Supplementary Information

Adaptive foraging behaviour increases vulnerability to climate change

Benoit Gauzens*, Benjamin Rosenbaum, Gregor Kalinkat, Thomas Boy, Malte Jochum, Susanne Kortsch, Eoin J. O'Gorman, Ulrich Brose

* Corresponding author: benoit.gauzens@idiv.de

Supplementary information I: Environmental characteristics

Overall, the different environments considered were characterised by two contrasted levels of productivity, leading to a bimodal distribution.

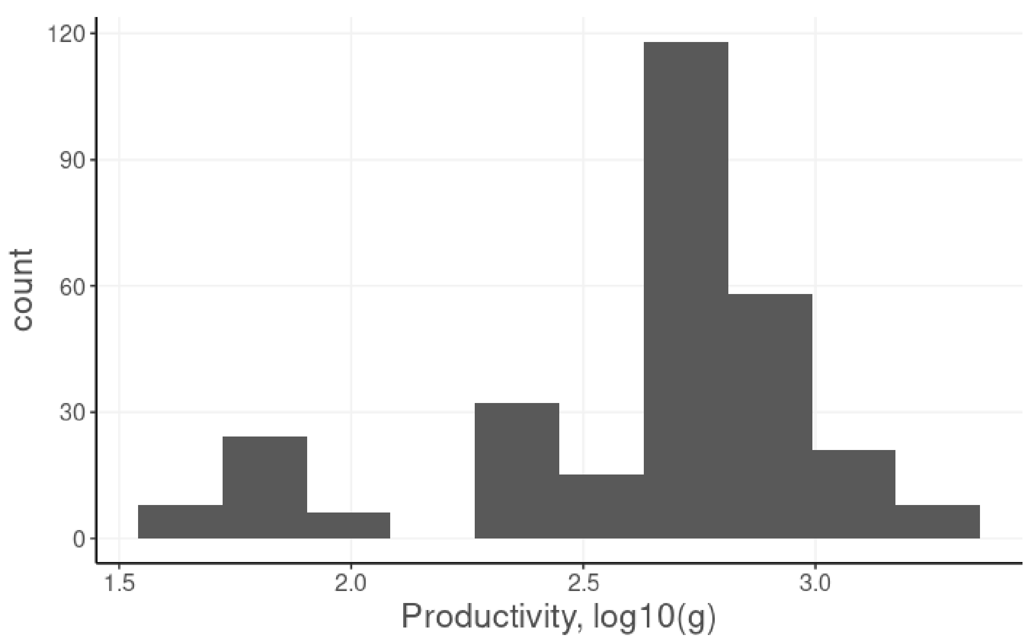

Fig. SI 1.1: distribution of the productivity values (g) for the different environments

Associated to these differences, we observed that the body mass distribution of the basal species (median and standard deviation) was responding differently to temperature depending on productivity values (Figure SI 1.2, Table SI 1.1):

