Supplementary information

Text S1: Chlorophyll random resampling method (*Fig. S1*)

Chlorophyll-a concentration (Chla) was gathered from MODIS and SeaWiFS datasets to cover the entire study period. Raw data were truncated to a maximum value of 1.6µg/l to avoid abnormal high values of Chla at coastal pixels due to turbidity (i.e. the 99% quantile, coherent with Gibbs et al. 1986). Because data were not available in each pixel (due to cloud cover), random subsampling was performed on both datasets to assess the minimum number of pixels necessary to obtain unbiased daily means (i.e. deviation smaller than 5%, Fig. S1).

To assess days with a sufficient number of gridded values to obtain an unbiased daily average, random subsamplings were performed separately for MODIS and SeaWiFS. Every day with more than 2,000 gridded values has been randomly resampled 10,000 times, from which we assessed the number of times were subsampling was significantly different from the daily average. More precisely, a subsampling was considered different from the daily average when mean(subsampling) > or < mean(daily gridded data) ± 5%. The minimum number of values to consider to assess an unbiased daily average is then defined as the lowest value were resampling is different from the daily average less than 5% of the time (all resampled days combined). Biased daily means due to too few pixels were then removed (1341 out of 3304 days for SeaWiFS and 1348 out of 6250 days for MODIS). SeaWiFS and MODIS daily time series were then merged based on their significant correlation over the 2002-2010 common period (Pearson's r = 0.56) and previous studies (Zhang et al. 2006). When MODIS and SeaWiFS data were available for the same day, only MODIS data were retained (due to a more precise grid).

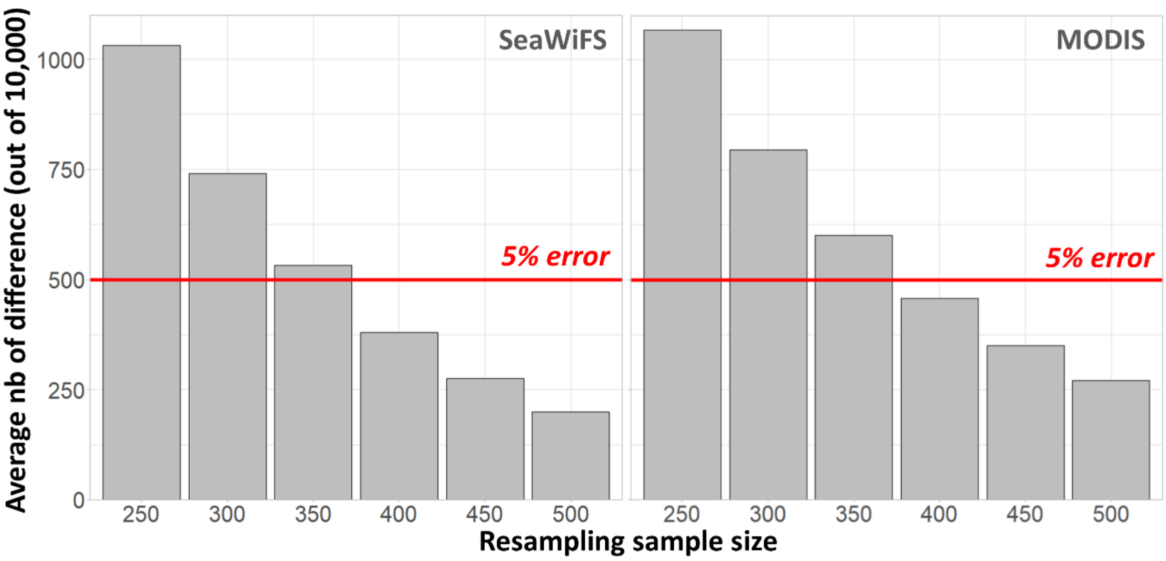

Fig. S1: [Chla] Resampling method. Average number of differences between full day data and random subsamplings of the day (5% difference with full day data) out of 10,000 random resamplings. Number of difference is tested for every day with more than 2000 gridded values. Minimum number of values to assess daily average is considered as the lowest sample size with less than 5% error (red line) = 400 daily values.

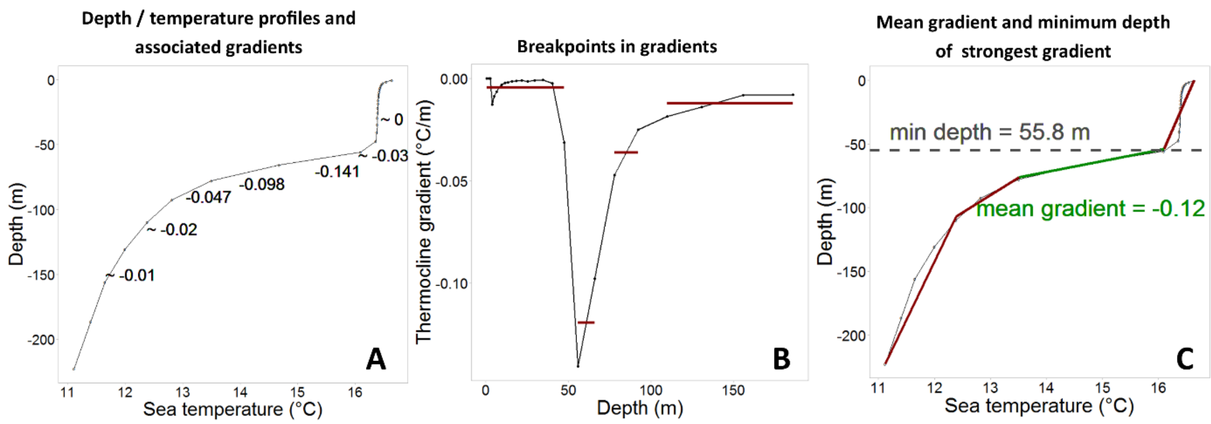

Fig. S2: Thermocline detection. Thermocline profile example (2002-04-10, 142.08 E – 39.33 S). Temperature gradients (shown in A) are defined as the temperature difference between each available depth. Breakpoints in temperature gradients depending on depth are assessed using breakpoints function from package strucchange 1.5-2, from which different segments are defined (red lines in B). Thermocline gradient is then computed as the mean gradient of the segment with stronger temperature gradient (green in C) and thermocline depth as the shallower point of this same segment (dashed grey line in C).

