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Update on species distribution modelling for harbour porpoises in the North Sea and Belt Seas

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Background

- Critical step towards conservation & management measures

  -> Predict distribution and determine which areas can be characterized as important habitats for species, e.g. serving as foraging or reproduction habitats, with ecological significance of these regions

- Outputs needed to perform risk-based assessments towards a broad range of anthropogenic activities
- Update species distribution model for harbour porpoises in the North Sea using state-of-the-art methods (e.g. Gilles et al. 2016, 2025; OSPAR QSR 2023, SCANS-IV)
- Sensitivity mapping of harbour porpoises in the context of marine spatial planning (e.g. DK Screening project)
- Trial different methods to objectively delineate hotspots or seasonal core habitats using the (final best) predicted distribution model for harbour porpoises

DATA COLLECTION AND MODELLING

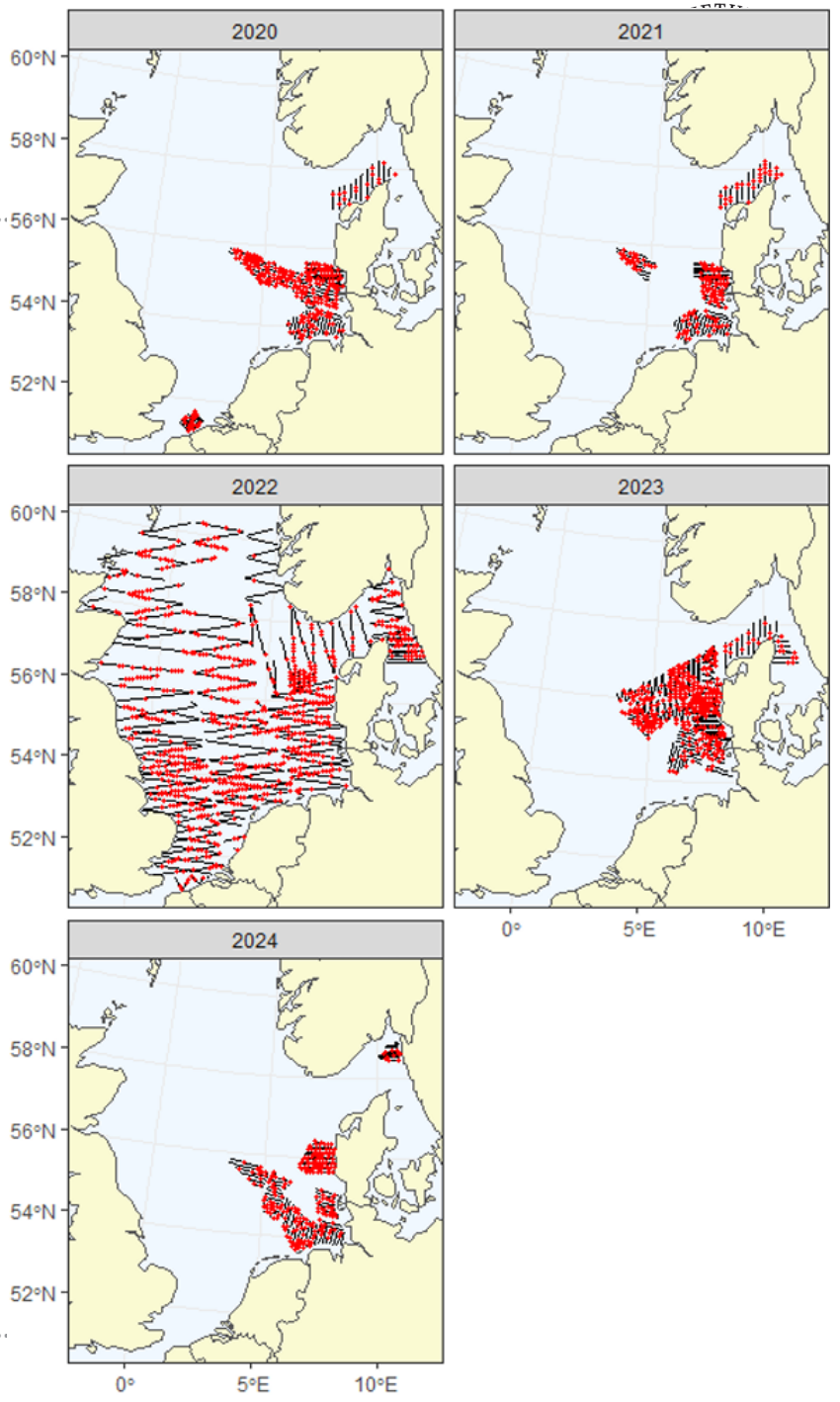
Tasks

- Collate recent dedicated visual survey data in the North Sea
- Perform quality- and plausibility checks of survey data (effort and observations)
- Extract relevant covariates, from spatially and temporally explicit and high-resolution grids
- Spatial modelling of density, predictions of summer density