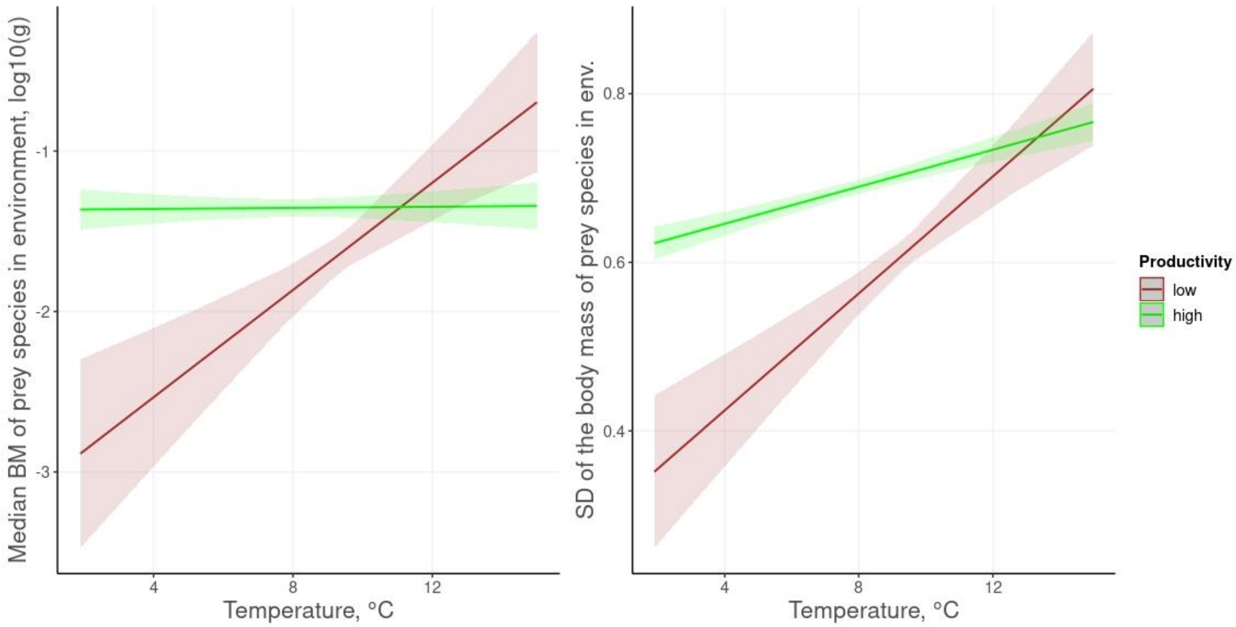

Fig. SI 1.2: response of the body mass structure of the resource species to temperature and productivity

Table SI 1.1: model estimate for the prediction of median and standard deviation of the environment distributions

	Median of BM			Standard deviation of BM		
Predictors	*Estimates*	*CI*	*p*	*Estimates*	*CI*	*p*
(Intercept)	-7.56	-9.74 – -5.38	**<0.001**	-0.46	-0.80 – -0.13	**0.007**
Productivity	2.29	1.53 – 3.06	**<0.001**	0.40	0.28 – 0.51	**<0.001**
Temperature	0.56	0.34 – 0.78	**<0.001**	0.09	0.06 – 0.13	**<0.001**
productivity:temperature	-0.21	-0.28 – -0.13	**<0.001**	-0.03	-0.04 – -0.02	**<0.001**
Observations	290			290		
R^2 / R^2 adjusted	0.209 / 0.201			0.311 / 0.304		

Supplementary information II: response of the preferred distribution to temperature at different levels of productivity

As we observed a strong interaction effect between temperature and productivity when explaining the response of the median of the body mass distributions in our different environments, we estimated for which levels of productivity the relationship between temperature and median was significant. At low productivity, we observed a positive slope between the median and temperature albeit not significant. The slope of the regression linearly decreased with productivity value, and became significantly lower than 0 for productivity levels larger than $10^{2.52}$.

