APPENDIX 2- Details on the Seabird-Windfarm Case Study

a) Detailed description on vulnerability and sensitivity factors

The sensitivity and vulnerability scores from Garthe & Huppöp (2004) have already been thoroughly reviewed and updated by Furness *et al.* (2013). We have updated the scores for the Bay of Biscay to be consistent with the review of Furness *et al.* 2013. The present appendix describes the vulnerability factors in detail, indicating how they were documented for the Bay of Biscay.

Vulnerability factors

F_1- proportion time spent flying. Values for the Bay of Biscay were mostly documented from Garthe & Huppöp (2004). Values for *Puffinus puffinus* and *Phalacrocorax carbo* were modified according to Furness *et al.* (2013).

F_2 - proprotion time at blade height. Furness *et al.* (2013) used a very extensive study on flight altitude (Cook *et al.* 2012) to precisely estimate the time spent at blade height when flying. However, not all Bay of Biscay species occur in Cook *et al.* (2012) study areas, and we could not directly use such a percentage for our study. Still, given the sometimes large discrepancies between the first estimates in Garthe *et al.* (2004) and the refined one in Furness *et al.* (2013), we updated the f_2 scores according to the following table, for the species documented in Cook *et al.* (2012).

time spent at blade height	f_2 score
0-5%	1
6-10%	2
11-15%	3
16-20%	4
20% -100%	5

F_3 - flight maneuverability. On this factor, Garthe & Huppöp (2004) and Furness *et al.* (2013) were in agreement, and we therefore applied their scoring.

F_4 - Nocturnal flight activity. On this factor, Garthe & Huppöp (2004) and Furness *et al.* (2013) were in agreement, and we therefore applied their scoring.

F_5 - Sensitivity to disturbance. On this factor, Garthe & Huppöp (2004) and Furness *et al.* (2013) were mostly in agreement, and we therefore applied their scoring. Scores for *Phalacrocorax aristotelis* were modified following Furness *et al.* (2013).

F_6 - Habitat flexibility. On this factor, Garthe & Huppöp (2004) and Furness *et al.* (2013) were mostly in agreement, and we therefore applied their scoring. Scores for shags and European storm petrels were modified following Furness *et al.* (2013).

Sensitivity factors

The three remaining factors in Garthe & Huppöp (2004), namely biogeographical population size (F_7), adult survival rate (F_8) and species conservation status (F_9) were treated differently in Furness *et al.* (2013). They computed species sensitivity by integrating 4 pieces of information: (i) the status of species in the Bird Directive, (ii) the % of the biogeographic population in Scotland, (iii) the adult survival rate, and (iv) the UK threat status.

This process ensures the integration of ecological parameters and conservation concerns at national and international scales in the species sensitivity score. In the Bay of Biscay however, robust estimates of the % of the biogeographic population located in the Bay are not available for each species, mostly because many occur only during the wintering period. Therefore, the overall species sensitivity of each species in the Bay of Biscay was evaluated by combining the four following pieces of information: (i) the status of each species in the international red list (F_7 in our study), (ii) the status of each species in the Bird Directives (F_8 in our study), (iii) the status of each species in the French red list (F_9 in our study), and (iv) the adult survival rate (F_{10} in our study).

This way, our scoring emphasizes conservation priorities at the international (F_7), European (F_8) and national (F_9) scales, which are related to population size.