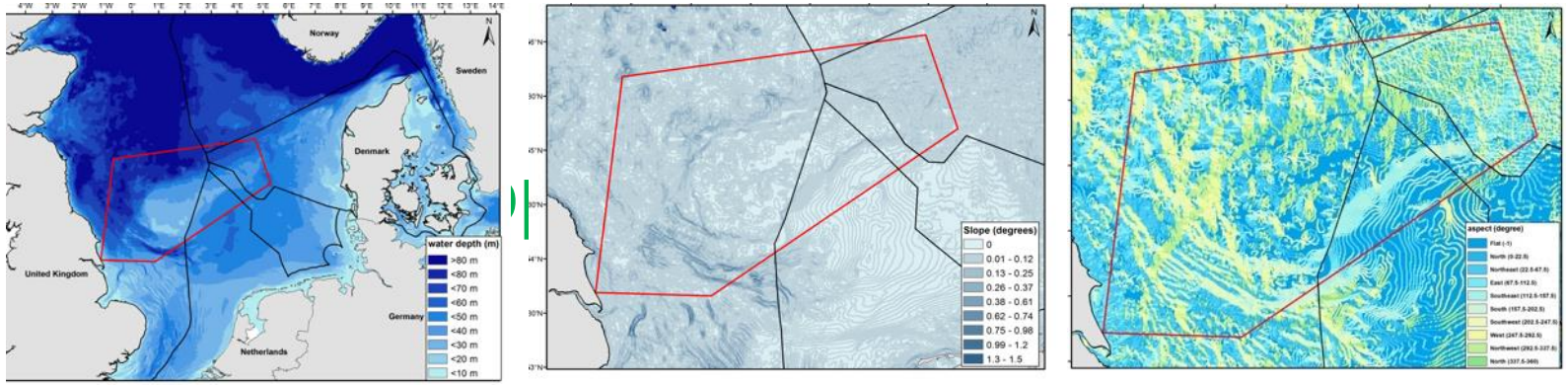
Survey Data overview 2020-2024 (summer) NORTH SEA

Year	Total no. of effort segments	No. of effort segments with groups	% effort segments with groups	Number of groups	Number of individuals	Effort (in km)
2020	537	270	50	600	755	5,344
2021	373	160	43	335	407	3,698
2022	2,284	820	36	1,537	2,072	22,623
2023	998	429	43	1,019	1,405	9,808
2024	547	244	45	535	674	5,406
Total	**4,739**	**7,923**	**41**	**4,026**	**5,313**	**46,879**

High-quality visual survey data collected using the same (standardised) method, following the so-called SCANS methodology (Hammond et al. 2013, 2021; Gilles et al. 2009, 2023)



Cetacean habitat-based modelling (GAM)



depth

slope

aspect

Workflow from SCANS-IV (Gilles et al. 2025)

Prey availability correlates with physical and biological marine properties (proxies)

