

## Selection and foraging response of harbour seals in an area of changing prey resources

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### SUPPLEMENT

#### Harbour seals scat sampling in Porsangerfjord

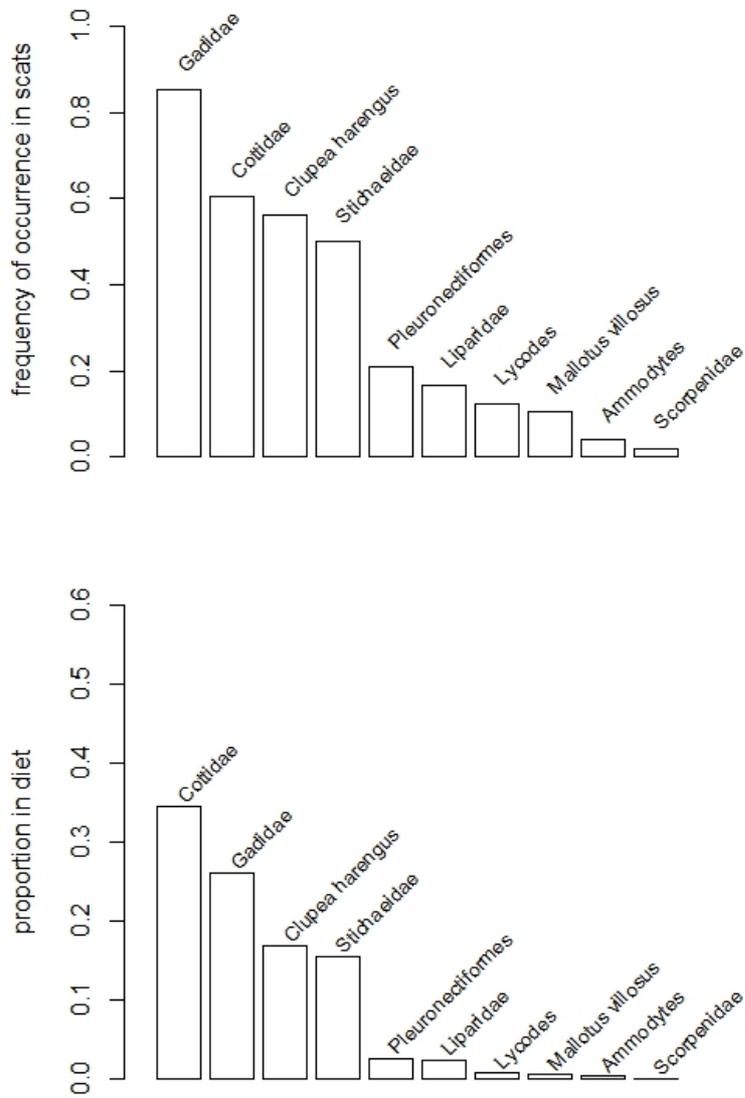
In order to investigate the diet of harbour seals in Porsangerfjord, known haulout sites in the area were repetitively visited for scat collection during the tagging attempts, in the falls of 2009 and 2010. Otoliths were extracted for taxonomic recognition to the lower possible level (Härkönen 1986). The number of prey items in each scat was estimated from the number of otolith pairs (left or right side) of each species in each scat. Fish length was estimated from the mean length of otolith pairs using species-specific regressions taken from literature (Breiby 1985; Härkönen 1986; Leopold *et al.* 2001; Svetochева, Stasenkova & Fooks 2007) or other unpublished data sources (catch data from the Barents Sea, IMR; data on sculpins from Porsangerfjord, courtesy of Källgren E, UiT). Different regressions were used for different ranges of otolith lengths for gadoids to account for decreasing growth rates with age. When taxonomic recognition could not be performed down to the species level, the regressions of the most common species belonging to that taxonomic group and present in the area were used and the results averaged.

A total of 48 harbour seals scats (37 of which were found in 2010) were sampled from a single site in inner Porsangerfjord (Lat 70.152° Lon 25.151°) despite several sites were visited. Not all otoliths could be recognized down to species level during analysis due to partial digestion in the scats and some species have been therefore grouped at the family level.