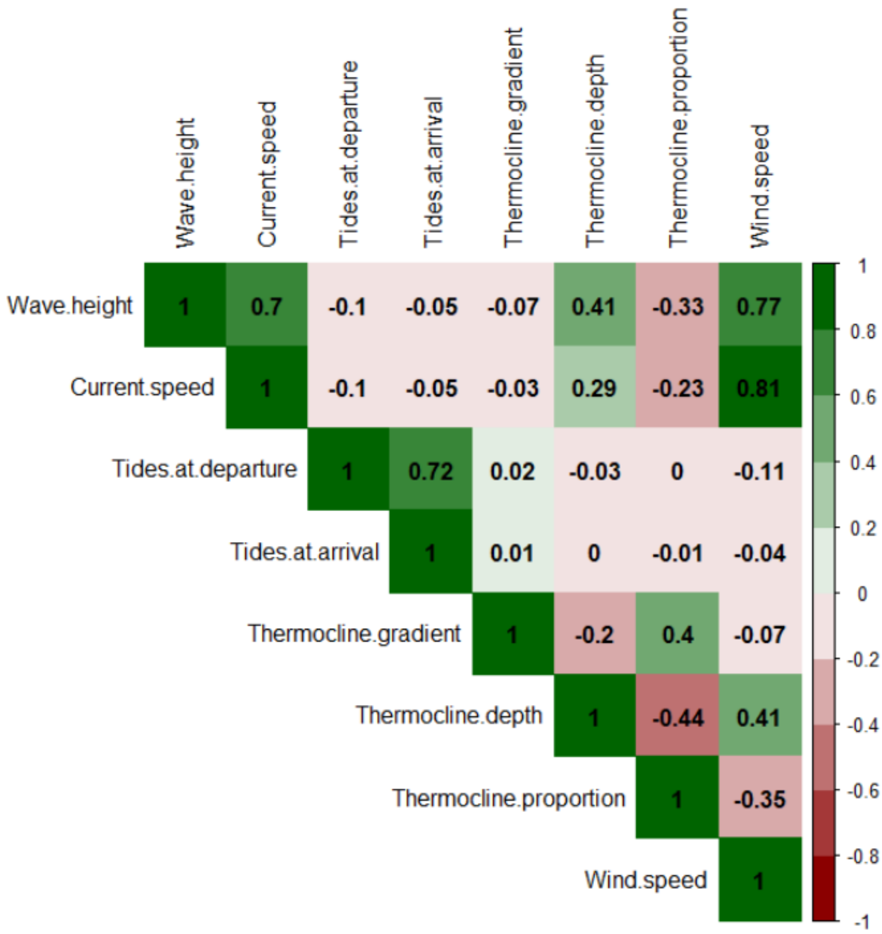

Fig. S3: Correlations of daily environmental variables. Pairwise correlations between daily anomalies (corrected by seasonal signal, except for tides) in different environmental variables including all the ones tested in linear models (wave height, current speed, tides and thermocline depth, gradient and proportion) and wind speed. Color shades represent the strength of positive (green) or negative (red) correlation between variables