dist. to coast

dist. to fish habitat

Sighting data

Effectively covered area

MLD - Mixed layer depth

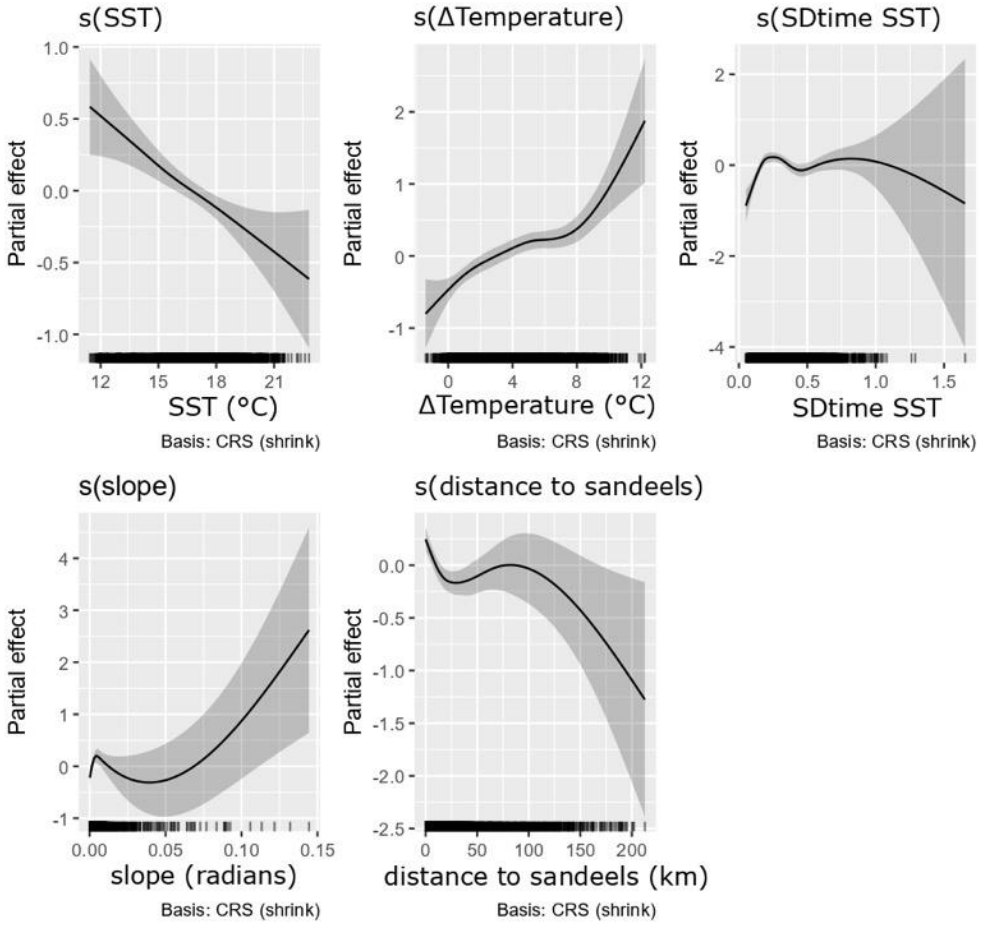
SST

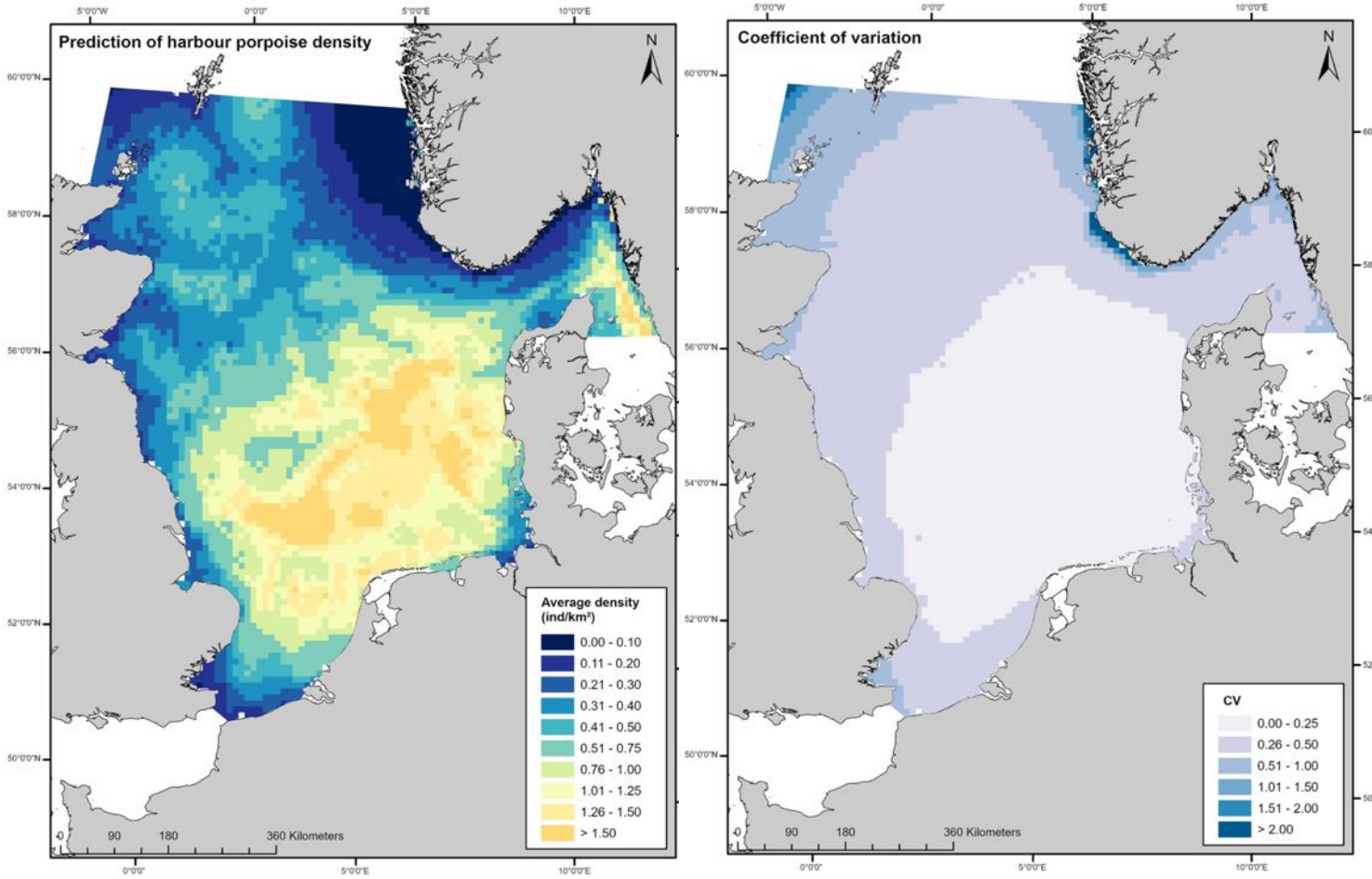
Remote sensed

SST fronts

Gilles et al.. 2011, 2016, 2025; Becker et al. 2016, 2017, 2018; Pigeault et al. 2024a,b