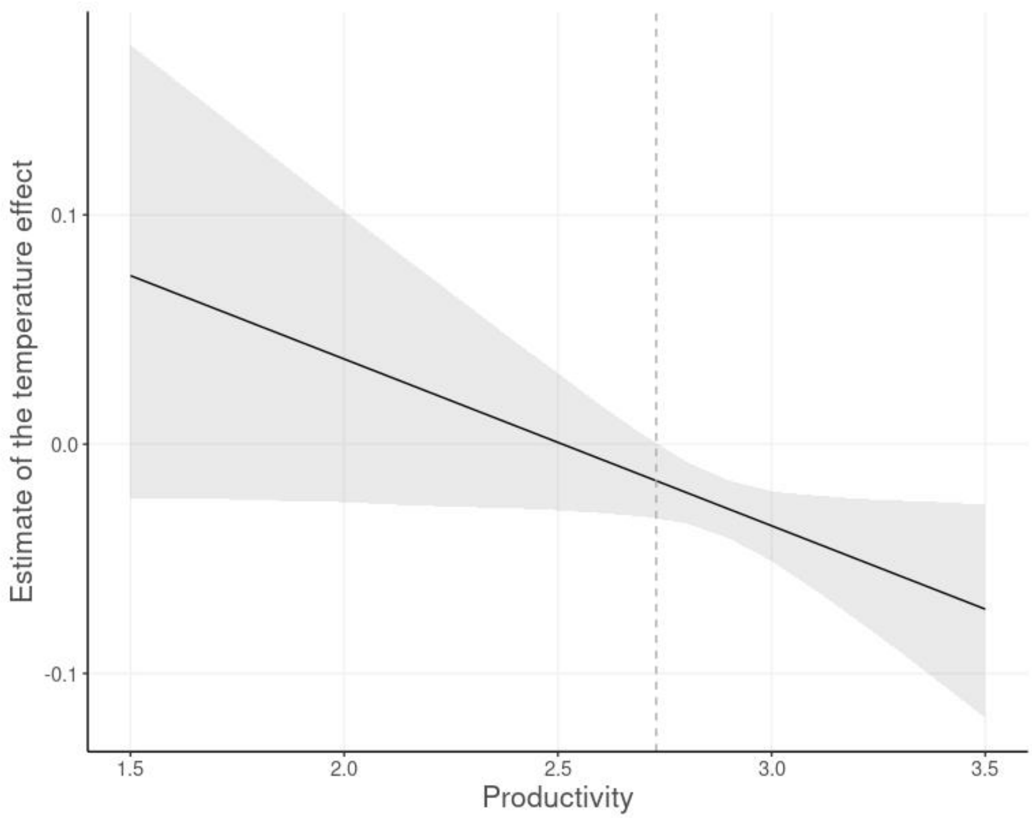

Fig. SI 2.1: Estimate and CI for the temperature effect at different levels of productivity. the dashed line indicates the productivity value above which the temperature effect become significant

Supplementary information III: response of the width of the preferred trophic niche to local conditions

To assess how the width of the preferred niche responded to environmental conditions we fitted the same models as for the median on the standard deviation of the body mass of the preferred distribution. We observed that the standard deviation was increasing with the predator body mass. Temperature effect is related to the productivity levels: at low productivity level, we observed that the standard deviation of the preferred body mass distribution increased, while this effect became weaker – and even negative- at higher productivity levels.

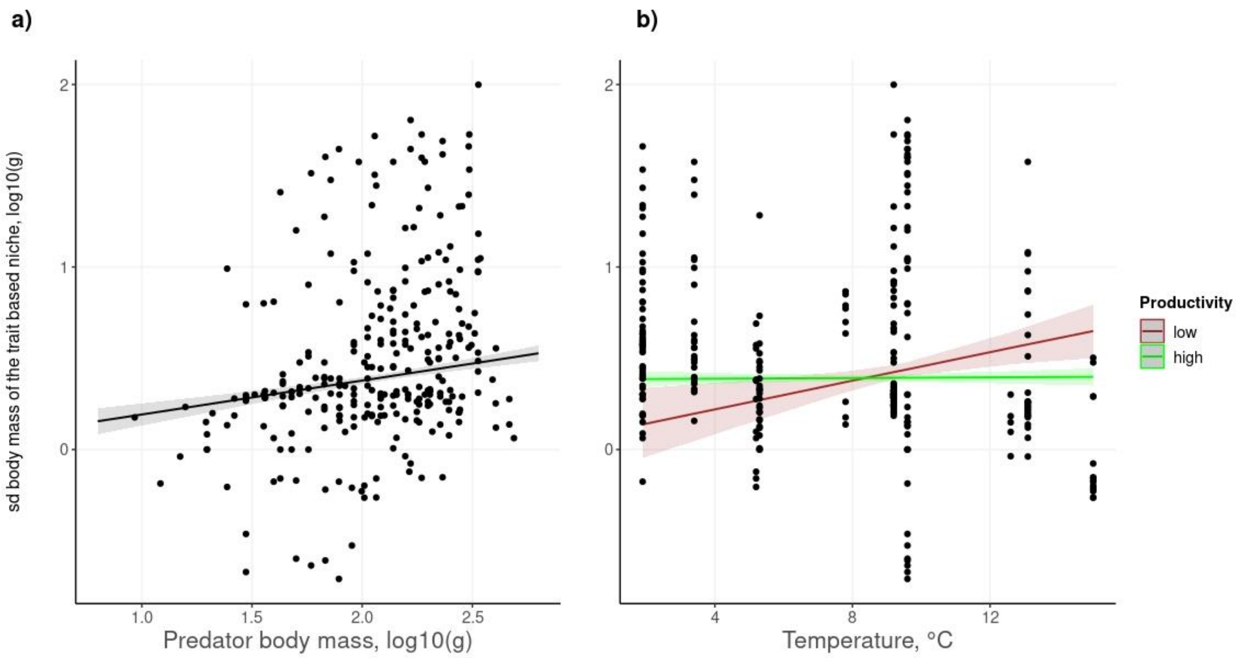

Fig. SI 3.1: Response of the width (standard deviation) of the preferred distribution to predator body mass (a) and temperature for different productivity gradients (b,c). Colours define the fish body shape.