Codfish (Gadidae) had the highest frequency of occurrence in the scats (present in 85% of the scats), with sculpins (Cottidae, 60%), herring (*Clupea harengus*, 56%) and pricklebacks (Stichaeidae, 50%) (Fig. S1 upper plot). The forenamed groups made up 93% of the fish items in the total population diet (Fig. S1 lower plot).

The group Gadidae included species as cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*) and saithe (*Pollachius virens*). Within the group Cottidae, the following species were identified with a certain degree of uncertainty: Bull rout (*Myoxocephalus scorpius*), Moustache sculpin (*Triglops murrayi*), Ribbed sculpin (*Triglops pingelii*) and Polar sculpin (*Cottunculus microps*). The last species, though belonging to the Psychrolutidae family, closely related to Cottidae, was grouped together with the other sculpins in this analysis.

Ninety nine % of the fish items in the data had an estimated length < 25 cm. Fish size estimation was not corrected for partial or total digestion in this analysis, potentially underestimating the size of prey. However the size of this bias was evaluated as small (Wilson 2014) and not altering the interpretation of the results.



**Figure S1:** Frequency of occurrence (incidence) of prey items in scats (upper plot) and proportion of prey items in the population's diet (lower plot).

## Fish biomass estimation from acoustic sampling

Continuous acoustic recordings of area backscattering coefficients ( $SA$ ), from ca. 10 m below surface to the sea bottom, were made using a 38 kHz Simrad EK-500 splitbeam echosounding system (Bodholt, Nes & Solli 1989). The conversion of  $SA$  values into abundance estimates was carried out on the basis of the acoustic character of species and the partitioning of species in trawl samples. Benthic trawl hauls were taken at predetermined stations along the fjord, whereas pelagic trawl hauls were taken in response to large changes in the echo sounder registrations. For pelagic trawling, a 14 fathom trawl (Harstad, Norway) fitted with a Scanmar depth recorder was used, while a Super Campelin 1400 mesh shrimp trawl was used for demersal trawling. Both trawls were fitted with an 8 mm net inside the codend thereby making it possible to sample juvenile fish as well. Pelagic and demersal trawling was standardized to 30 and 20 min duration respectively and the trawling speed was approximately 3 knots. The recorded  $SA$  values, averaged over one square nautical mile ( $\text{nm}^2$ ) and 10 m depth strata, were converted to abundances ( $\rho$ ) according to the relation:

$$\rho_i = \frac{SA_i}{4 \cdot \pi \cdot 10^{0.1 \cdot TS_i}} \quad (1)$$

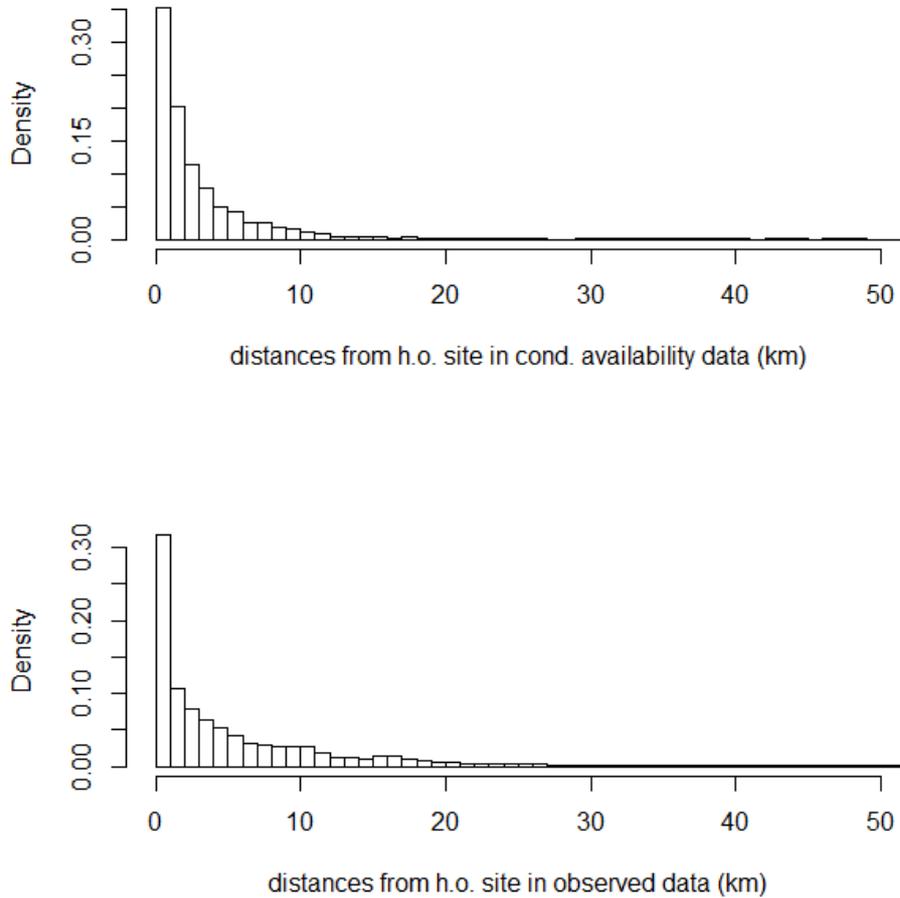
where  $TS_i$  is the mean target strength of species  $i$ , which varies with species and body length (McLennan & Simmonds 1992). Abundances were then transformed into biomasses by multiplying them with species specific mean body weight from the trawl hauls. The final fish biomass estimates per depth interval were cumulated for the entire water column.