North Sea: Model results and predicted density surfaces



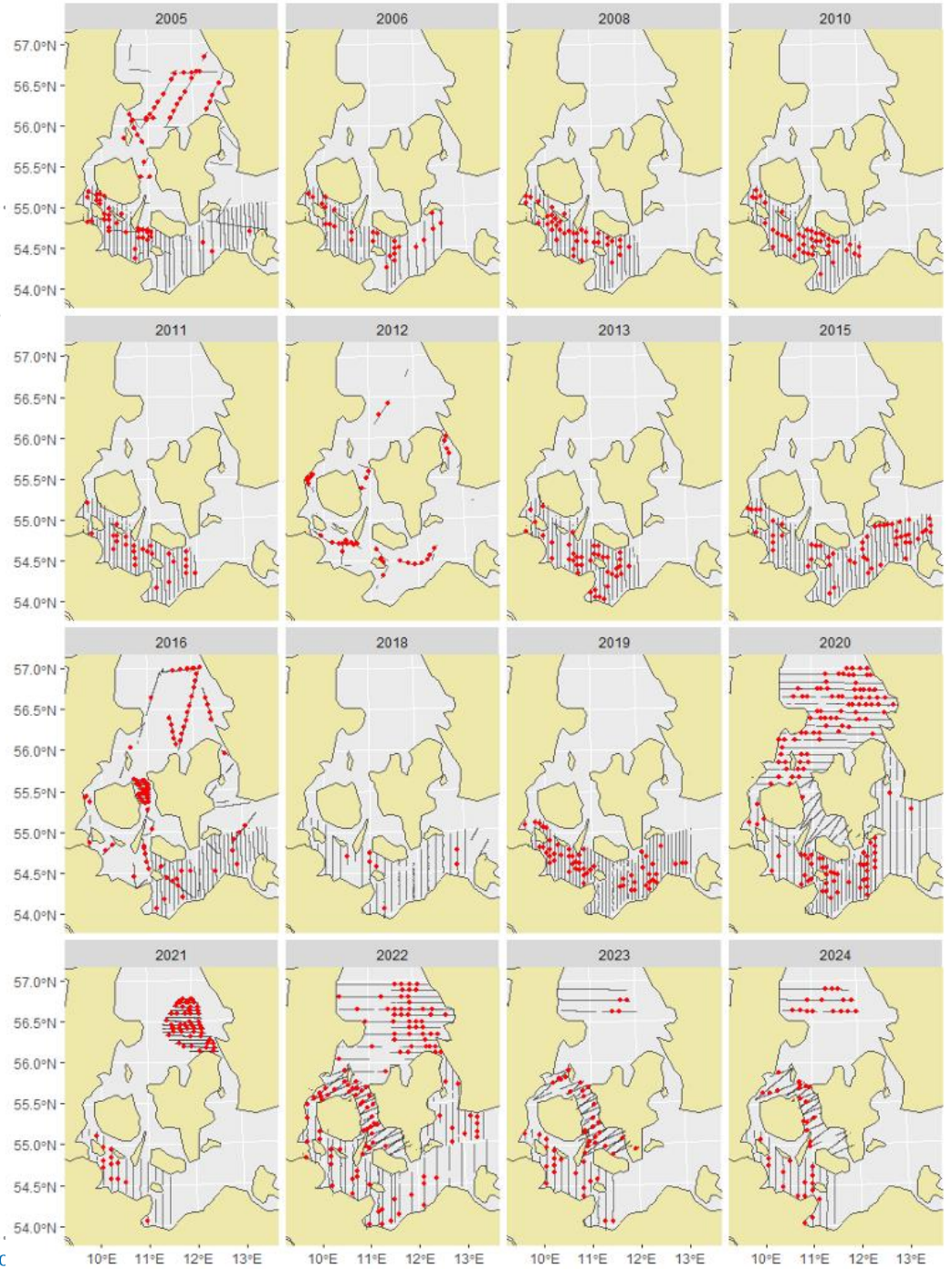


Predicted surface of estimated summer density [left] and associated coefficient of variation (CV) [right] for harbour porpoise, fitting the model to survey data collected between 2020-2024 in the North Sea.

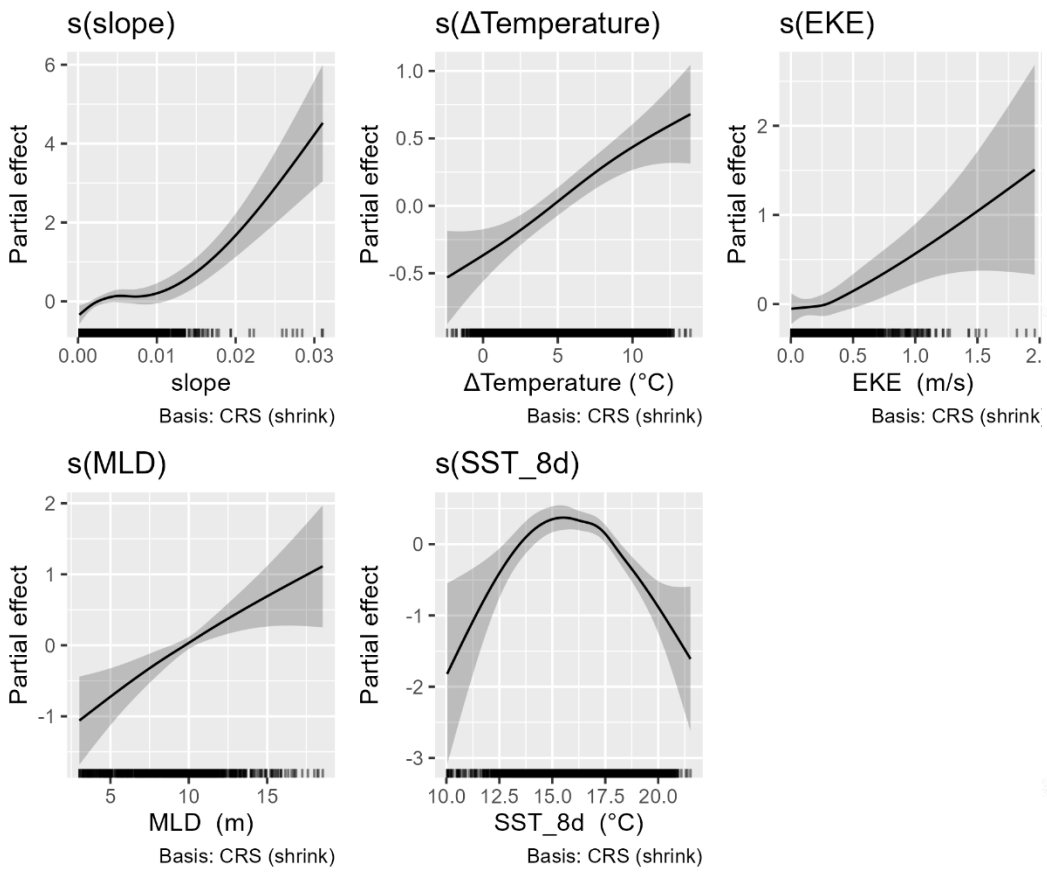
Survey Data overview 2005-2024 (summer) BELT SEA