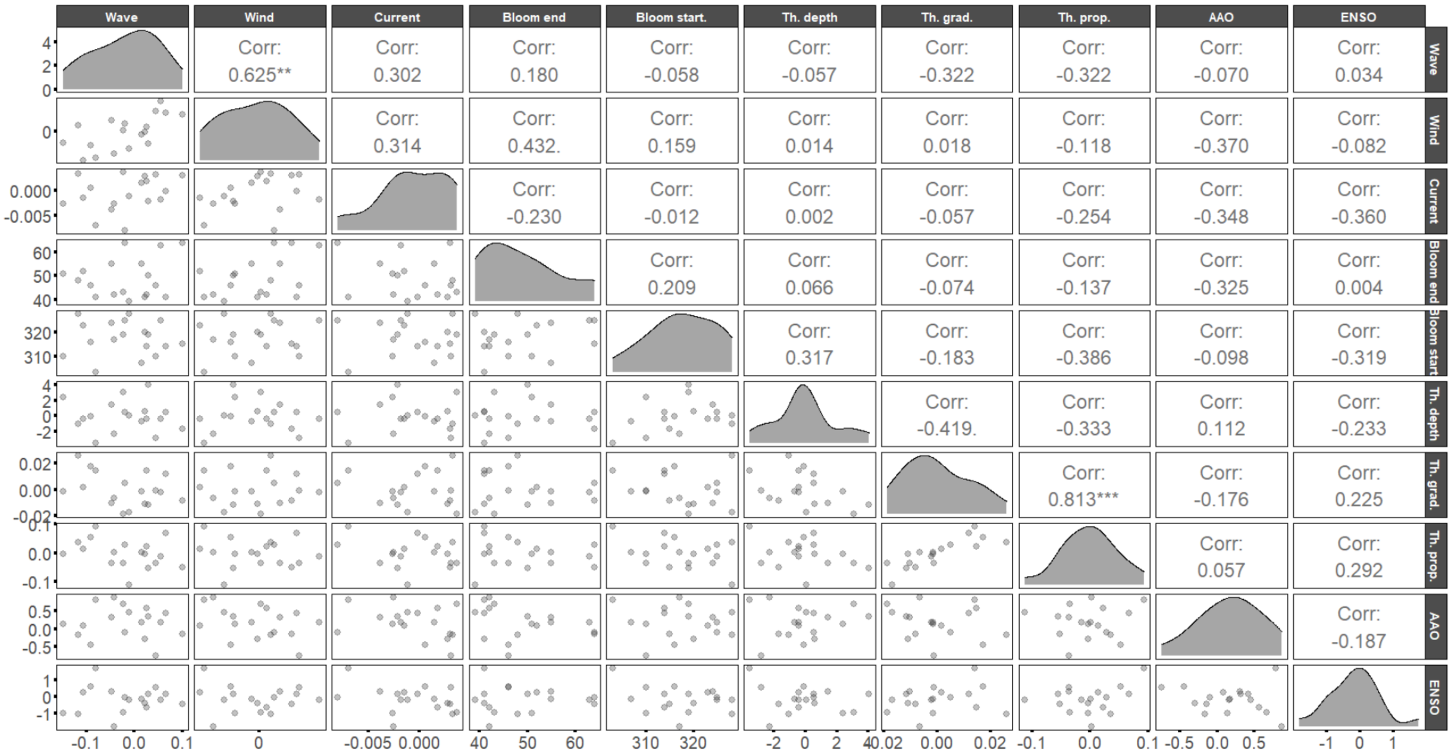

Fig. S4: Correlations of annual environmental variables. Pairwise correlations and scatterplots of annual averaged anomalies (corrected by seasonal signal) in different environmental variables including wave height (m), current speed (m/s), bloom start and end dates, thermocline depth (m), thermocline gradient (°C/m), thermocline proportion and wind speed.

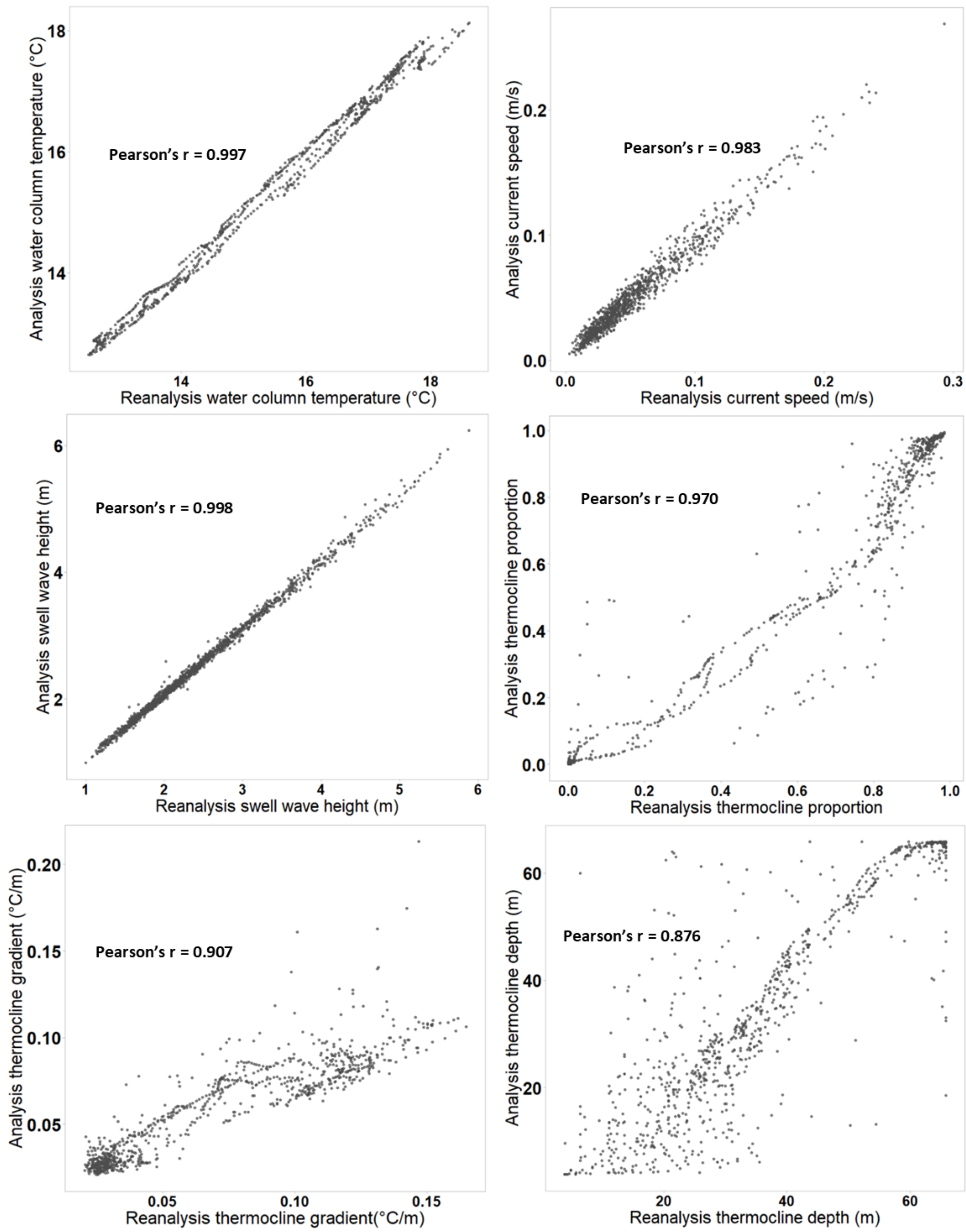

Fig. S5: Correlations between environmental daily values obtained from the **analysis and reanalysis datasets (Copernicus)** based on the common period of availability (from July 2018 to the end of 2018).