Table SI 3.1: model estimates for the prediction of the standard deviation of the preference distributions

	Median of the preference distribution	
Predictors	*Estimates*	*CI (95%)*
Intercept	-1.07	-3.01 – 0.87
Predator body mass	0.55	0.40 – 0.71
Temperature	0.18	-0.02 – 0.37
Productivity	0.18	-0.49 – 0.85
temperature:productivity	-0.07	-0.14 – -0.00
Observations	290	
R^2 Bayes	0.279	

Supplementary information IV: Effect of nutrient availability and predators' functional responses type on predictions about species coexistence.

As maximum nutrient availability (variable S_i) and shape of the functional response (q) are not empirically informed, we analysed how sensitive to these two parameters model's predictions are. We varied S_i from 5 to 240 and q from 1 to 1.8. Overall, we observed an effect of nutrient availability on the pattern observed (Fig. SI5.1). The classic result of nutrient availability rescuing food webs form the detrimental of temperature increase is only observed without the consideration of adaptive foraging. The type of the functional response used resulted in more variations on the number of extinctions observed, with differences in extinctions between the two different models increasing with q (Fig. SI5.2).

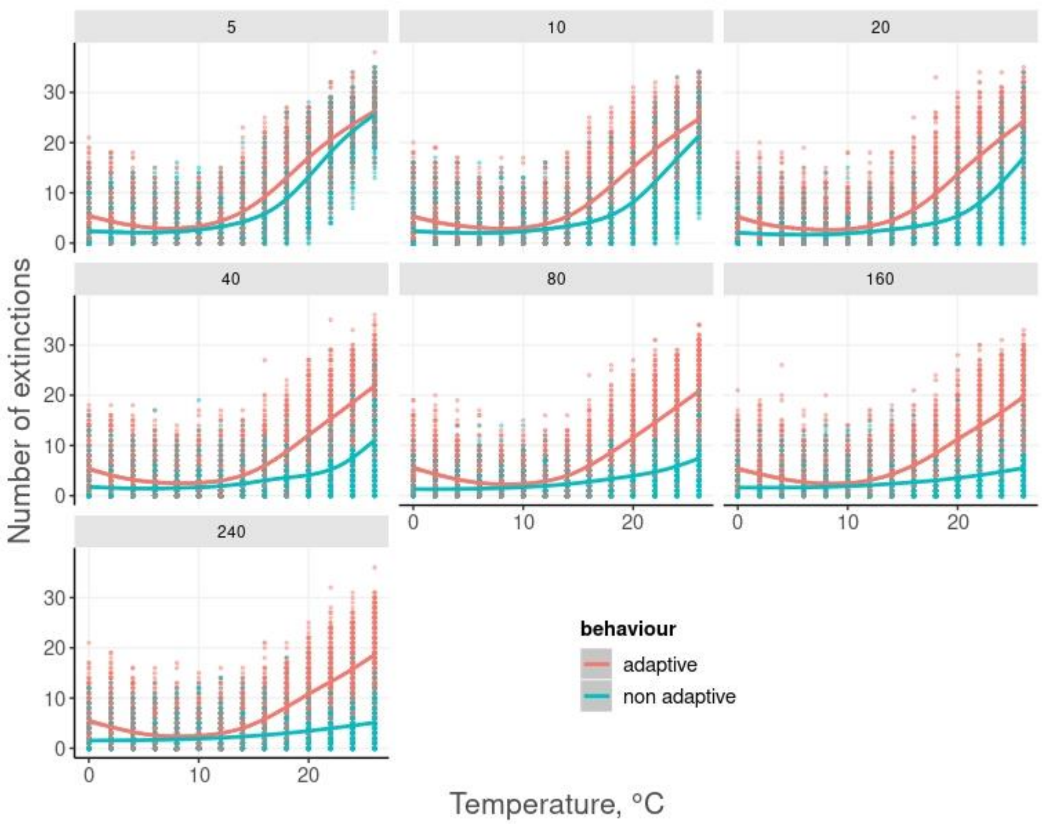

Figure SI 4.1: Effect of different levels of nutrient availability on the number of extinctions predicted by the model. Simulations where ran with all hill exponent (q) values.