## Details on regression kriging for the predictions of fish biomass distributions

For the variable resources (herring, capelin, cod and haddock), we assumed the relationship of each species with the environmental variables to be invariant with time, while we considered this not to be the case for their spatial covariance structure, which was therefore allowed to vary across time periods. We therefore fitted linear models, separately for each species and size group, of biomass density against all covariates using pooled data across time periods and then kriged the model residuals separately for each time period, allowing the variograms to change. The final biomass density distribution was computed as the sum of the predicted average biomass from the linear model and the kriged residuals. For sculpins, stations sampled in different years and different locations were pooled together in one RK analysis to obtain a better spatial coverage, assuming both the relationship with covariates and the spatial characteristics were invariant with time.

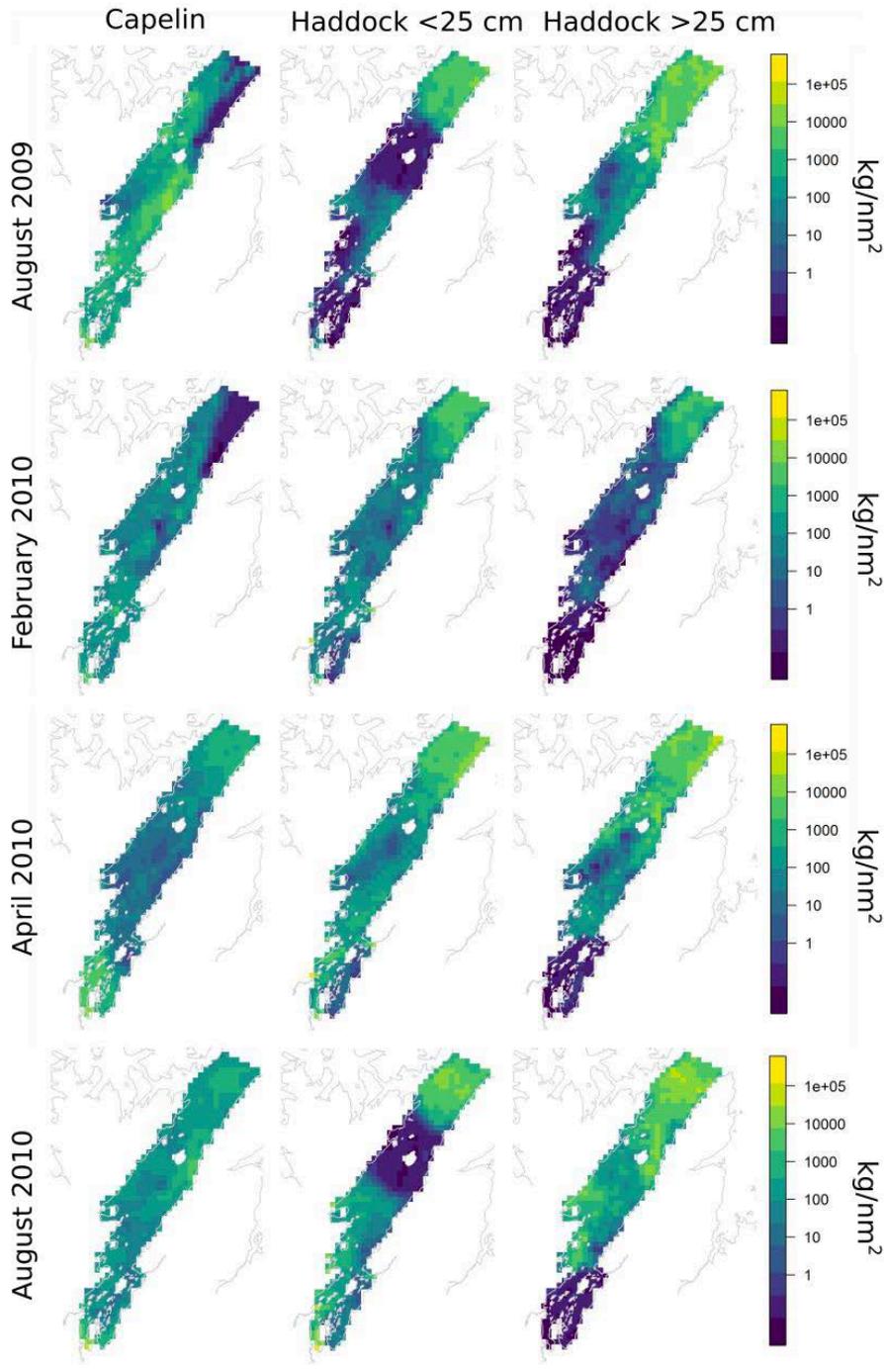
For the stochastic model component, we computed the empirical variograms with a threshold maximum distance of 20 km (width of the fjord) and distance lags of 2 km for the species sampled with acoustic transects (comparable to the integration distance along transects = 1 nm or 1.8 km) and 500 m for the sculpins, given some of the benthic stations were very close in space. We then fitted exponential models to the empirical variograms.