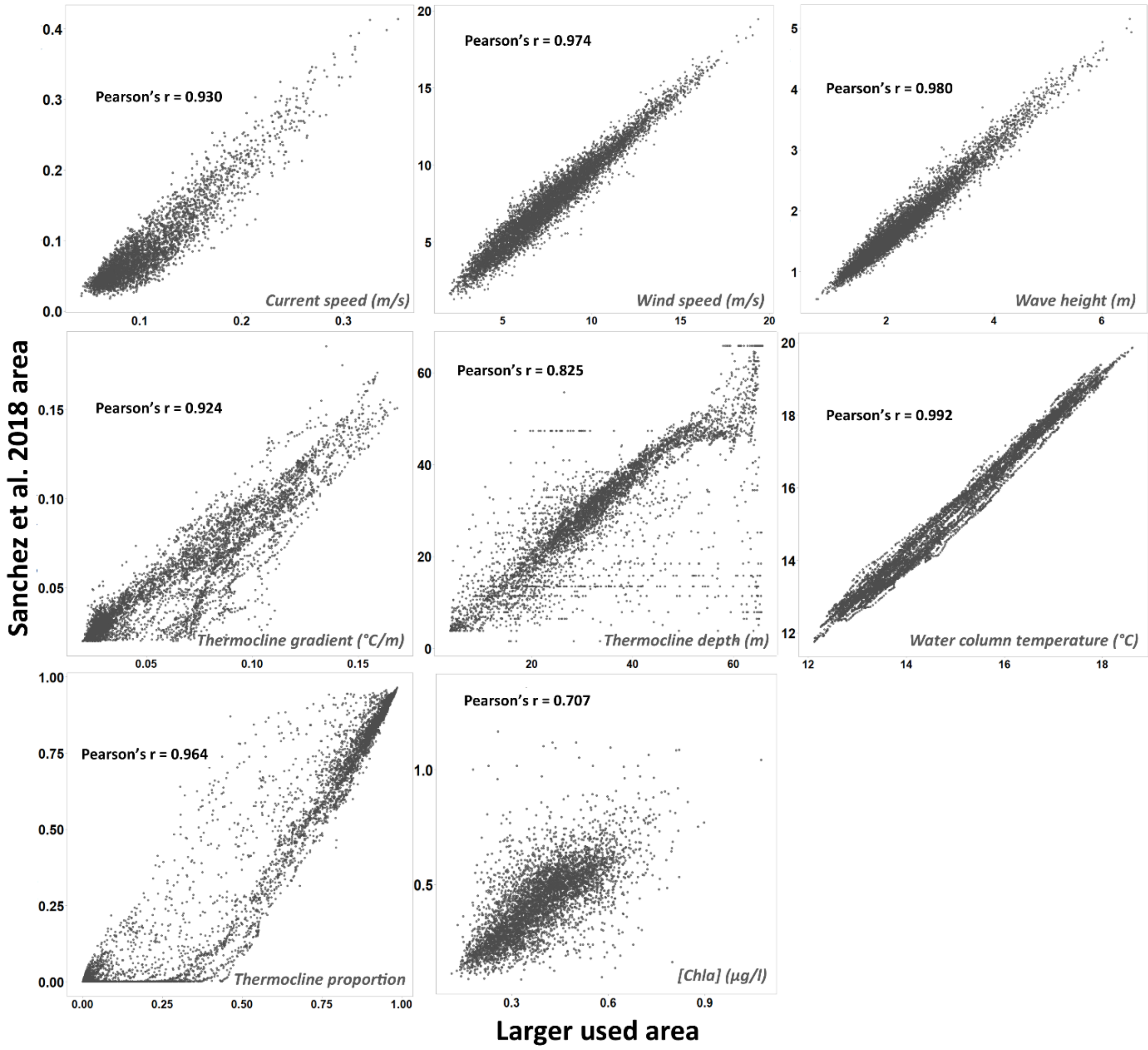

Fig. S6: Correlations between environmental daily values averaged over a known foraging area established by Sanchez et al. 2018 (144 to 146° E, 38.2 to 40° S) and a larger area including most of the Bass Strait as well as the continental slope (140 to 148° E, 38.2 to 41° S) for every gridded environmental variable.

