The following supplements accompany the article

Relationships between isotopic ratios, body condition and breeding success in a High Arctic seabird community

Johanna E. H. Hovinen, Arnaud Tarroux, Francisco Ramírez, Manuela Forero, Sébastien Descamps*

*Corresponding author: sebastien.descamps@npolar.no

Marine Ecology Progress Series 613: 183–195 (2019)

Supplement 2. *Seabird body condition*

We defined bird body condition as the residual from a linear regression of individual body mass on individual capture date (in Julian days) and wing length (a proxy of body size). As the regression parameters may differ among species, we considered the interactions between capture date and species and between wing length and species. The year and individual identity (ring number) were included as random factors. Model was run with the *lmer* function of the package *lme4*.

The R-output is represented in Fig. S1.

```
Linear mixed model fit by REML ['lmerMod']
Formula: Mass ~ (Julian + Wing) * Species + (1 | YR) + (1 | MetalRing)
   Data: Selection

REML criterion at convergence: 5692.9

Scaled residuals:
     Min       1Q   Median       3Q      Max
-10.3800  -0.0145   0.0014   0.0377   2.7941

Random effects:
 Groups    Name        Variance Std.Dev.
 MetalRing (Intercept) 32740.6  180.94
 YR        (Intercept)   104.9   10.24
 Residual                982.9   31.35
Number of obs: 493, groups:  MetalRing, 232; YR, 7

Fixed effects:
                     Estimate Std. Error t value
(Intercept)         -5499.579   1147.655  -4.792
Julian                  9.745      3.363   2.898
Wing                   11.240      2.300   4.886
SpeciesLiau          5736.100   1474.300   3.891
SpeciesRitri         5584.727   1529.180   3.652
SpeciesUrlom         6617.300   1294.259   5.113
Julian:SpeciesLiau    -10.736      3.501  -3.066
Julian:SpeciesRitri   -10.867      3.378  -3.217
Julian:SpeciesUrlom   -11.326      3.449  -3.284
Wing:SpeciesLiau      -10.199      7.535  -1.353
Wing:SpeciesRitri      -9.648      3.916  -2.464
Wing:SpeciesUrlom     -10.511      3.526  -2.981
```

```
Analysis of Variance Table
               Df Sum Sq Mean Sq  F value
Julian          1 145379  145379 147.9138
Wing            1 438557  438557 446.2046
Species         3 701919  233973 238.0528
Julian:Species  3  12613    4204   4.2776
Wing:Species    3  11121    3707   3.7716
```

Figure S1. *R-output for the linear regression of individual body mass on individual capture date and wing length (with the species as an interacting factor).*

Supplement 3. ***Relationships between Svalbard seabird body condition, breeding success and isotopic ratios (during the breeding season) when excluding the years based on different tissue samples (i.e. red blood cells instead of whole blood for little auks in 2011 and Brünnich's guillemots in 2010).***

Results are from linear models and all variables were normalized (within species normalizing) so that models with only species or "species + δ^{13}C or δ^{15}N" as fixed effects were not informative. $\delta^{13}C_{breeding}$ and $\delta^{15}N_{breeding}$ were adjusted to the sampling date (to remove the intra-seasonal variation in isotopic ratios during the breeding season). df represents the degrees of freedom, AIC_C the Akaike Information Criterion corrected for small sample size, and ΔAIC_C the difference in AIC_C from the model with the lowest AIC_C and R^2 represents the proportion of variance explained by the model.

Table S4. *Results from linear models testing the effects of isotopic ratios (during the breeding season) on seabird body condition and breeding success when excluding the years based on different tissue samples*

Response variable	n	Fixed effects	df	AICc	ΔAICc
Average body condition	**15**	**Null (intercept only)**	**1**	**43.53**	**0.04**
		$\delta^{13}C_{breeding}$	2	46.20	2.71
		$\delta^{13}C_{breeding}$ × Species	6	60.04	16.55
		$\delta^{15}N_{breeding}$	2	43.49	0.00
		$\delta^{15}N_{breeding}$ × Species	6	53.38	9.89
Average hatching success	16[a]	**Null (intercept only)**	**1**	**45.09**	**0.00**
		$\delta^{13}C_{breeding}$	2	47.44	2.36
		$\delta^{13}C_{breeding}$ × Species	8	75.06	29.98
		$\delta^{15}N_{breeding}$	2	47.55	2.47
		$\delta^{15}N_{breeding}$ × Species	8	73.31	28.23
Average chick survival	14[a]	**Null (intercept only)**	**1**	**40.68**	**0.65**
		$\delta^{13}C_{breeding}$	2	43.29	3.26
		$\delta^{13}C_{breeding}$ × Species	6	55.29	15.26
		$\delta^{15}N_{breeding}$	2	40.03	0.00
		$\delta^{15}N_{breeding}$ × Species	6	58.39	18.36