## Validation of the usage of the distance distribution model for grey seals (*Halichoerus grypus*)



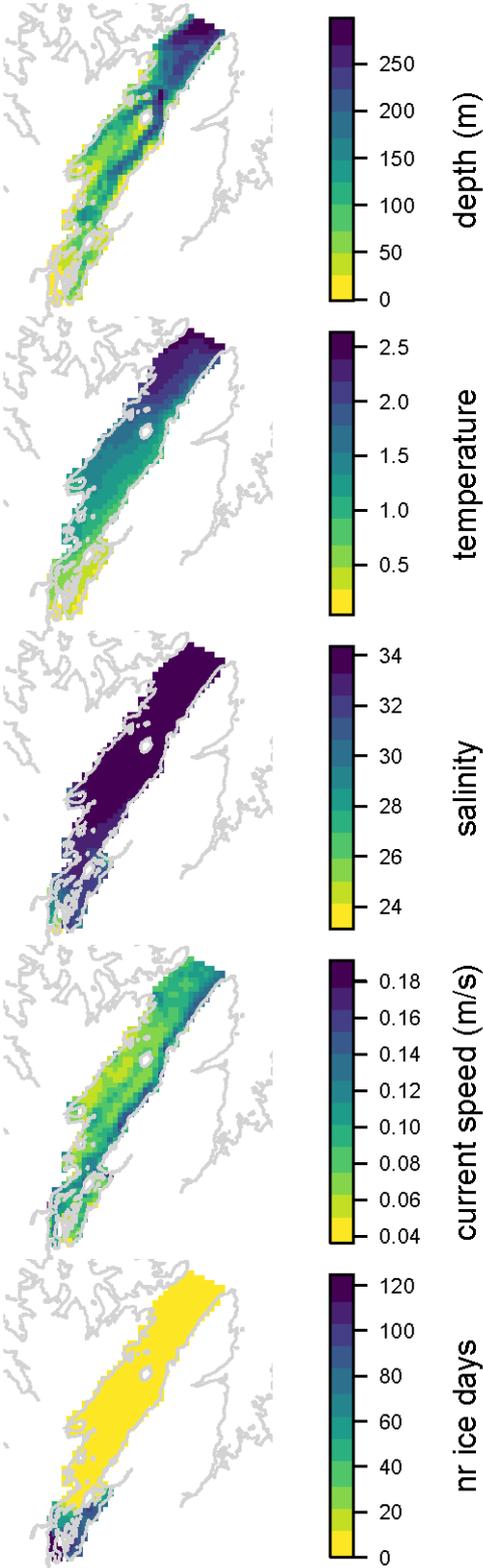
**Figure S2** The distribution of distances from the haulout site for simulated points of conditional availability, derived from a model for grey seals (upper plot), and for observed harbour seals data (lower plot). Simulated distances were expected to be larger than the range of movements observed for harbour seals, since grey seals generally move faster and further away from the coast. Contrary to expectations, the upper 95 percentile of the distribution of simulated points was smaller (13 km) than the one observed (32 km). The grey seal model therefore does not overestimate availability of resources far from the haulout sites as expected and can be considered valid for harbour seals.