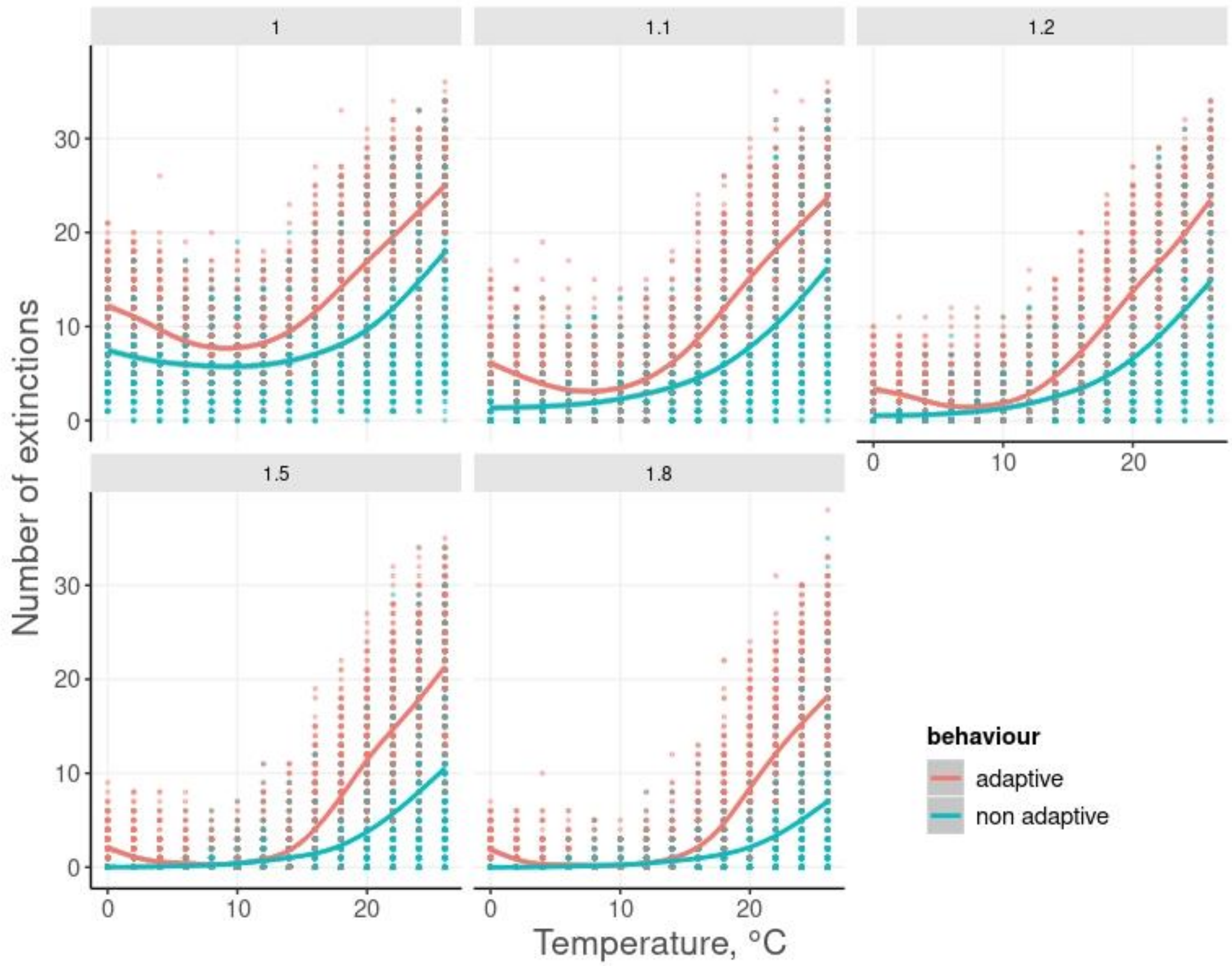

Figure SI4.2: effect of the choice of functional response type on the number of extinctions predicted by the model. Simulations where ran for a all level of maximum nutrient concentration (S).