[a]*: no reproduction data for Brünnich's guillemot in 2010 so that the only difference here with analyses presented in Table 2 (main document) is the absence of little auk reproductive data for 2011.*

Supplement 4. *Repeatability in black-legged kittiwake isotopic ratios*

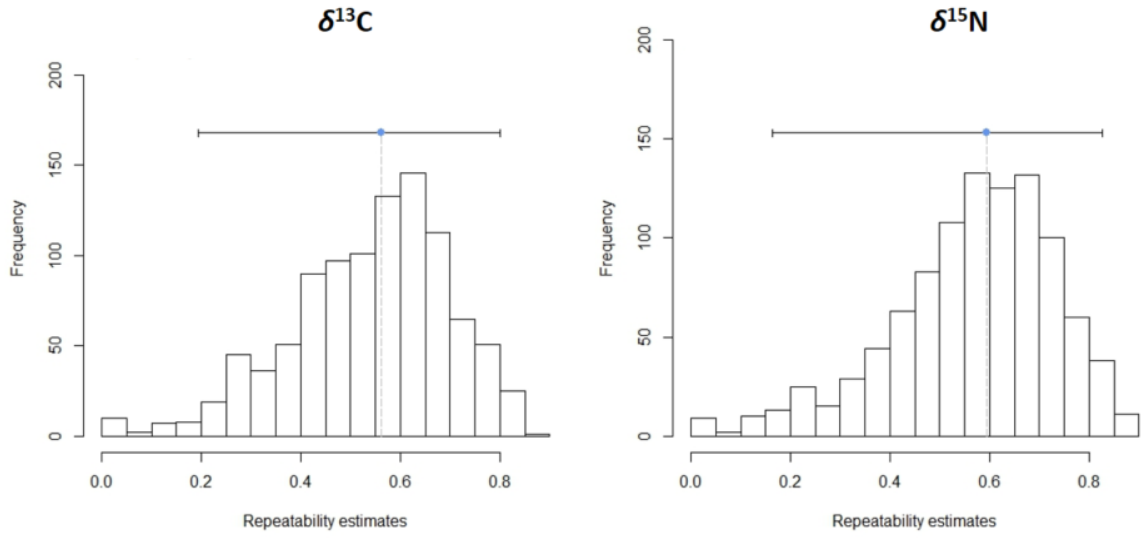


Figure S2. *Bootstrapped repeatability of blood $\delta^{13}C$ and $\delta^{15}N$, and their associated 95% confidence intervals, in black-legged kittiwakes breeding on Svalbard (Grumantbyen colony, 78°17'N 15°10'E). Repeatability has been calculated using the rpt function of the rptR package (Stoffel et al., 2017). Kittiwakes were sampled during chick-rearing and isotopic ratios were centered on their annual mean (within year centering). N=37 samples from 18 individuals and 4 years (2011, 2012, 2014 and 2015). Likelihood ratio tests indicate that repeatability in both ratios is significantly different from zero ($\delta^{13}C$: D=6.82, df=1, p=0.005; $\delta^{15}N$: D=8.78, df=1, p=0.002).*

Literature cited

Stoffel MA, Nakagawa S, Schielzeth H (2017) rptR: repeatability estimation and variance decomposition by generalized linear mixed-effects models. Meth Ecol Evol 8:1639-1644 https://doi.org/10.1111/2041-210X.12797