## Biomass distribution of capelin and haddock



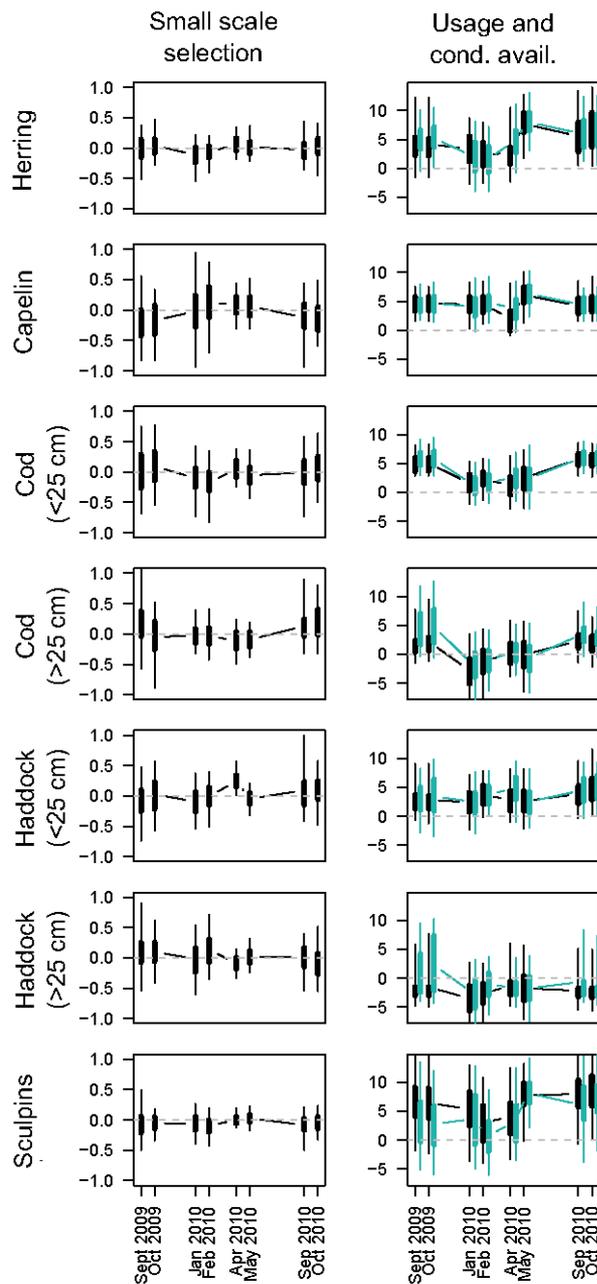
**Figure S3** Average prediction maps of log biomass (colour scale) of capelin, and the two size classes of haddock (< 25 cm and > 25 cm). The distribution is shown for the 4 sampling periods (August 2009 – August 2010).

