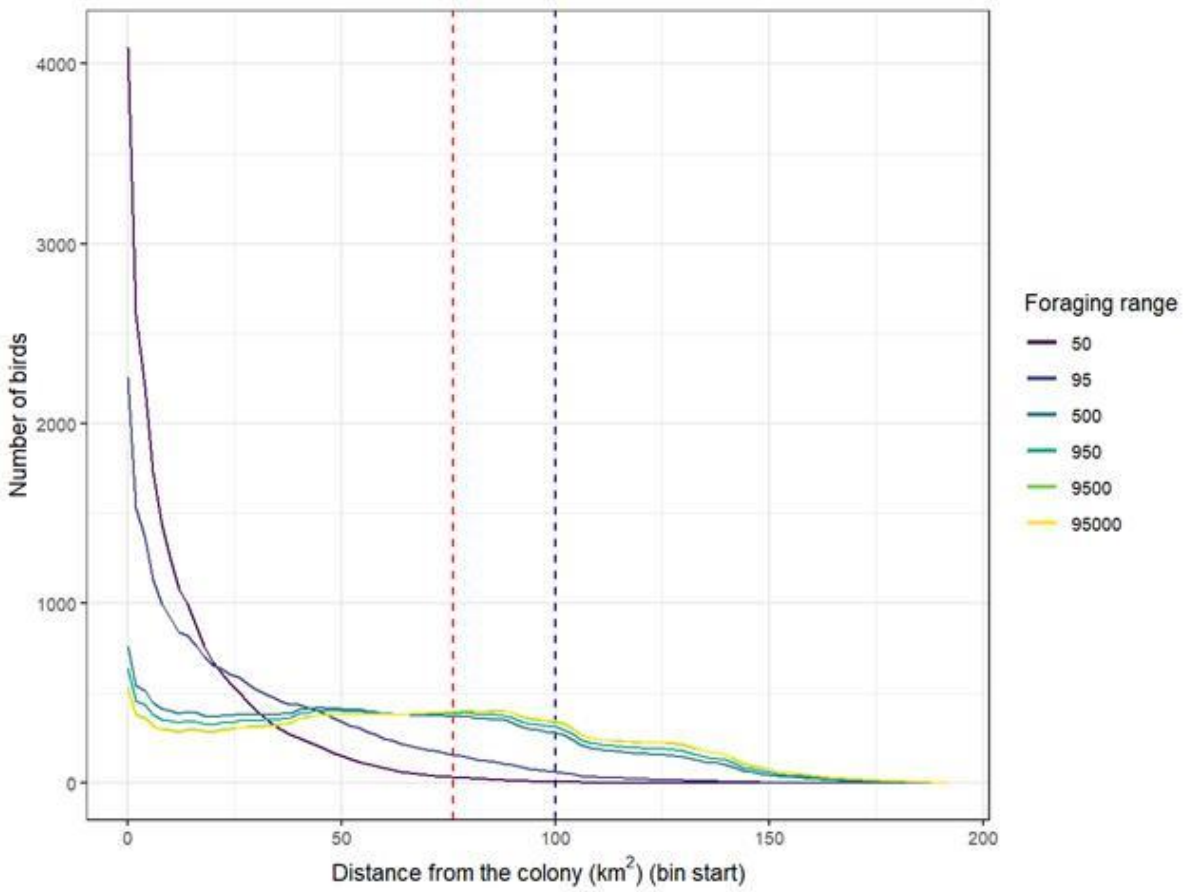

Figure 1.1 Number of Birds Predicted to be Foraging within Different Distance bins from the Colony for the Troup, Pennan and Lion's Heads SPA Based on Different Values of r. (proportion within range (p) assumed to be 0.95.).

The red dashed line represents the distance of the Project from the colony and the blue dashed line represents the guillemot mean max foraging range plus one standard deviation.