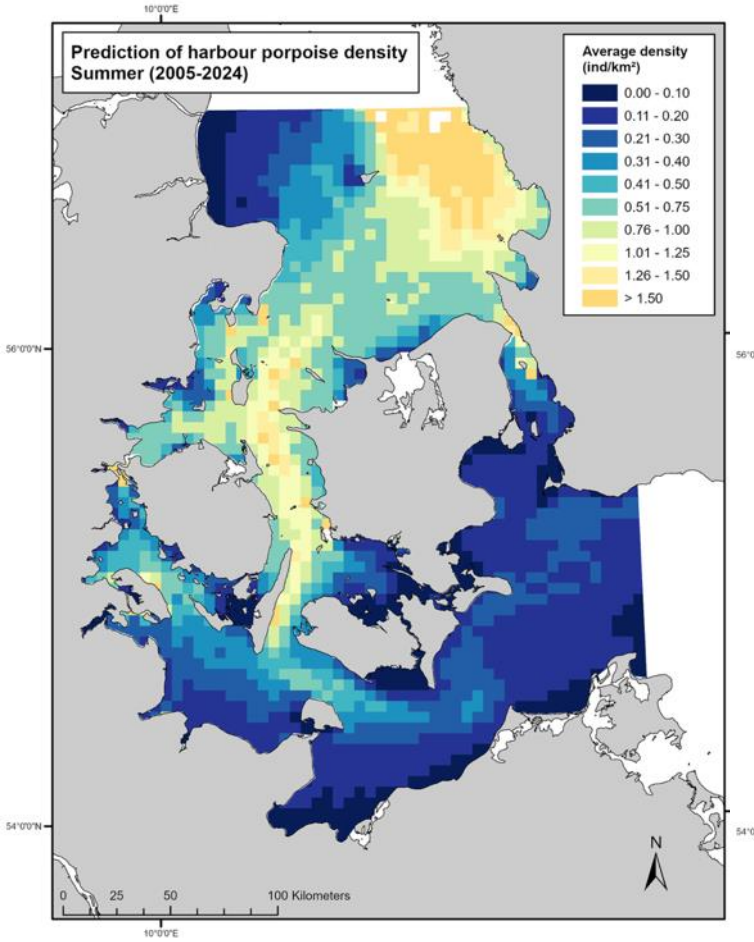
Summary of 2005-2024 survey data from visual surveys, showing no. effort segments, no. harbour porpoise groups and individuals sighted in the summer of each year, as used for model fitting.

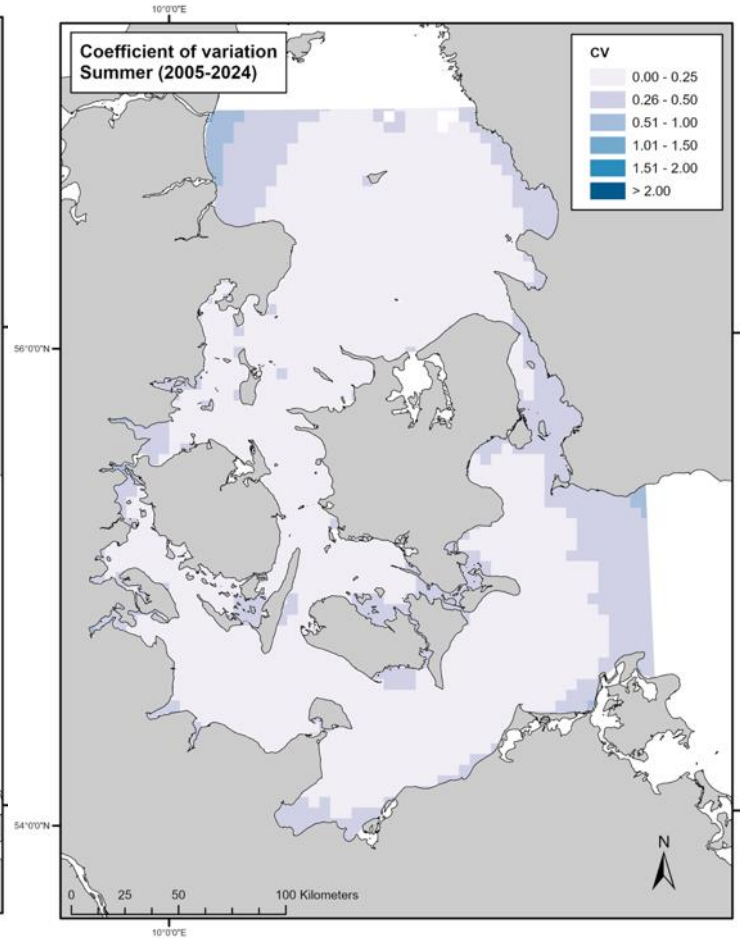
Year	Total no. of effort segments	No. of effort segments with groups	% effort segments with groups	Number of groups	Number of individuals	Effort (in km)
2005	316	68	21.5	131	162	3,074
2006	135	26	19.3	37	40	1,363
2008	138	39	28.3	57	81	1,365
2010	149	42	28.2	61	74	1,481
2011	154	26	16.9	33	38	1,478
2012	72	38	52.8	104	141	532
2013	149	39	26.1	55	78	1,416
2015	242	53	21.9	73	82	2,370
2016	301	91	30.2	349	462	2,960
2018	125	7	5.6	9	10	1,228
2019	249	55	22.1	79	102	2,462
2020	524	433	25.4	210	259	4,987
2021	202	70	34.7	144	211	2,013
2022	453	123	27.2	178	252	4,250
2023	188	49	26.1	65	74	1,800
2024	163	48	29.5	68	79	1,567
Total	**3,560**	**907**	**25.5**	**1,653**	**2,145**	**34,346**



Belt Sea: Model results and predicted density surfaces (2005-2024)