### Environmental characteristics of Porsangerfjord



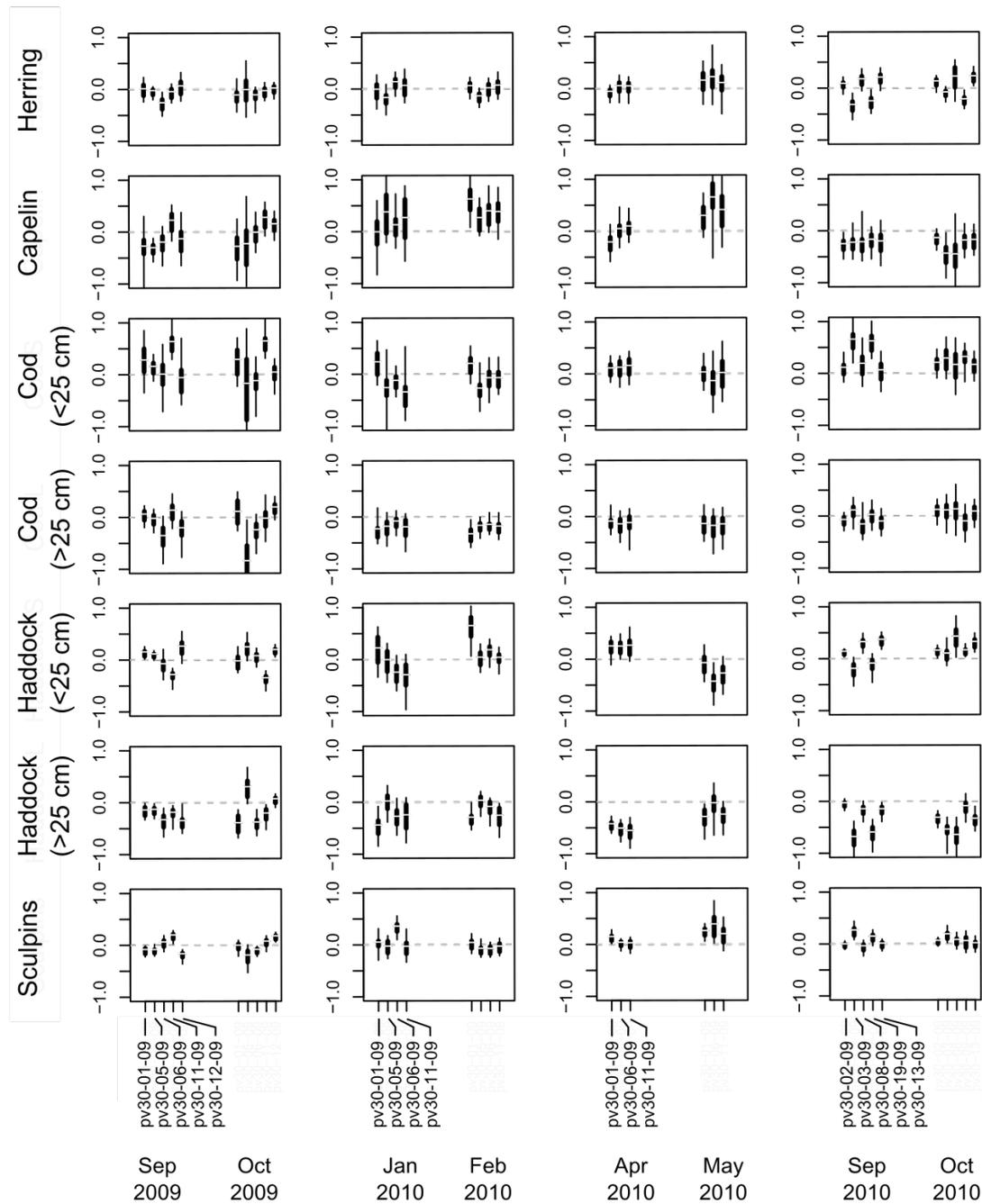
**Figure S4** Spatial patterns of the environmental variables used as predictors for the potential prey resources in the deterministic component (linear regression) of the regression kriging analysis (RK).