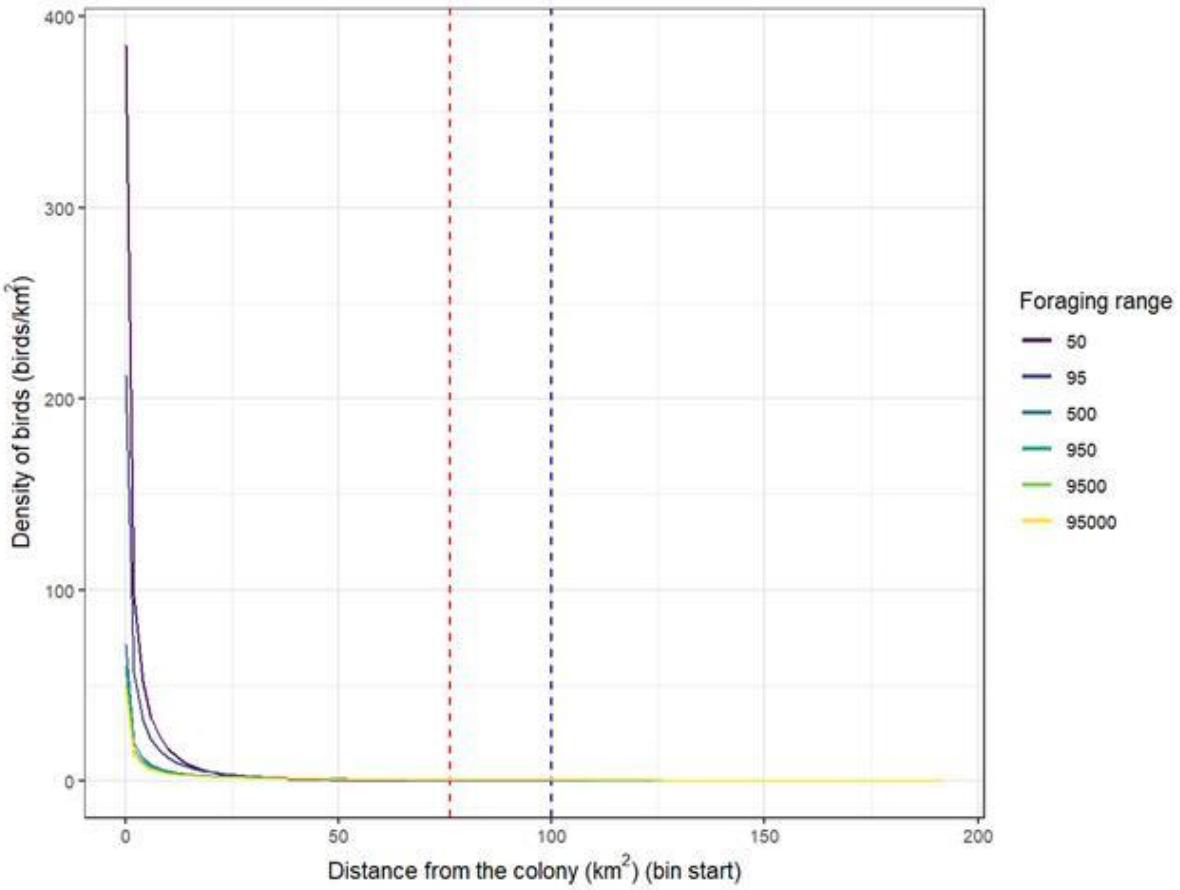

Figure 1.2 Density of Birds Predicted to be Foraging within Different Distance bins from the Colony for the Troup, Pennan and Lion's Heads SPA Based on Different Values of r. (proportion within range (p) assumed to be 0.95.).

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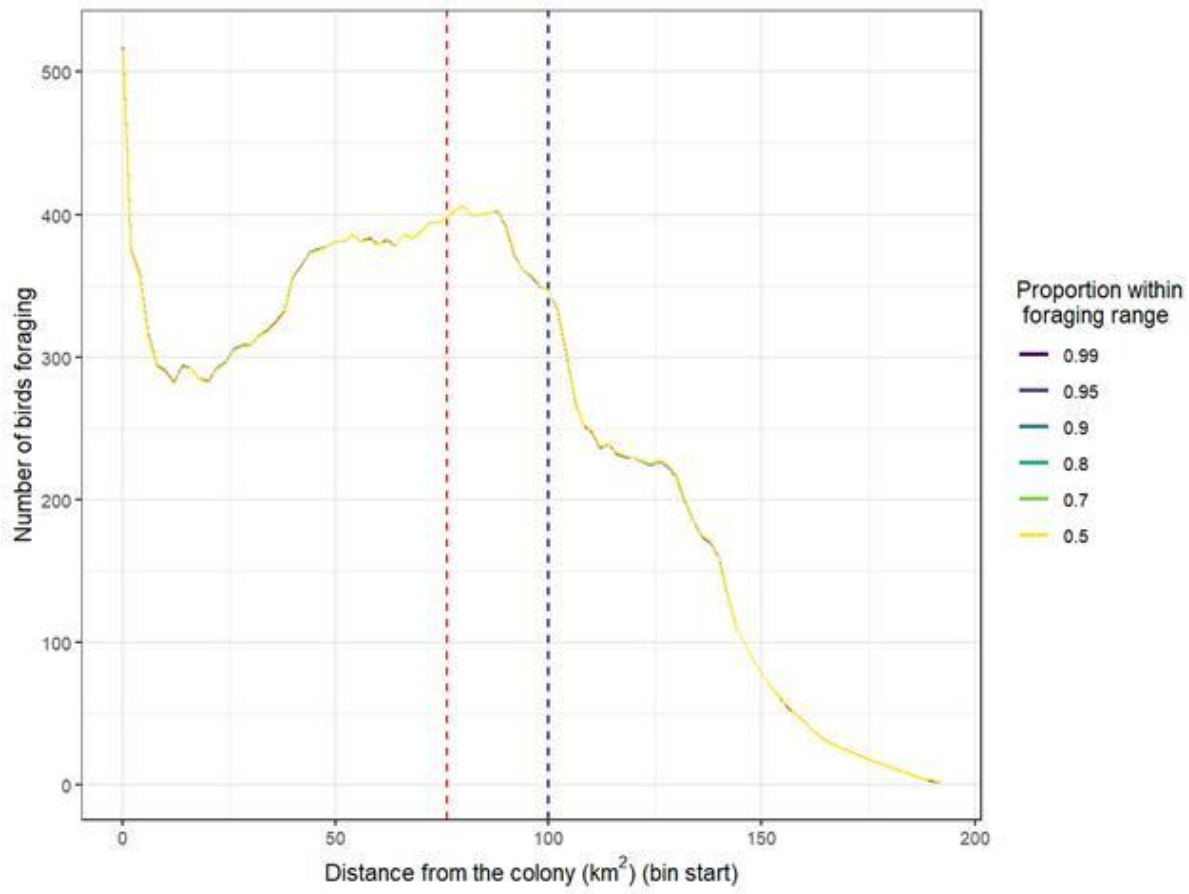