Supplementary information V: Effect of considering different detection probabilities for prey in stomachs

As prey composed of soft tissues only are supposed to be less likely to be detected because of a faster digestion time, we corrected our observation by multiplying the abundance of species with hard body parts by 0.8. This was done to mirror the importance of these species that should persist longer in stomachs. As we are missing a general framework to properly describe how digestion time changes for the different species we used a unique correction factor that is a free parameter in our model (prey are either easy or difficult to digest, Table SI 6.3). We here present the results we would have obtained without using this correction factor.

Figure SI5.1: Response of the median body mass of the preferred prey body mass distribution to predator body mass (a), temperature (b) at different productivity levels. Points represent non-transformed data and lines present model predictions. The shaded areas show the 95% confidence interval on the predicted values.

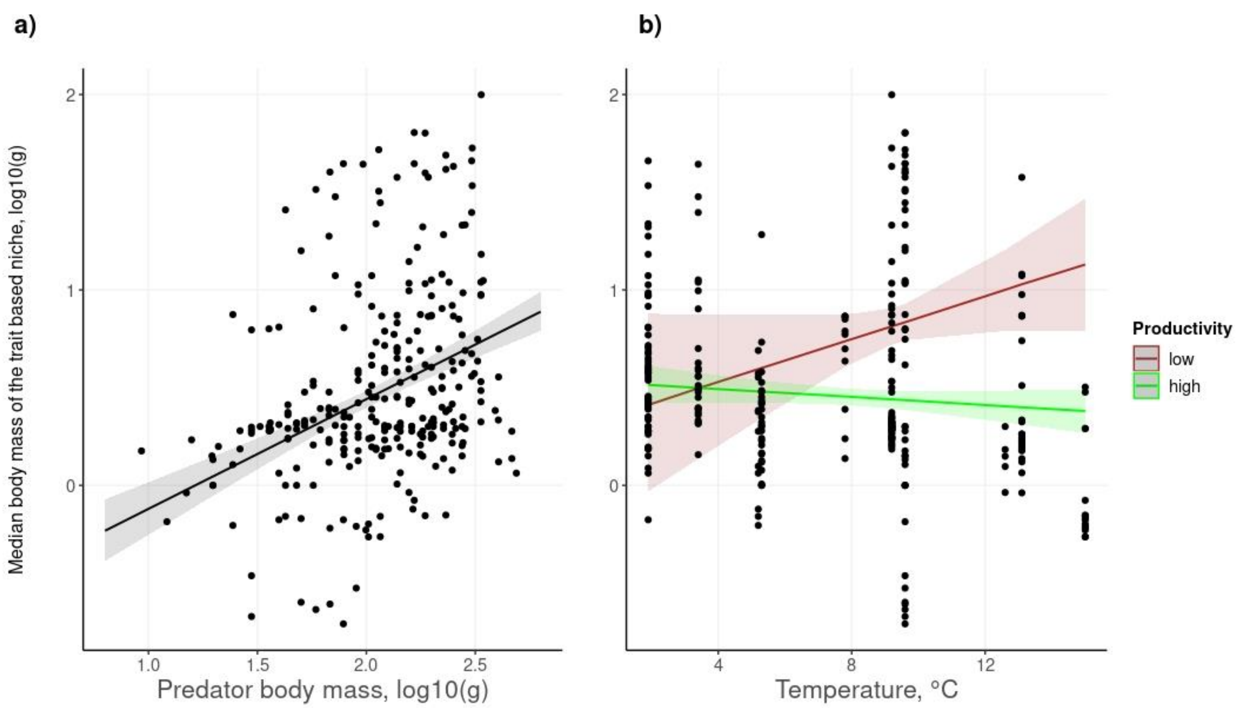

Table SI5.1: response of the realised distribution to predator body mass and environmental gradients

	Median of the preference distribution	
Predictors	*Estimates*	*CI (95%)*
Intercept	-1.38	-3.39 – 0.76
Predator body mass	0.57	0.41 – 0.71
Temperature	0.21	-0.01 – 0.41
Productivity	0.28	-0.46 – 0.98
temperature:productivity	-0.08	-0.15 – -0.01
Observations	290	
R^2 Bayes	0.279	

We can observe that the absence of correction factor does not qualitatively change the trends observed for the preference distributions. We can only detect slight changes in the model estimates.