## Small scale resource selection coefficients



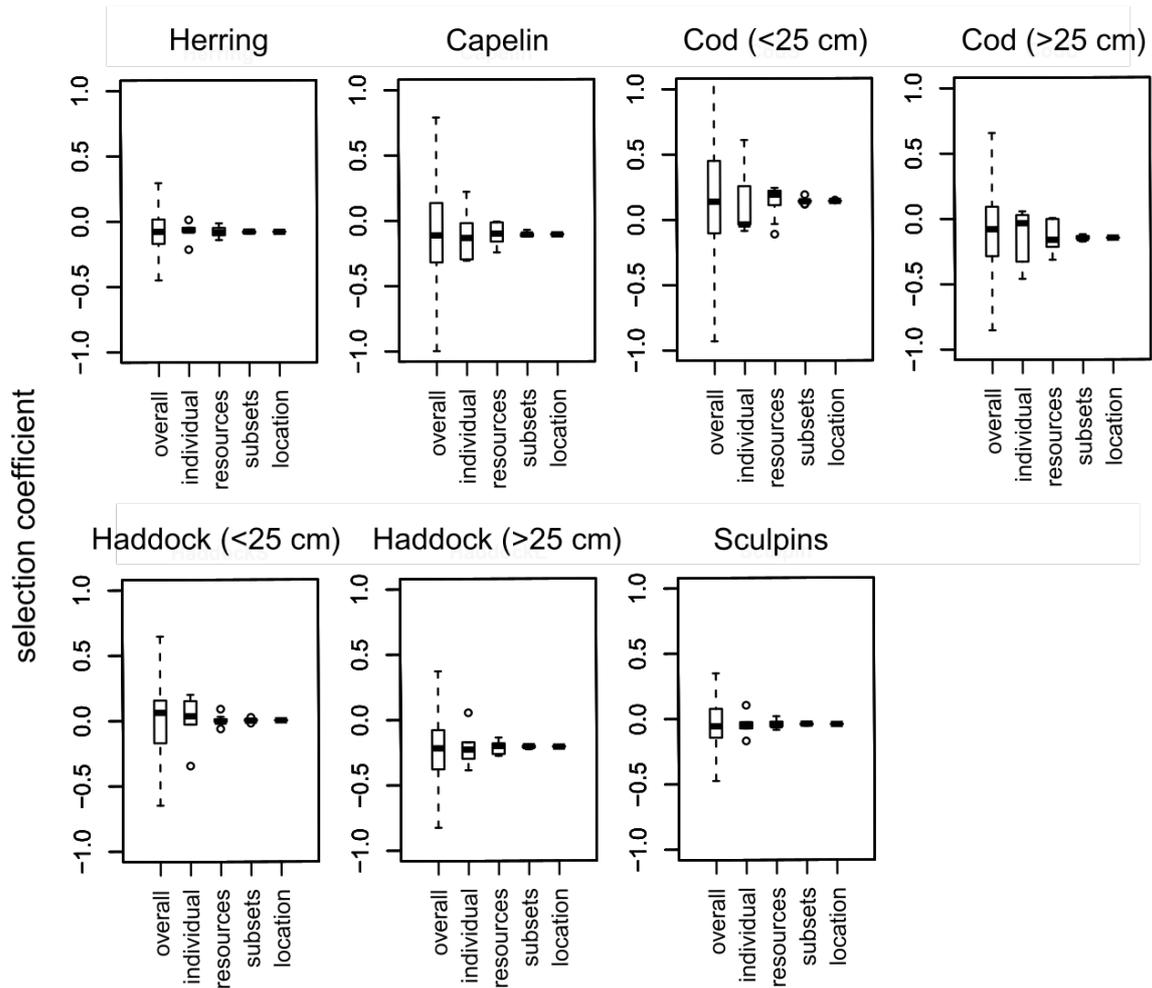
**Figure S5** Temporal patterns in small scale resource selection (left column), usage and conditional availability (black and blue boxplots, respectively, right column). The boxplots show the range of the selection coefficients across individuals and simulations (range of 50% and 95% of data: respectively thick and thin vertical lines). Positive and negative selection is represented by selection coefficient values above and below zero (horizontal dashed line). While resource coefficients are unitless, resource usage and availability are expressed in log biomass ( $\text{kg nm}^{-2}$ ).