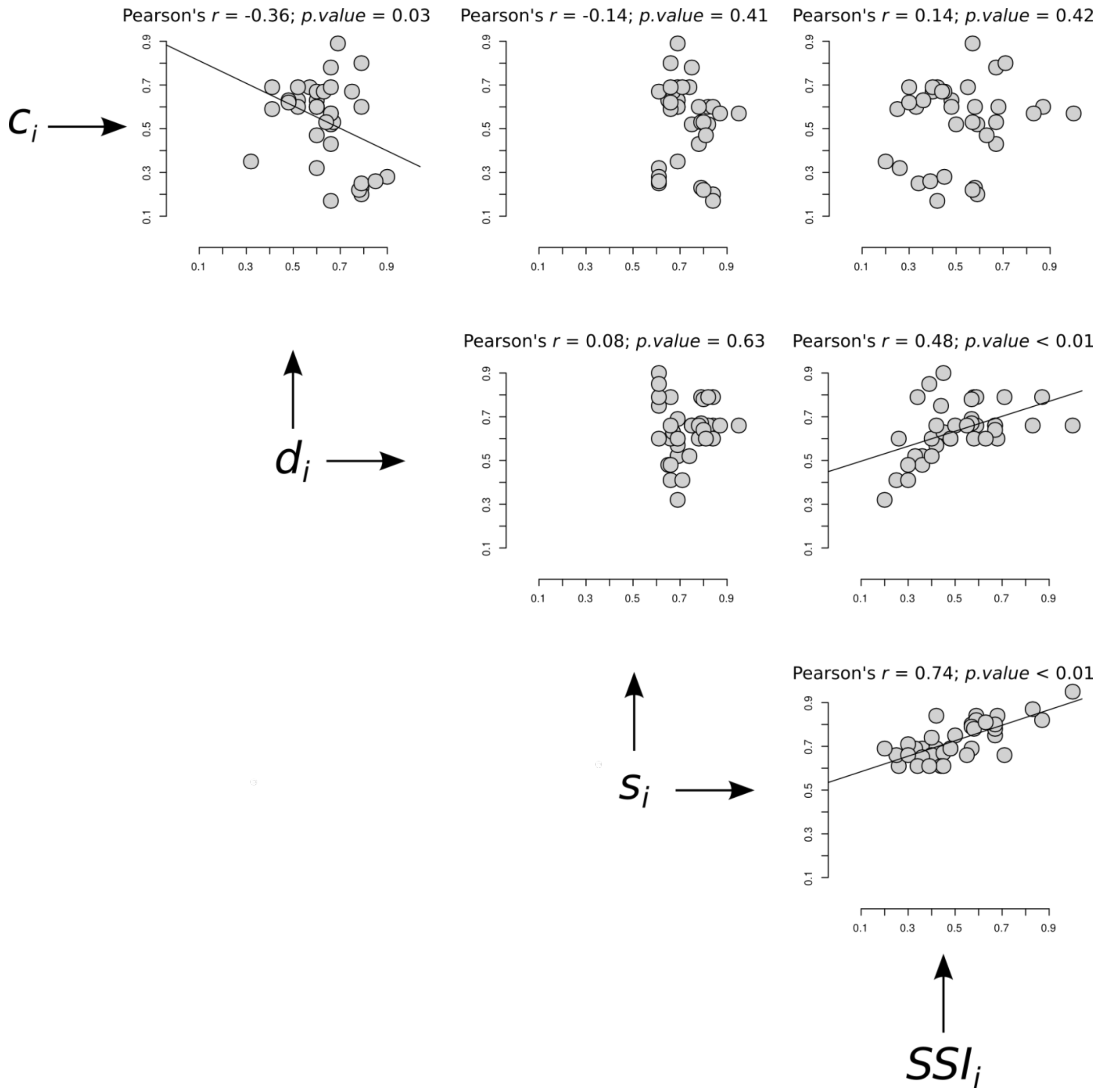
b) F_{if} matrix for seabirds

Group	Species (latin)	Proportion in group	f1	f2	f3	f4	f5	f6	f7	f8	f9	f10
Large gulls	*Larus argentatus*	0.3	2	5	2	3	2	1	1	3	1	5
Large gulls	*Larus fuscus*	0.3	2	5	1	3	2	1	1	3	1	5
Large gulls	*Larus marinus*	0.2	2	5	2	3	2	2	1	3	1	5
Large gulls	*Larus michaelis*	0.2	4	5	2	3	3	1	1	3	1	5
Large gulls	*Large larus spp*	NA	2.4	5.0	1.7	3.0	2.2	1.2	1.0	3.0	1.0	5.0
Small gulls	*Rissa tridactyla*	0.5	3	4	1	3	2	2	1	3	2	3
Small gulls	*Larus melanocephalus*	0.2	4	4	2	2	2	3	1	5	1	4
Small gulls	*Larus minutus*	0.1	3	4	1	2	1	3	1	5	1	2
Small gulls	*Larus ridibundus*	0.1	1	4	1	2	2	2	1	3	1	3
Small gulls	*Larus sabiini*	0.1	4	4	2	3	3	3	1	3	1	4
Small gulls	*Small larus spp*	NA	3.1	4.0	1.3	2.6	2.0	2.4	1.0	3.6	1.5	3.2
Auks	*Uria aalge*	0.8	1	1	4	2	3	3	1	3	4	4
Auks	*Alca torda*	0.1	1	1	4	1	3	3	1	3	5	5
Auks	*Fratercula arctica*	0.1	1	1	3	1	2	3	1	3	5	5
Auks	*Auks spp*	NA	1.0	1.0	3.9	1.8	2.9	3.0	1.0	3.0	4.2	4.2
Terns	*Sterna sandvicensis*	0.45	5	2	1	1	2	3	1	5	3	4
Terns	*Sterna hirundo*	0.45	5	2	1	1	2	3	1	5	1	4
Terns	*Chlidonias niger*	0.1	5	2	2	2	3	3	1	5	3	4
Terns	*Terns spp*	NA	5.0	2.0	1.1	1.1	2.1	3.0	1.0	5.0	2.1	4.0