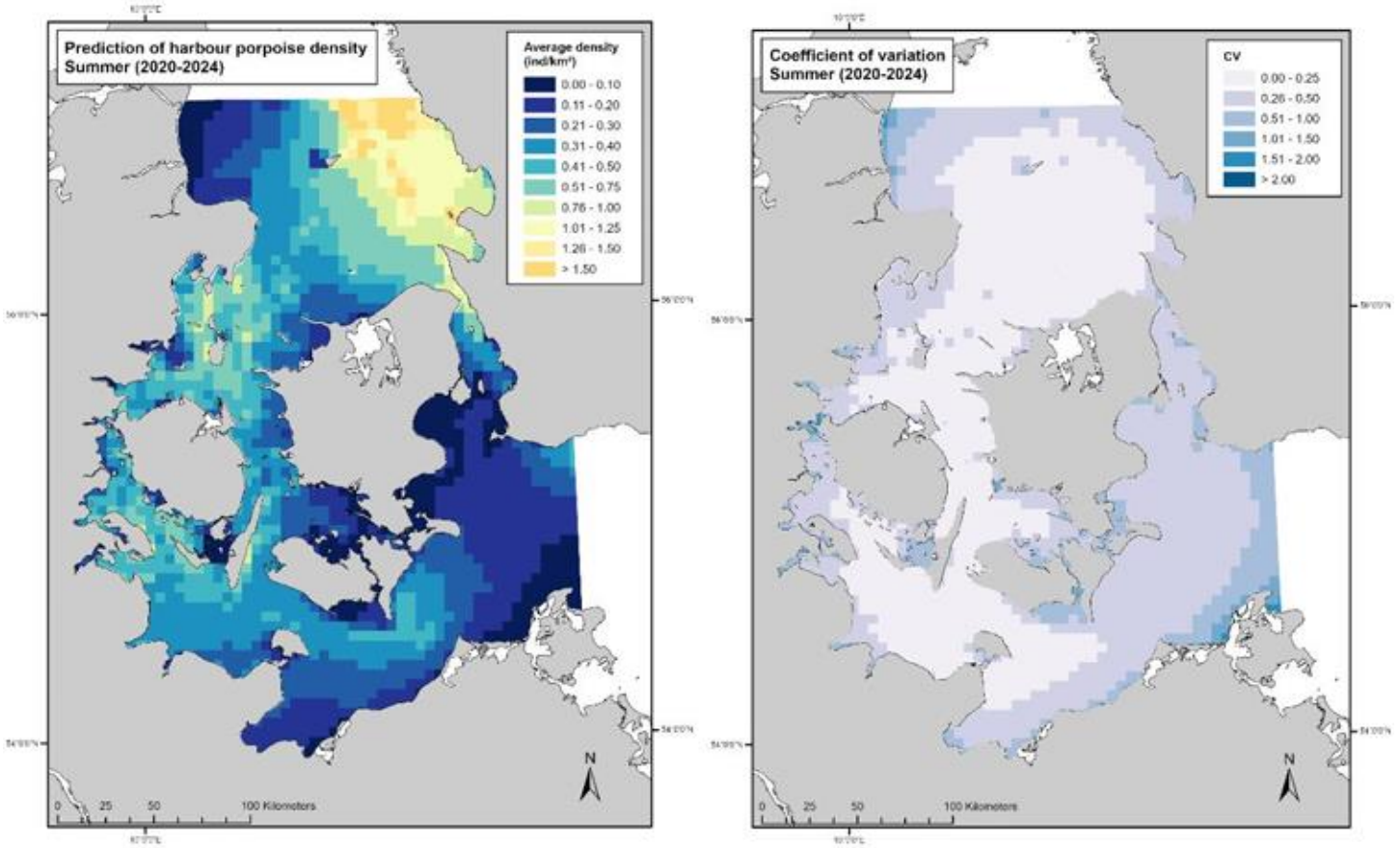


Predicted surface of estimated summer density [left] and associated coefficient of variation (CV) [right] for harbour porpoise, fitting the model to survey data collected between **2005-2024** in the management unit of the Belt Sea harbour porpoise population.

Belt Sea: Model results and predicted density surfaces (2020-2024)

Model description and diagnostics for the final selected model of harbour porpoise individuals for the period 2020-2024.

Distribution	Model covariates	Estimated degrees of freedom	Model degrees of freedom	% Deviance explained
Negative Binomial (0.527)	X,Y	14.7	18.5	16.7
	Slope	1.2		
	MLD	2.3		
	EKE	0.2		
	SST	0.1		



Predicted surface of estimated summer density [left] and associated coefficient of variation (CV) [right] for harbour porpoise, fitting the model to survey data collected between **2020-2024** in the management unit of the Belt Sea harbour porpoise population.

Hotspot Analysis: North Sea Harbour Porpoise

What are we interested in?

- Understand ecological significance of areas and optimise conservation and management strategies
- Identify "hotspots", i.e. areas of higher-than-average biodiversity or abundance (Harvey et al. 2017)

Density thresholds

- Most common aspatial approach (Parviainen et al. 2009, Tolimieri et al. 2015)
- Easy to implement and interpret
- Top 5% / 10% / 15% / 20% of density are highlighted

Getis-Ord Gi* (Getis 2010)

- Spatial statistical method
- Detects spatial clustering of high and low densities (Harvey et al. 2017 applied on marine mammals in British Columbia)
- Includes a test hypothesis and a measure of statistical significance (p-value)
- Computed on the DSM output then on effort-corrected observations