Supplement 5. *Residual isotopic ratios*

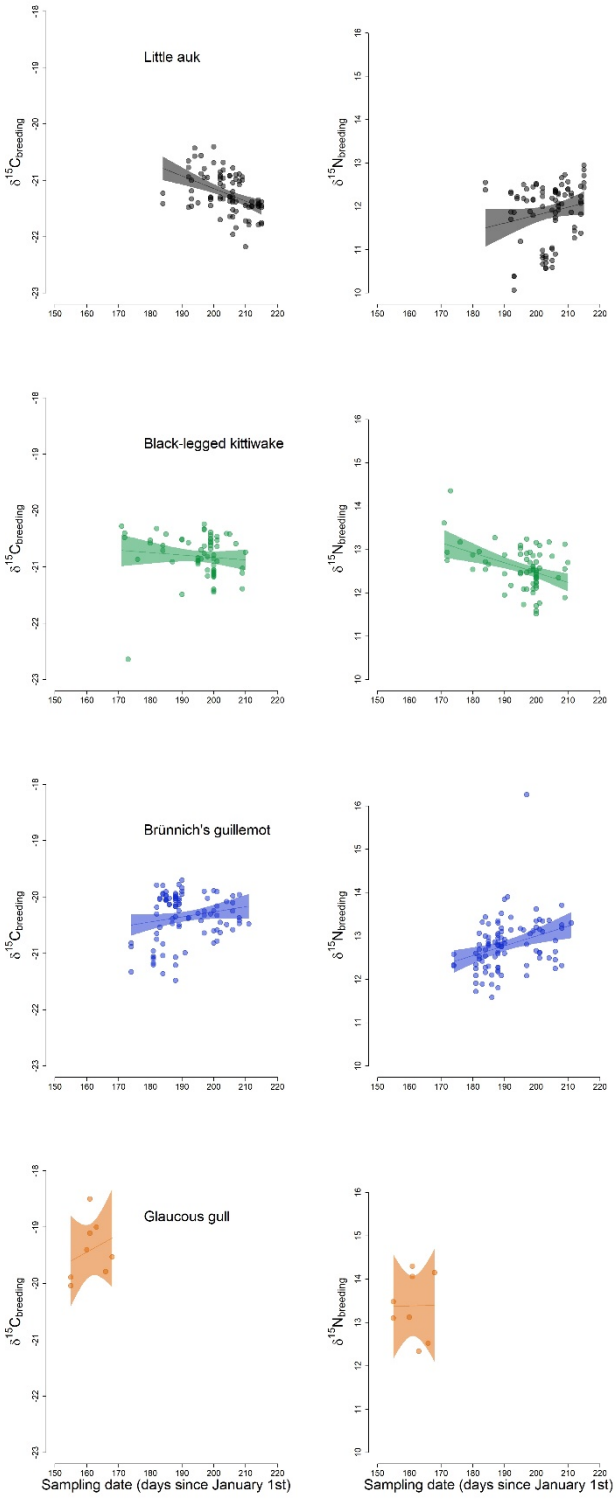


Figure S3. *Raw isotope values (carbon and nitrogen) as a function of the sampling date. The line and shaded areas represent the estimated relationship between isotope and sampling date, and the associated 95% confidence interval.*

Results below are from a linear mixed-effects model with individual identity as a random factor. Model was run with the *lmer* function of the package *lme4*.

The R-output is represented in *Figs. S4 and S5.*

```
Linear mixed model fit by maximum likelihood  ['lmerMod']
Formula: D13C ~ Julian * Species + (1 | MetalRing)
   Data: Select

     AIC      BIC   logLik deviance df.resid
   218.5    253.7    -99.3    198.5      240

Scaled residuals:
     Min       1Q   Median       3Q      Max
-3.08274 -0.71102  0.04843  0.84172  2.53235

Random effects:
 Groups    Name        Variance Std.Dev.
 MetalRing (Intercept) 0.0000   0.0000
 Residual              0.1295   0.3599
Number of obs: 250, groups:  MetalRing, 205

Fixed effects:
                     Estimate Std. Error t value
(Intercept)         -24.45617    4.72286  -5.178
Julian                0.03133    0.02930   1.069
SpeciesLiau           7.77766    4.85065   1.603
SpeciesRitri          6.26982    4.82887   1.298
SpeciesUrlom          2.39238    4.79335   0.499
Julian:SpeciesLiau   -0.05367    0.02980  -1.801
Julian:SpeciesRitri  -0.04461    0.02975  -1.500
Julian:SpeciesUrlom  -0.02233    0.02961  -0.754
```

```
Analysis of Variance Table
               Df Sum Sq Mean Sq  F value
Julian          1 28.281 28.2810 218.3269
Species         3 21.186  7.0622  54.5195
Julian:Species  3  3.232  1.0773   8.3168
```

Figure S4. *R-output for the linear mixed testing the effect of Julian date (with species as an interacting factor) on the carbon isotopic ratio during the breeding season.*