Table SI5.2: Classification of species' digestibility Classification of species' digestibility

Prey species	Class	Digestibility
Abra alba	Bivalvia	Hard
Aloidis gibba	Bivalvia	Hard
Amphicteis gunneri	Polychaeta	Easy
Amphipoda spp.	Malacostraca	Easy
Anaitides spp.	Polychaeta	Easy
Anthozoa spp.	Anthozoa	Easy
Aphia minuta	Actinopterygii	Hard
Aphroditidae spp.	Polychaeta	Easy
Arenicola marina	Polychaeta	Easy
Ascidiacea spp.	Ascidiacea	Easy
Astarte spp.	Bivalvia	Hard
Balanus spp.	Hexanauplia	Hard
Brada villosa	Polychaeta	Easy
Capitella capitata	Polychaeta	Easy
Carcinus maenas	Malacostraca	Hard
Cardium fasciatum	Bivalvia	Hard
Castalia punctata	Polychaeta	Easy
Clupea harengus	Actinopterygii	Hard
Corophium spp.	Malacostraca	Easy
Crangon crangon	Malacostraca	Hard
Cumacea spp.	Malacostraca	Easy
Mysidacea spp.	Malacostraca	Hard
Cyprina islandica	Bivalvia	Hard
Diastylis rathkei	Malacostraca	Easy
Disoma multisectosum	Polychaeta	Easy
Euchone papillosa	Polychaeta	Easy
Gastosaccus spinifer	Malacostraca	Hard
Gobiidae spp.	Actinopterygii	Hard
Halicryptus spinolosus	Halicryptomorpha	Hard
Harmothoe imbricata	Polychaeta	Easy
Harmothoe spp.	Polychaeta	Easy
Hyperia galba	Malacostraca	Easy
Idothea spp.	Malacostraca	Hard
Isopoda spp.	Malacostraca	Hard
Limanda limanda	Actinopterygii	Hard

Prey species	Class	Digestibility
Macoma spp.	Bivalvia	Hard
Metridium senile	Anthozoa	Hard
Microdeutopus sp.	Malacostraca	Easy
Musculus spp.	Bivalvia	Hard
Mya truncata, Mya arenaria	Bivalvia	Hard
Mysis mixta	Malacostraca	Hard
Mytilus edulis	Bivalvia	Hard
Nemertea spp.	Nemertea	Easy
Nephthys spp.	Polychaeta	Easy
Nucula nitida	Bivalvia	Hard
Ophiura albida	Ophiuroidea	Hard
Other Decapoda	Decapoda	Hard
Other Gastropoda	Gastropoda	Hard
Other Polychaeta	Polychaeta	Easy
Pectinaria koreni	Polychaeta	Easy
Phaxas pellucidus	Bivalvia	Hard
Pherusa plumosa	Polychaeta	Easy
Phtisica marina, Caprella	Malacostraca	Easy
Pisces spp.	Actinopterygii	Hard
Pleuronectiformes spp.	Actinopterygii	Hard
Polydora sp.	Polychaeta	Easy
Pomatoschistus minutus	Actinopterygii	Hard
Priapulus caudatus	Priapulida	Easy
Saxicava arctica	Bivalvia	Hard
Scoloplos armiger	Polychaeta	Easy
Spionidae spp.	Polychaeta	Easy
Terebellides stroemi	Polychaeta	Easy
Thyonidium pellucidum	Holothuroidea	Hard

Supplementary information VI: Comparison of models with and without fish body shape as a covariate to predict the median of the preferred distribution

Table SI5.2: Results of model selection using Leave-one-out cross validation

	elpd_diff	se_diff
Model with shape	0.0	0.0
model.without shape	-1.0	2.4