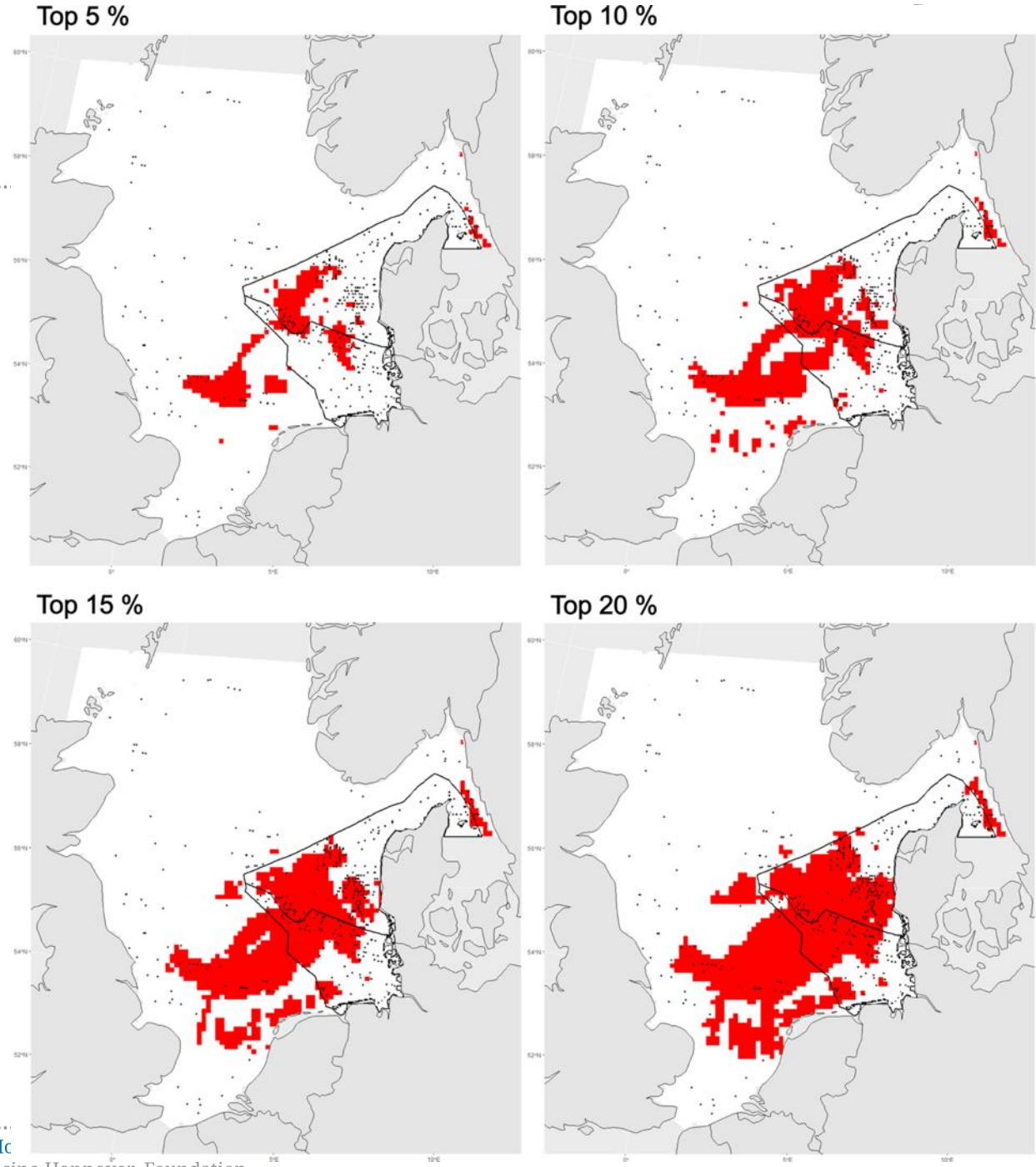
Density Thresholds

Decision on which percentage/quantile to use depends on the specific application

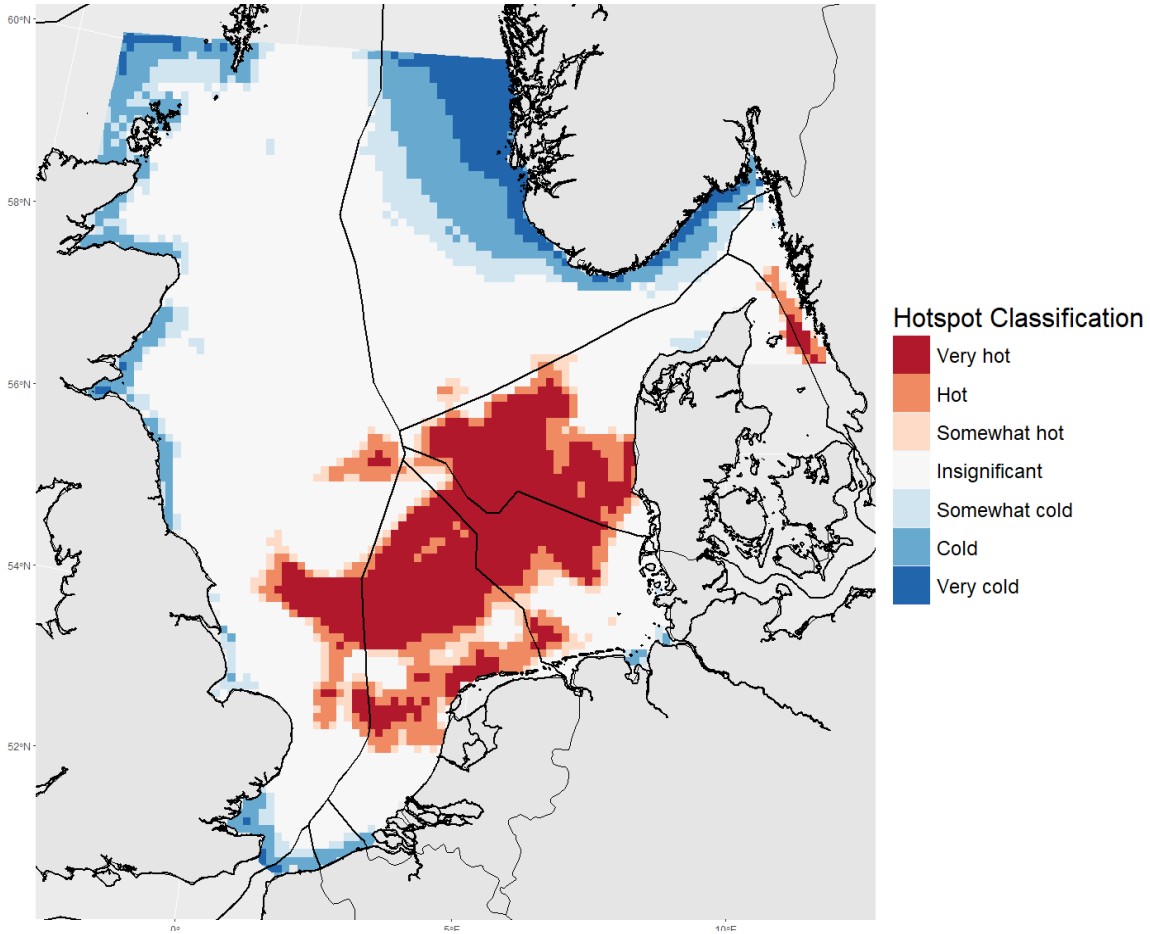
Overlaid with observations of **mother-calf pairs** to evaluate if hotspots are consistent with areas of high ecological importance for reproduction

