QUANTIFYING ENVIRONMENTAL IMPACTS FOR TWO DANISH OFF-SHORE WIND FARMS USING THE COMPLEX REGION SPATIAL SMOOTHER (CRESS).

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Animal numbers collected as a part of baseline monitoring and impact assessment studies are typically highly uneven across the survey area. Animal distribution data can also be patchy in terms of the temporal survey effort in the area, particularly when weather/logistics preclude servicing the experimental design originally planned. Some of these renewables sites can also have complex topography which excludes animals from particular areas (e.g. marine mammals and islands) or may contain areas which the animals avoid (e.g. sea birds and large areas of land). Data of this sort also typically contain complex (e.g. highly nonlinear) relationships with the environmental covariates and across the spatial area. Additionally these data are typically correlated along transects (or within grid cells from vantage point studies) and the models fitted typically fall short in explaining this correlation due to lack of at least one of the important (dynamic) drivers of animal abundance (e.g. prey distribution). For this reason some of the pattern in the data remains unexplained by the model and this violates the critical `independent errors' assumption of standard modelling techniques (e.g. Generalized Additive Models). For all of these reasons, any modelling methods used for such data ought to be able to accommodate all of these features in order to make reliable predictions and inference.

The complex region spatial smoother (CReSS) is a recently developed spatially adaptive smoothing technique which is designed to model highly uneven distributions while respecting natural boundaries (e.g. land) relevant for the species of interest and can also deal with complex relationships between density and environmental covariates. Coupled with SALSA2D and Generalized Estimating Equations (GEEs), this approach tackles model selection and spatio-temporal auto-correlation (e.g. along transects) which is invariably present in model residuals. Addressing this aspect of the modelling is crucial if any confidence intervals about differences pre/post installation(s) are to be believed and used for decision making.

This methodology provides accurate predictions for species' distributions across the surveyed area but *as* importantly, returns defensible predictions about any spatially explicit differences across the area pre/post installation(s).

We present this methodology and its application to bird abundance and distribution for two large scale off-shore wind farm examples in Denmark: Nysted and Rødsand II (using Long-tailed Duck *Clangula hyemalis*) and the Horns Rev 2 windfarm (using Common Scoter *Melanitta nigra* and Red-throated/Black-throated Diver *Gavia stellate/arctica*). The results clearly indicate significant decreases in bird numbers in and around the footprints of each wind farm and some redistribution within the survey area. These analyses were carried out using the recently developed, and now publicly available, `MRSea` package in R.