## Individual variation in resource selection



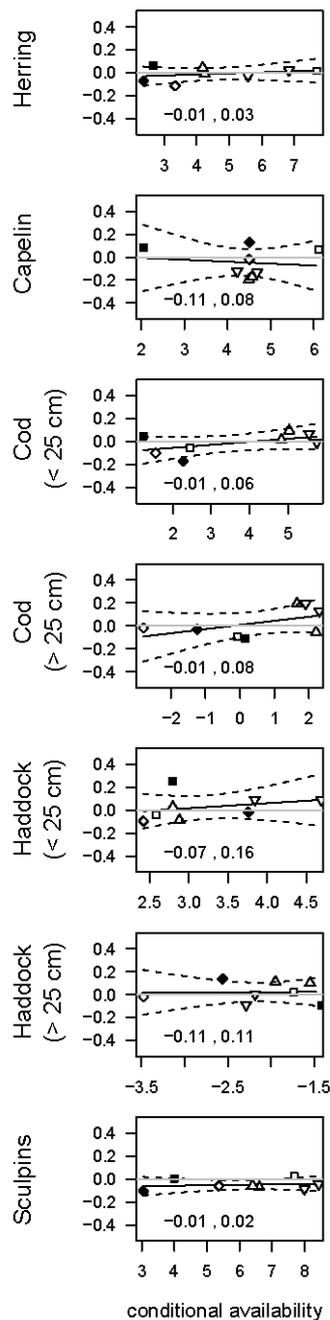
**Figure S6** General resource selection coefficients for individual harbour seals during each of the two-months periods (x axis). Boxplots show the distribution of selection coefficients across simulations for the different potential prey species (plot lines), for the 4 periods analysed (plot columns). Mean (horizontal white lines), 50% (thick vertical lines) and 95% confidence intervals (thin vertical lines), and the level of zero selection (horizontal dashed line) are shown.

## Sources of variation in resource selection



**Figure S7** The overall variance in selection coefficient estimates for the population and the specific variance attributable to the different sources of variation. The coefficients were estimated by Montecarlo simulations across all possible combinations of datasets, generated by modulating one source of variation at the time, keeping the others constant. The variance of selection coefficients is therefore represented by their spread along the y axis (extent of the boxplots). The different sources of variation are shown on the x axis in order of decreasing importance (respectively individual, resource prediction error, random subset selection and location error). The coefficients are shown for all potential prey species for period 1 only (Autumn 2009).

## Small scale foraging response



**Figure S8** Foraging response to changes in resource availability, conditional to the haulout sites. Linear models were fit on the population's mean resource selection coefficients (y-axis) against the conditional availability (in log biomass density,  $\text{kg nm}^{-2}$ ) for each month during the 4 periods analysed ( $\triangle$ : summer 2009,  $\nabla$ : summer 2010,  $\diamond$ : winter,  $\square$ : spring; black-filled when ice cover was large). The regression's 95% confidence bands (dashed lines) and the zero line of no selection (grey line) are shown. The confidence intervals of each regression slope (CI slope) are printed on the bottom of each plot.

## Regression kriging parameters

**Table S1** The parameters for the deterministic component (linear regression) of the regression kriging analysis.

	<u>Herring</u>		<u>Capelin</u>		<u>Cod (&lt; 25 cm)</u>		<u>Cod (&gt;25 cm)</u>		<u>Haddock (&lt;25 cm)</u>		<u>Haddock (&gt;25 cm)</u>		<u>Cottidae</u>	
	Estimate	Std. Error	Estimate	Std. Error	Estimate	Std. Error	Estimate	Std. Error	Estimate	Std. Error	Estimate	Std. Error	Estimate	Std. Error
<b>(Intercept)</b>	52.744	5.583	24.081	4.830	16.243	4.030	-21.464	5.196	28.652	5.485	-31.712	5.227	-5.581	3.227
<b>temperature</b>	1.444	0.213	-0.205	0.184	0.137	0.154	1.229	0.198	2.756	0.209	2.091	0.199	1.664	2.273
<b>depth</b>	0.004	0.001	0.006	0.001	0.013	0.001	0.018	0.001	0.009	0.001	0.016	0.001	-0.009	0.012
<b>current</b>	-20.572	3.400	-18.352	2.941	10.367	2.442	19.402	3.149	33.660	3.324	26.474	3.168	59.613	26.797
<b>salinity</b>	-1.491	0.169	-0.555	0.146	-0.448	0.122	0.619	0.157	-0.986	0.166	0.826	0.158	6.01E-17	5.80E-15
<b>ice days</b>	0.025	0.004	0.008	0.004	-0.018	0.003	-0.025	0.004	-0.016	0.004	-0.009	0.004	0.113	0.019
<b>Adjusted R<sup>2</sup></b>	0.13		0.06		0.20		0.50		0.34		0.54		0.59	

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