Figure 1.3 Number of Birds Predicted to be Foraging within Different Distance bins from the Colony for the Troup, Pennan and Lion's Heads SPA Based on Different Values of p. (foraging range assumed to be 95.2 km.).

The red dashed line represents the distance of the Project from the colony and the blue dashed line represents the guillemot mean max foraging range plus one standard deviation.

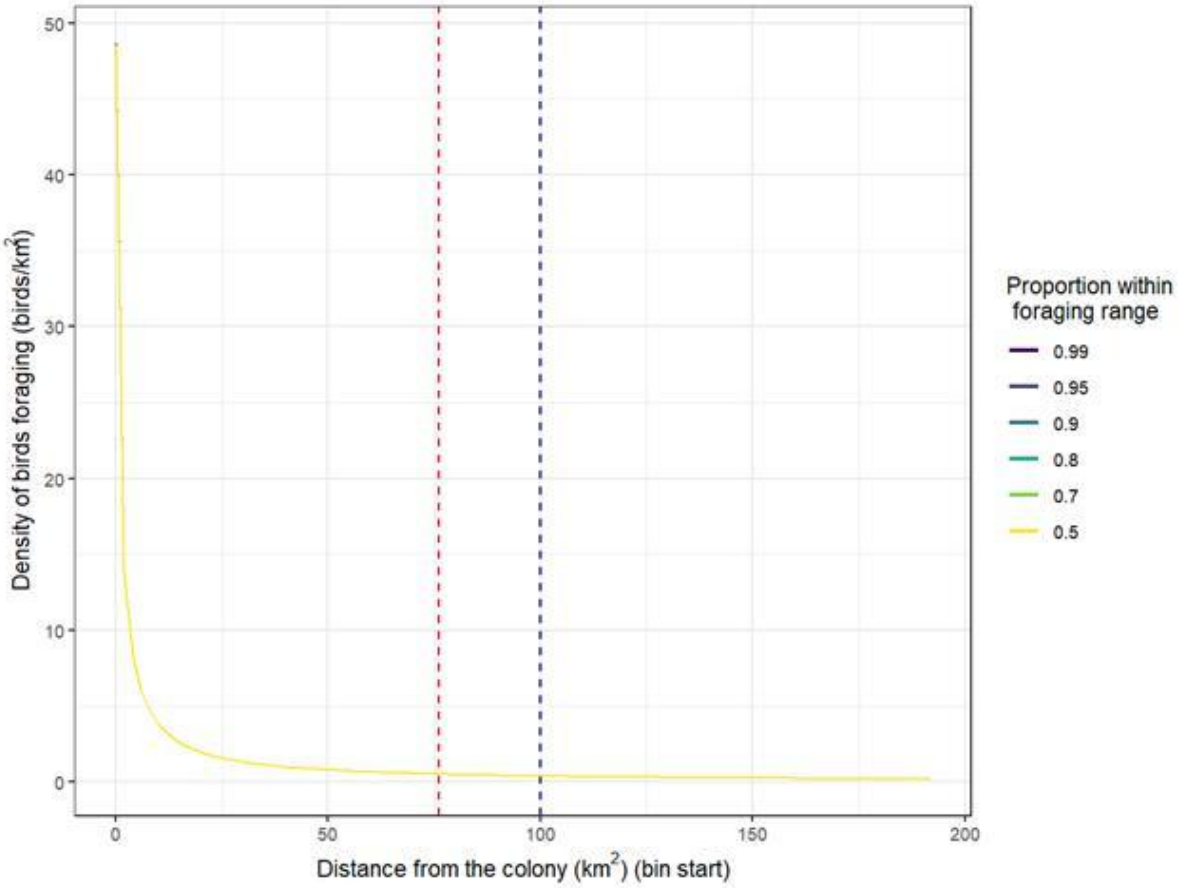

Figure 1.4 Density of Birds Predicted to be Foraging within Different Distance bins from the Colony for the Troup, Pennan and Lion's Heads SPA Based on Different Values of p. (foraging range assumed to be 95.2 km.).

The red dashed line represents the distance of the Project from the colony and the blue dashed line represents the guillemot mean max foraging range plus one standard deviation.

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