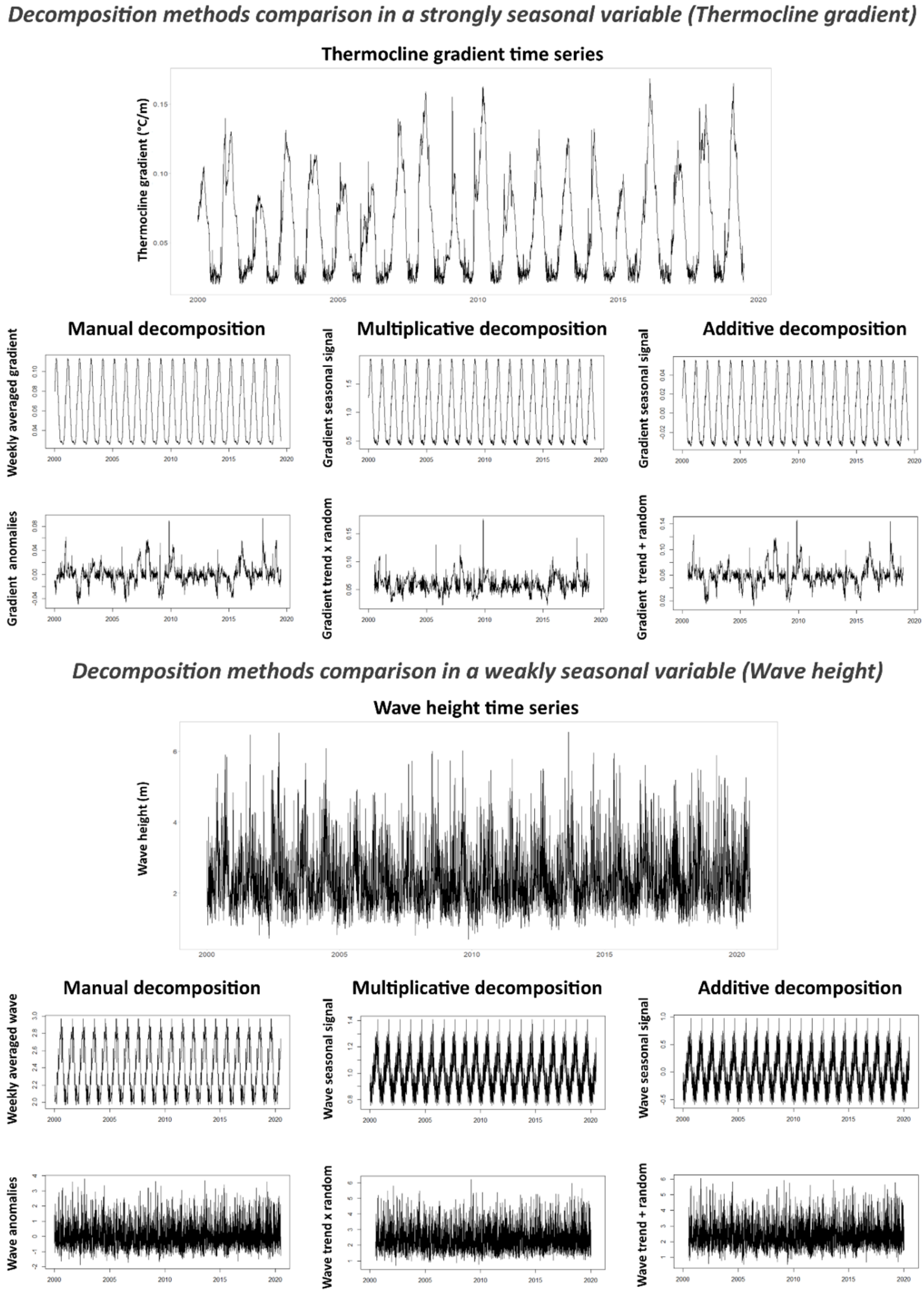

Fig. S7: Comparison of different methods for time series decomposition into seasonal signal and anomalies from daily time series in both strongly (Thermocline gradient) and weakly seasonal (Wave height) variables. Manual decomposition is achieved by assessing both average value of each calendar week (seasonal signal) and daily values minus average value of the corresponding week (anomalies). Additive and multiplicative decomposition methods are done using the *decompose* function from R package stats 4.0.3