Shearwaters	*Calonectris diomedea*	0.1	4	2	3	3	2	2	1	5	3	5
Shearwaters	*Puffinus gravis*	0.2	4	2	3	3	2	2	1	3	1	5
Shearwaters	*Puffinus griseus*	0.1	4	2	3	3	2	2	2	3	2	5
Shearwaters	*Puffinus mauretanicus*	0.1	4	2	3	2	2	3	5	5	3	5
Shearwaters	*Puffinus puffinus*	0.4	4	1	3	3	2	3	1	3	3	5
Shearwaters	*Puffinus yelkouan*	0.1	4	2	3	2	2	3	2	5	3	5
Shearwaters	*Puffins spp*	NA	4.0	1.6	3.0	2.8	2.0	2.6	1.6	3.6	2.5	5.0
Gannets	*Morus bassanus*	1	3	4	3	2	2	1	1	3	2	5
Skuas	*Stercorarious skua*	0.7	4	3	1	1	1	2	1	3	1	4
Skuas	*Stercorarius longicaudus*	0.1	5	3	1	1	1	2	1	3	3	3
Skuas	*Stercorarius parasiticus*	0.1	4	3	2	2	3	2	1	3	1	3
Skuas	*Stercorarius pomarinus*	0.1	4	3	2	3	2	3	1	3	1	4
Skuas	*Skuas spp*	NA	4.1	3.0	1.2	1.3	1.3	2.1	1.0	3.0	1.2	3.8
Storm petrels	*Hydrobates pelagicus*	1	4	1	2	5	2	2	1	5	2	5
Shags	*Phalacrocorax aristotelis*	0.5	2	1	3	1	3	3	1	3	1	3
Shags	*Phalacrocorax carbo*	0.5	2	1	4	1	4	3	1	3	1	3
Shags	*Shags spp*	NA	2.0	1.0	3.5	1.0	3.5	3.0	1.0	3.0	1.0	3.0
Northern fulmars	*Fulmarus glacialis*	1	2	1	3	4	1	1	1	3	1	5

c) Vulnerability to collision c_i, disturbance d_i, species sensitivity s_i and Seabird Sensitivity Index SSI_i