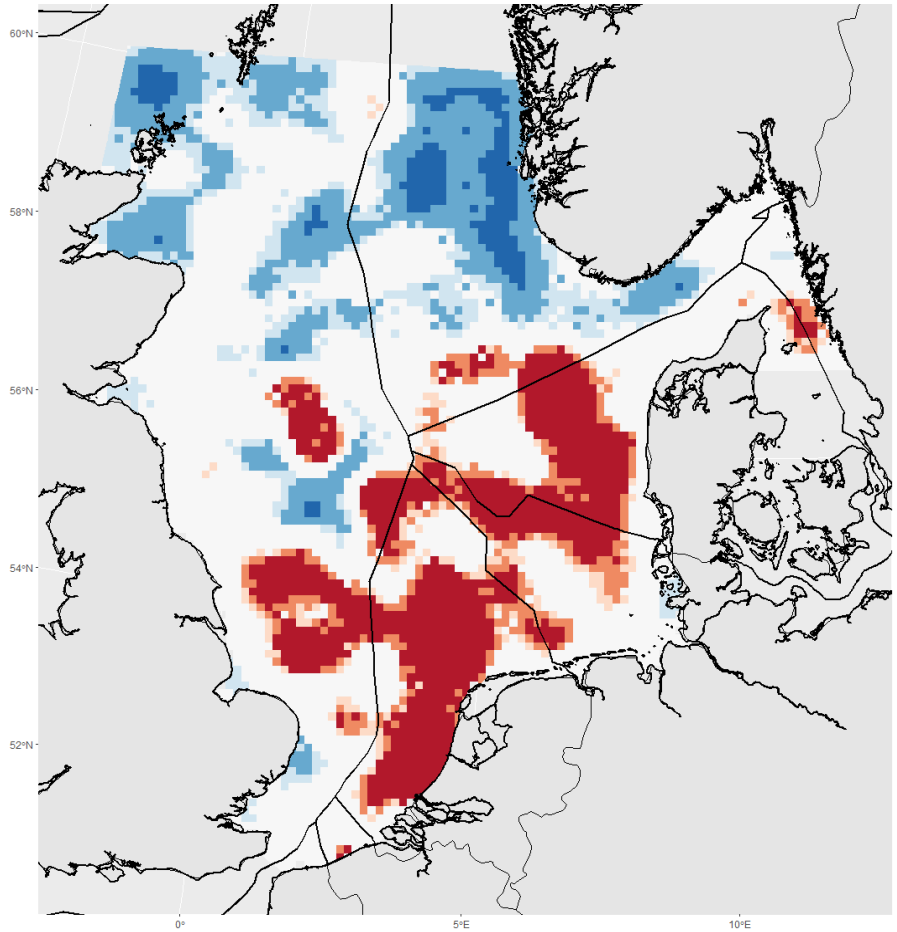
Hotspot	Number of calves sightings inside hotspot	Percentage of all calves sightings
top 5%	63	19%
top 10%	112	34%
top 15%	163	49%
top 20%	212	64%

Note: only hotspot extent and mother-calf pair sightings within the Danish or German EEZ (n=333) in the period 2020-2024 were included.



Getis-Ord Gi* (Getis 2010)





DSM output:

- Null hypothesis of spatial homogeneity rejected
- p-values cannot be interpreted
- Gi* simply reflects the highest densities, loses statistical meaning
- Consistent with results of top 15% with added coldspots

Effort-corrected observations:

- Null hypothesis respected
- p-values can be interpreted in the usual way
- Fragmented pattern (no smoothing)
- No modelling benefits (link to environmental covariates, extrapolation, …)

Funding support (surveys, analysis)

Denmark

Ministry of Environment of Denmark
Environmental Protection Agency

Danish Energy Agency

Germany

Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection

BfN Federal Agency for Nature Conservation

Sweden

Swedish Agency for Marine and Water Management

Thanks for listening

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Technical briefs

North Sea:
https://dce.au.dk/fileadmin/dce.au.dk/Udgivelser/Eksterne_udgivelser/2025/DK_North_Sea_Modelling_report_TiHo_20251002.pdf

Belt Sea:
https://dce.au.dk/fileadmin/dce.au.dk/Udgivelser/Eksterne_udgivelser/2025/ITAW_2025_DK_Belt_Sea_Modelling_report_20251202.pdf