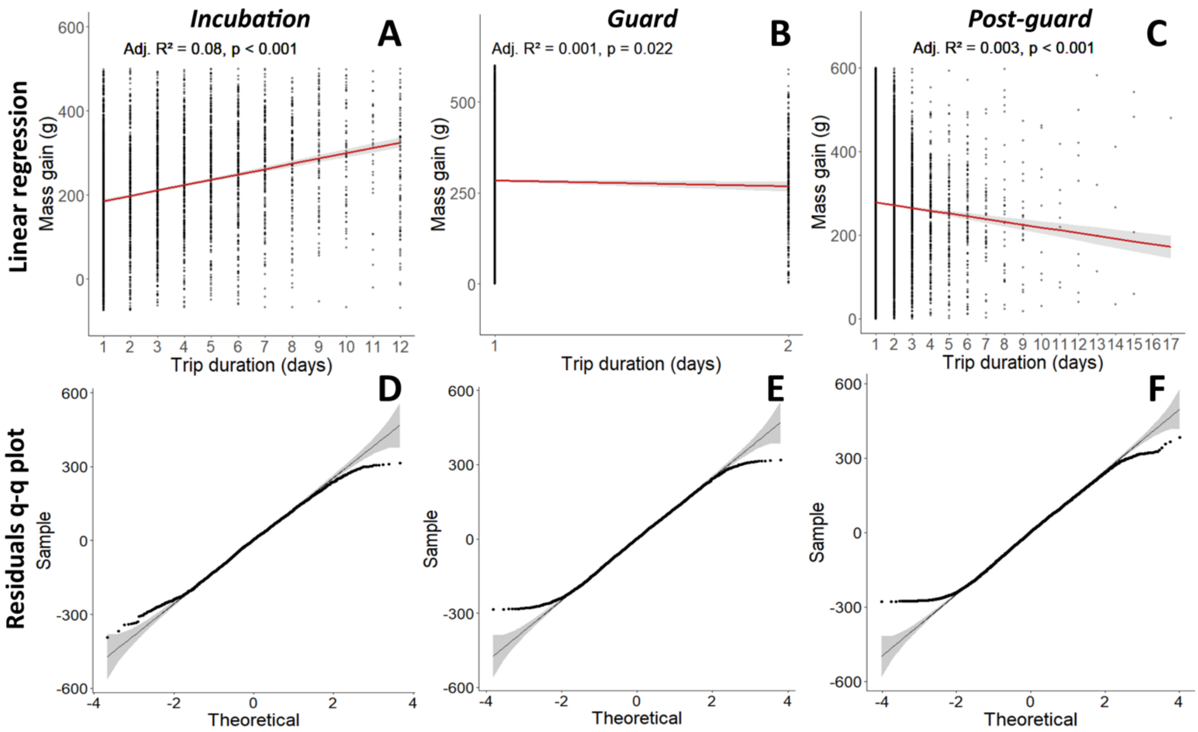

Fig. S8: Mass gained per trip depending on trip duration in days (A to C) with associated linear regressions (red lines), R^2 and p-values. Residuals of these regressions (that have further been used as mass gain corrected by trip duration) are displayed under the form of a q-q plot in panels D to F.

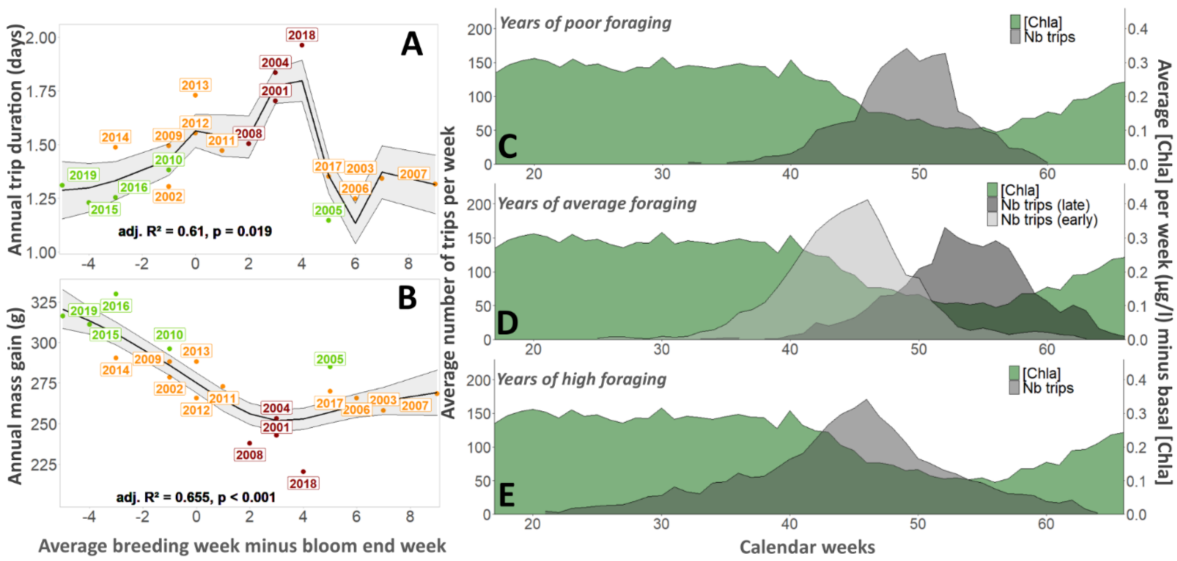

Fig. S9: Effect of synchrony between post-guard foraging and primary production on annual mass gain and trip duration (A & B), with generalised additive model (black curve) ± SE (grey area). Points are colored according to established high (green), average (orange) and poor (red) foraging clusters. Weekly average Chla concentration (dark green) and trip density (grey) during the year are presented for each of the 3 clusters (C, D & E). Trip density in the average foraging cluster (D) is split in two different categories based on breeding timing: early breeding (2002, 2009, 2011, 2012 and 2013 in light grey) and very late breeding (2003, 2005, 2006, 2007 and 2014 in grey) based on A & B.

Text S2: Partition of variance in foraging performances (*Table S1*)

Individuals age was assessed assuming first seen as adults (not tagged as chicks) were 3-yr old (mean age of first breeding). Sex was assessed using bill depth measurements (Arnould et al. 2004) and confirmed with male and female pairing data. Chick age was determined as the difference in days between the hatching date and the parent departure from the colony before every trip; thus negative age values correspond to the number of days before hatching.

Mixed models in *Table S1* included temporal factors (years and weeks of the year), endogenous factors (identity, sex, age and clutch) and breeding factors (breeding stage and chick age) and explained respectively 6.8% of the trip duration model deviance compared to null model (GLMM with Poisson distribution) and 23.3% of the mass gain model variance (LMM). Variations in foraging duration and mass gain were mainly due to the week of the year (that explained respectively 24% and 37% of the explained variance). Changes among years also accounted for 3% and 9% of trip duration and mass gain variance, respectively. Temporal factors apart, trip duration was mainly explained by the breeding stage (around 53%) and the age of the chick (around 14%), while mass gain variation was mainly due to the clutch (15%) as well as differences among individuals (17%) and sexes (12%).