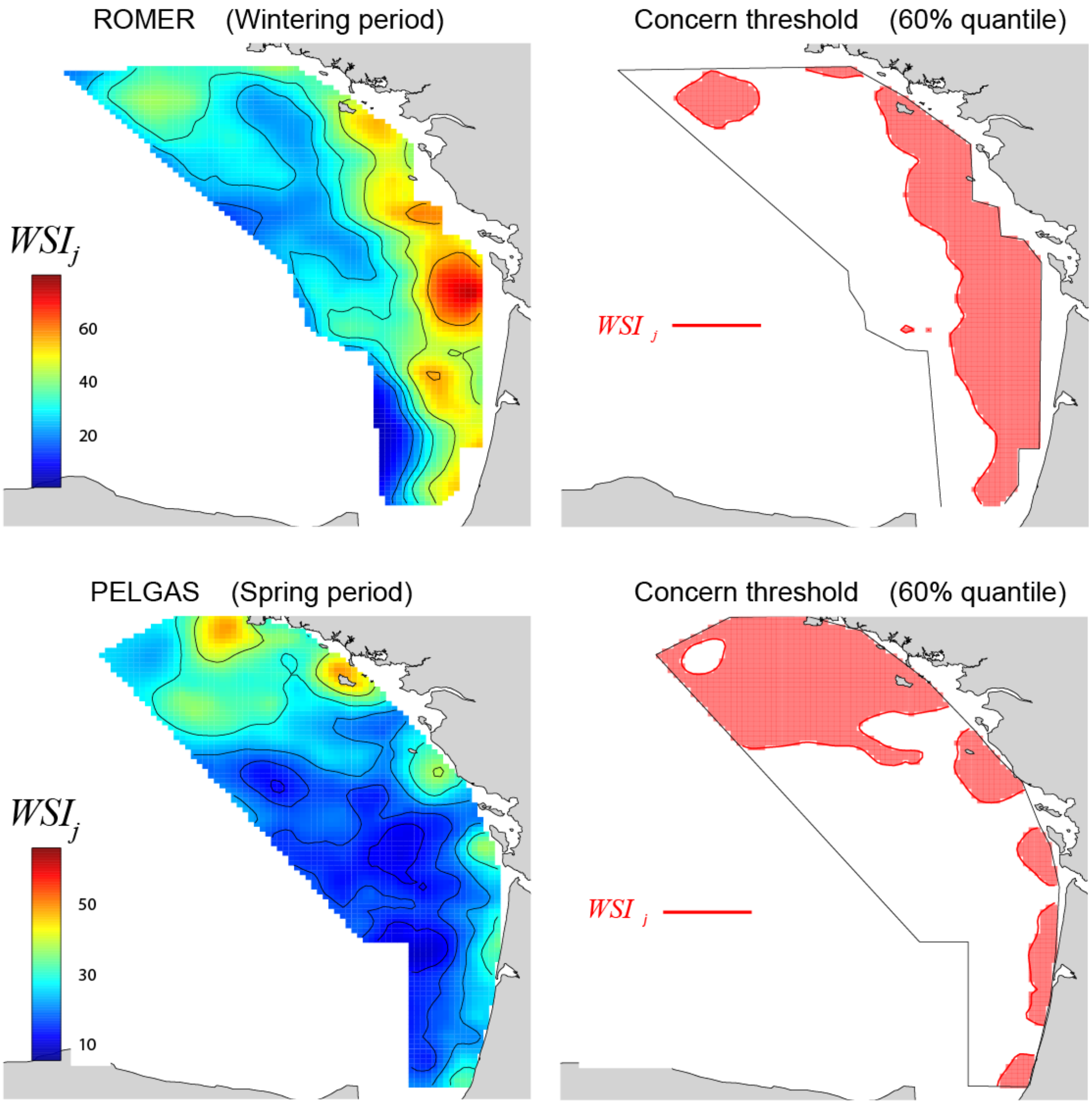
Group	Species_latin	c_i	d_i	s_i	SSI_i
Large gulls	*Larus argentatus*	0.63	0.52	0.69	11.25
Large gulls	*Larus fuscus*	0.6	0.52	0.69	10.31
Large gulls	*Larus marinus*	0.63	0.6	0.69	15.00
Large gulls	*Larus michaelis*	0.89	0.69	0.69	17.50
Large gulls	*Large larus spp*	0.69	0.57	0.69	12.86
Small gulls	*Rissa tridactyla*	0.67	0.6	0.66	12.38
Small gulls	*Larus melanocephalus*	0.78	0.66	0.75	20.63
Small gulls	*Larus minutus*	0.63	0.48	0.65	11.25
Small gulls	*Larus ridibundus*	0.32	0.6	0.61	8.00
Small gulls	*Larus sabiini*	0.8	0.79	0.66	21.94
Small gulls	*Small larus spp*	0.67	0.63	0.67	14.07
Auks	*Uria aalge*	0.23	0.79	0.79	18.00
Auks	*Alca torda*	0.2	0.79	0.84	18.38
Auks	*Fratercula arctica*	0.17	0.66	0.84	13.13
Auks	*Auks spp*	0.22	0.78	0.8	17.60
Terns	*Sterna sandvicensis*	0.52	0.66	0.82	18.28
Terns	*Sterna hirundo*	0.52	0.66	0.75	15.47
Terns	*Chlidonias niger*	0.6	0.79	0.82	26.81