Table S1: Variance in foraging performances depending on different factors (n = number of trips, N = number of individuals)

	Trip duration		Mass Gain	
Explained variance	**0.3859**		**3,741.1**	***23.3%***
Residuals			11,857.1	*76.0%*
Model deviance	98,683.2	*93.2%*		
Nul model deviance	105,903.3	*100%*		
	Part of explained variance (%)			
Week in season	0.0939	***24.3%***	1,400.7	***37.4%***
Individual	0.0170	*4.4%*	652.2	***17.4%***
Age	0.0010	*0.3%*	104.9	*2.8%*
Year	0.0104	*2.7%*	345.6	***9.2%***
Sex	0.0070	*1.8%*	464.0	***12.4%***
Clutch	0.0002	*0.1%*	572.3	***15.3%***
Chick age	0.0529	***13.7%***	201.4	*5.4%*
Breeding stage	0.2035	***52.7%***		
n	**33,478**		**28,633**	
N	**399**		**311**	

Table S2: Generalized Additive Models estimates (and confidence intervals) for the effects of week of the year signals on trip duration and mass gain during incubation, guard and post guard
Significant effects are presented with a bold p-value. CI = 95% Confidence Interval around mean.

Trip duration

Incubation

A

Predictors	*Estimates*	**mean** *CI*	*p*
(Intercept)	3.22	3.06 – 3.37	**<0.001**
Smooth term (week)			**0.001**
Observations	29		
R^2	0.616		

Post guard

B

Predictors	*Estimates*	**mean** *CI*	*p*
(Intercept)	1.36	1.32 – 1.40	**<0.001**
Smooth term (week)			**<0.001**
Observations	34		
R^2	0.569		

Mass gain

Incubation

C

Predictors	*Estimates*	**mean** *CI*	*p*
(Intercept)	-1.67	-7.92 – 4.58	0.586
Smooth term (week)			0.320
Observations	29		
R^2	0.151		

Guard

D

Predictors	*Estimates*	**mean** *CI*	*p*
(Intercept)	-5.86	-16.49 – 4.76	0.268
Smooth term (week)			**0.009**
Observations	31		
R^2	0.340		

Post guard

E

Predictors	*Estimates*	**mean** *CI*	*p*
(Intercept)	3.77	-1.00 – 8.54	0.116
Smooth term (week)			**<0.001**
Observations	34		
R^2	0.766		

Text S3: Detailed description of seasonal environmental effects on foraging and mixed model outputs (*Tables S3–S7*)

Regarding the effects of seasonal environmental signal, current speed had a constant negative effect on foraging performances, indicating that at periods of the year when the current is stronger, foraging performances decreased. Mass gain decreased by -81.3±37.3g per 0.1 m/s quicker current in incubation and -219.3±30.4 in guard (LMM, $p = 0.029$ & $p < 0.001$, although not significant in post guard, $p = 0.130$), trip duration conversely increased by 0.59±0.24 days per 0.1m/s quicker current in incubation and 1.54±0.24 days in post guard (GLMM, $p < 0.001$). Deeper and more present (higher proportion) thermocline also had a very detrimental effect on foraging trips during post guard (LMM, 1.9±0.4g less, and GLMM: 0.01 days longer per meter of thermocline depth, LMM: -3.0±0.8g less, GLMM: 0.29±0.05 days per 10% point more thermocline, $p = 0.002$ for post guard trip duration, otherwise $p < 0.001$, *Figure 5 A & B*). However, thermocline depth had a positive effect on trip duration in incubation (GLMM: 0.02±0.00 days shorter per meter of thermocline depth, $p < 0.001$) and on mass gain in guard (1.4±0.7g per meter of thermocline depth, $p = 0.046$). Finally, an increase of thermocline gradient also had a negative effect on foraging, although only tested for mass gain during incubation and guard due to high VIF (LMM, $p < 0.001$).

Table S3: Linear Mixed Model estimates (and confidence intervals CI) for the effects of seasonal environmental signals and environmental anomalies on mass gain during incubation with random effects of individual (tag), season and sex. All explanative variables were scaled so that estimates can be compared. Significant effects are presented with a bold p-value. σ^2 = within-group variance, τ_{00} = among-group variance, ICC = intra-class correlation coefficient.

	Mass gain - Incubation		
Predictors	*Estimates*	*CI*	*p*
Intercept	-0.78	-25.31 – 23.74	0.950
Current speed	-6.94	-11.34 – -2.54	**0.002**
Tides at departure	-2.70	-6.89 – 1.50	0.208
Tides at arrival	-0.47	-4.70 – 3.75	0.826
Thermocline depth	-2.37	-7.24 – 2.49	0.339
Thermocline proportion	4.37	-1.49 – 10.22	0.144
Thermocline gradient	-0.80	-7.73 – 6.13	0.821
Seasonal current speed	-6.98	-13.26 – -0.71	**0.029**
Seasonal thermocline depth	4.95	-0.86 – 10.77	0.095
Seasonal thermocline gradient	-13.77	-20.86 – -6.67	**<0.001**
Random Effects			
σ^2	13712.76		
$\tau_{00\ tag}$	246.87		
$\tau_{00\ season}$	472.09		
$\tau_{00\ sex}$	250.55		
ICC	0.07		
N_{season}	19		
N_{tag}	276		
N_{sex}	2		
Observations	3258		
Marginal R^2 / Conditional R^2	0.013 / 0.078		

Tab S4: Linear Mixed Model estimates (and confidence intervals CI) for the effects of seasonal environmental signals and environmental anomalies on mass gain during guard with random effects of individual (tag), season and sex. All explanative variables were scaled so that estimates can be compared. Significant effects are presented with a bold p-value. σ^2 = within-group variance, τ_{00} = among-group variance, ICC = intra-class correlation coefficient.

	Mass gain - Guard		
Predictors	*Estimates*	*CI*	*p*
Intercept	-5.27	-35.76 – 25.22	0.735
Wave height	-18.18	-23.02 – -13.34	**<0.001**
Current speed	8.73	4.13 – 13.34	**<0.001**
Tides at departure	0.98	-1.87 – 3.82	0.502
Thermocline depth	4.01	-0.02 – 8.04	0.051
Thermocline proportion	-1.21	-6.32 – 3.90	0.643
Thermocline gradient	-4.16	-10.31 – 2.00	0.186
Seasonal current speed	-14.90	-19.07 – -10.73	**<0.001**
Seasonal thermocline depth	4.68	0.08 – 9.27	**0.046**
Seasonal thermocline gradient	-25.06	-31.59 – -18.53	**<0.001**
Random Effects			
σ^2	12293.99		
$\tau_{00\ tag}$	827.28		
$\tau_{00\ season}$	1324.31		
$\tau_{00\ sex}$	323.55		
ICC	0.17		
N_{season}	18		
N_{tag}	261		
N_{sex}	2		
Observations	5984		
Marginal R^2 / Conditional R^2	0.036 / 0.198		

Table S5: Linear Mixed Model estimates (and confidence intervals CI) for the effects of seasonal environmental signals and environmental anomalies on mass gain during post guard with random effects of individual (tag), season and sex. All explanative variables were scaled so that estimates can be compared. Significant effects are presented with a bold p-value. σ^2 = within-group variance, τ_{00} = among-group variance, ICC = intra-class correlation coefficient.

	Mass gain - Post guard		
Predictors	*Estimates*	*CI*	*p*
Intercept	-5.71	-37.49 – 26.06	0.724
Wave height	-7.12	-10.22 – -4.02	**<0.001**
Current speed	-0.49	-3.37 – 2.38	0.737
Tides at departure	-3.74	-6.87 – -0.61	**0.019**
Tides at arrival	3.84	0.67 – 7.01	**0.017**
Thermocline depth	4.52	1.41 – 7.63	**0.004**
Thermocline proportion	-1.60	-5.01 – 1.80	0.356
Thermocline gradient	2.07	-1.73 – 5.88	0.285
Seasonal current speed	-2.53	-5.81 – 0.75	0.131
Seasonal thermocline depth	-7.52	-10.68 – -4.36	**<0.001**
Seasonal thermocline proportion	-7.00	-10.68 – -3.32	**<0.001**
Random Effects			
σ^2	12948.82		
$\tau_{00\ tag}$	993.57		
$\tau_{00\ season}$	519.59		
$\tau_{00\ sex}$	455.01		
ICC	0.13		
N_{season}	18		
N_{tag}	248		
N_{sex}	2		
Observations	13185		
Marginal R^2 / Conditional R^2	0.012 / 0.142		

Table S6: Linear Mixed Model estimates (and confidence intervals CI) for the effects of seasonal environmental signals and environmental anomalies on trip duration during incubation with random effects of individual (tag), season and chick age. All explanative variables were scaled so that estimates can be compared. Significant effects are presented with a bold p-value. σ^2 = within-group variance, τ_{00} = among-group variance, ICC = intra-class correlation coefficient.

	Trip duration - Incubation		
Predictors	*Incidence Rate Ratios*	*CI*	*p*
Intercept	2.75	2.31 – 3.29	**<0.001**
Current speed	0.97	0.95 – 0.99	**0.002**
Tides at departure	1.00	0.98 – 1.01	0.848
Tides at arrival	1.01	0.99 – 1.02	0.372
Thermocline depth	0.97	0.95 – 0.99	**0.004**
Thermocline proportion	0.94	0.92 – 0.96	**<0.001**
Thermocline gradient	0.98	0.95 – 1.01	0.183
Seasonal wave height	0.88	0.85 – 0.92	**<0.001**
Seasonal current speed	1.14	1.10 – 1.19	**<0.001**
Seasonal thermocline depth	0.94	0.92 – 0.96	**<0.001**
Random Effects			
σ^2	0.31		
$\tau_{00\ tag}$	0.09		
$\tau_{00\ chick.age}$	0.28		
$\tau_{00\ season}$	0.06		
ICC	0.58		
N_{tag}	358		
N_{season}	19		
$N_{chick.age}$	83		
Observations	5463		
Marginal R^2 / Conditional R^2	0.014 / 0.585		

Table S7: Linear Mixed Model estimates (and confidence intervals CI) for the effects of seasonal environmental signals and environmental anomalies on trip duration during post guard with random effects of individual (tag), season and chick age. All explanative variables were scaled so that estimates can be compared. Significant effects are presented with a bold p-value. σ^2 = within-group variance, τ_{00} = among-group variance, ICC = intra-class correlation coefficient.

	Trip duration - Post guard		
Predictors	*Incidence Rate Ratios*	*CI*	*p*
Intercept	1.46	1.36 – 1.56	**<0.001**
Wave height	1.04	1.02 – 1.06	**<0.001**
Current speed	1.02	1.00 – 1.03	0.067
Tides at departure	0.98	0.97 – 1.00	0.071
Tides at arrival	1.03	1.01 – 1.05	**0.002**
Thermocline depth	0.99	0.98 – 1.01	0.556
Thermocline proportion	1.04	1.02 – 1.06	**<0.001**
Thermocline gradient	0.95	0.93 – 0.97	**<0.001**
Seasonal current speed	1.03	1.01 – 1.05	**0.001**
Seasonal thermocline depth	1.03	1.01 – 1.05	**0.003**
Seasonal thermocline proportion	1.07	1.05 – 1.09	**<0.001**
Random Effects			
σ^2	0.52		
τ_{00} tag	0.01		
τ_{00} chick.age	0.00		
τ_{00} season	0.02		
ICC	0.05		
N_{tag}	321		
N_{season}	18		
$N_{chick.age}$	88		
Observations	20544		
Marginal R^2 / Conditional R^2	0.016 / 0.070		

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