Terns	*Terns spp*	0.53	0.67	0.79	17.74
Shearwaters	*Calonectris diomedea*	0.6	0.6	0.84	21.00
Shearwaters	*Puffinus gravis*	0.6	0.6	0.69	15.00
Shearwaters	*Puffinus griseus*	0.6	0.6	0.78	18.00
Shearwaters	*Puffinus mauretanicus*	0.57	0.66	0.95	30.94
Shearwaters	*Puffinus puffinus*	0.43	0.66	0.78	20.63
Shearwaters	*Puffinus yelkouan*	0.57	0.66	0.87	25.78
Shearwaters	*Puffins spp*	0.53	0.64	0.8	20.81
Gannets	*Morus bassanus*	0.69	0.52	0.74	12.38
Skuas	*Stercorarious skua*	0.59	0.41	0.66	7.59
Skuas	*Stercorarius longicaudus*	0.69	0.41	0.71	9.38
Skuas	*Stercorarius parasiticus*	0.67	0.75	0.61	13.75
Skuas	*Stercorarius pomarinus*	0.69	0.66	0.66	16.88
Skuas	*Skuas spp*	0.62	0.48	0.66	9.18
Storm petrels	*Hydrobates pelagicus*	0.47	0.6	0.81	19.50
Shags	*Phalacrocorax aristotelis*	0.25	0.79	0.61	10.50
Shags	*Phalacrocorax carbo*	0.28	0.9	0.61	14.00
Shags	*Shags spp*	0.26	0.85	0.61	12.19
Northern fulmars	*Fulmarus glacialis*	0.35	0.32	0.69	6.25

d) **correlations between c_i, d_i, s_i and SSI_i scores.**



The correlation analysis between them revealed that c_i and d_i were slightly negatively correlated (Pearson's r = -0.36, *p-value*=0.03), while SSI_i and d_i and SSI_i and s_i were positively correlated (Pearson's r = 0.48 and 0.74 respectively, *p-value*<0.01 in both cases). No significant relationships were found between c_i and s_i, d_i and s_i, and c_i and SSI_i.

e) Assessment based on Garthe & Huppop's method



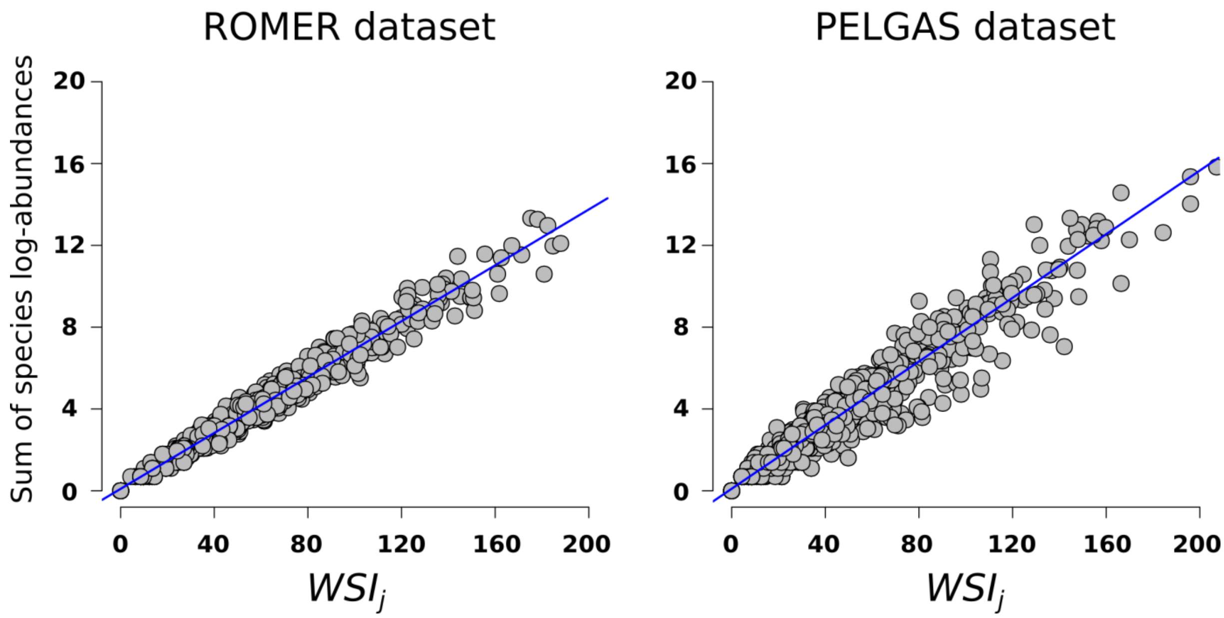
These maps clearly showed that, when compared to our assessment map (fig 2), a whole collision-sensitive area is missed in winter, *i.e.* in a time period where most seabirds species are abundant in the Bay of Biscay. The differences between the assessment based on WSI_j and the assessment based on C_j, D_j and A_j, and particularly the fact that WSI_j neglects collision risk, can be explained by two elements. First, SSI_i and c_i are negatively correlated (see section **d)** in this appendix) and therefore combining SSI_i with abundance automatically down-weights collision-sensitive species. Second, WSI_j strongly correlates with summed log-abundances (see section **f)** in this appendix) and in the Bay of Biscay collision-vulnerable species present slightly lower densities than species vulnerable to disturbance, and they are distributed in different areas.

f) Relationship between summed species log-abundances and WSI_j

Let us recall the WSI_j equation:

$$WSI_j = \sum_{i=1}^{S} \log\left(A_{ij} + 1\right) \times SSI_i \; (1)$$

The WSI_j is the sum over the species of the product of log abundances by SSI_i. To understand how much SSI_i values affect the WSI_j compared to simple log abundances, we simply plotted the WSI_j values against the summed log abundances. The graph below shows that these two patterns are extremely similar, with Pearson's correlation being of 0.99 (ROMER) and 0.98 (PELGAS).



Furthermore, we looked at the output of the assessment, if it was solely based on the summed log abundance instead of the WSI_j. The maps below show the 60% quantile area for the summed log abundances for the two datasets. They are highly similar to the WSI_j maps (see fig 4 in the main manuscript), meaning that vulnerability assessment based on WSI_j is in fact based on log abundances only.