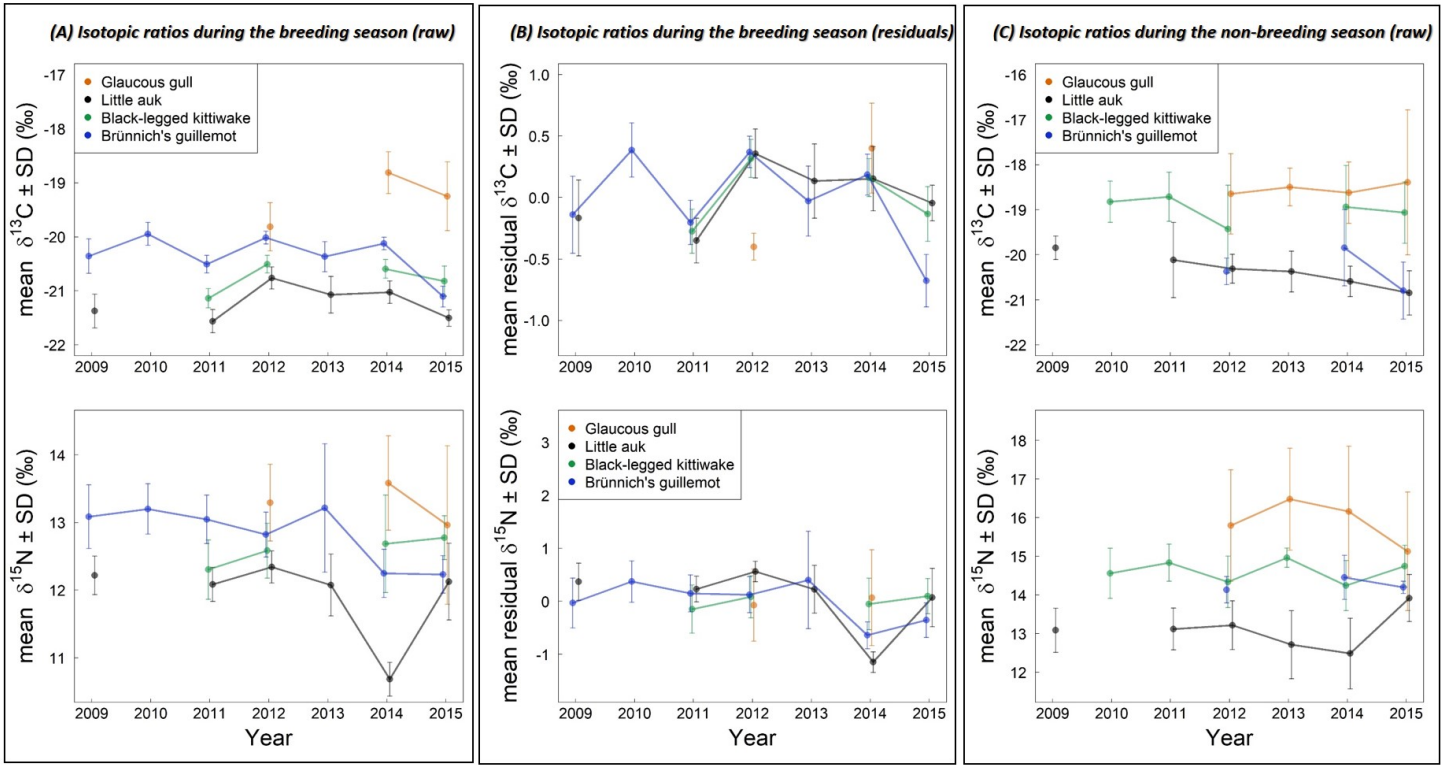
```
Linear mixed model fit by maximum likelihood  ['lmerMod']
Formula: D15N ~ Julian * Species + (1 | MetalRing)
   Data: Select

     AIC      BIC   logLik deviance df.resid
   460.6    495.8   -220.3    440.6      241

Scaled residuals:
    Min      1Q  Median      3Q     Max
-2.3288 -0.5652  0.0863  0.5757  4.8233

Random effects:
 Groups    Name        Variance Std.Dev.
 MetalRing (Intercept) 0.09557  0.3091
 Residual              0.24891  0.4989
Number of obs: 251, groups:  MetalRing, 205

Fixed effects:
                     Estimate Std. Error t value
(Intercept)         13.013977   7.701848   1.690
Julian               0.002295   0.047783   0.048
SpeciesLiau         -4.620921   7.903832  -0.585
SpeciesRitri         4.551149   7.846941   0.580
SpeciesUrlom        -4.456133   7.813495  -0.570
Julian:SpeciesLiau   0.014725   0.048569   0.303
Julian:SpeciesRitri -0.027886   0.048398  -0.576
Julian:SpeciesUrlom  0.019897   0.048277   0.412
```

```
Analysis of Variance Table
               Df  Sum Sq Mean Sq F value
Julian          1 10.2616 10.2616 41.2257
Species         3 22.8421  7.6140 30.5892
Julian:Species  3  5.9638  1.9879  7.9865
```

Figure S5. *R-output for the linear mixed testing the effect of Julian date (with species as an interacting factor) on the nitrogen isotopic ratio during the breeding season.*

Supplement 6. ***Inter-annual variation in carbon and nitrogen isotopic ratios, body condition, hatching success and chick survival during the breeding and non-breeding season***

(a)



(b)

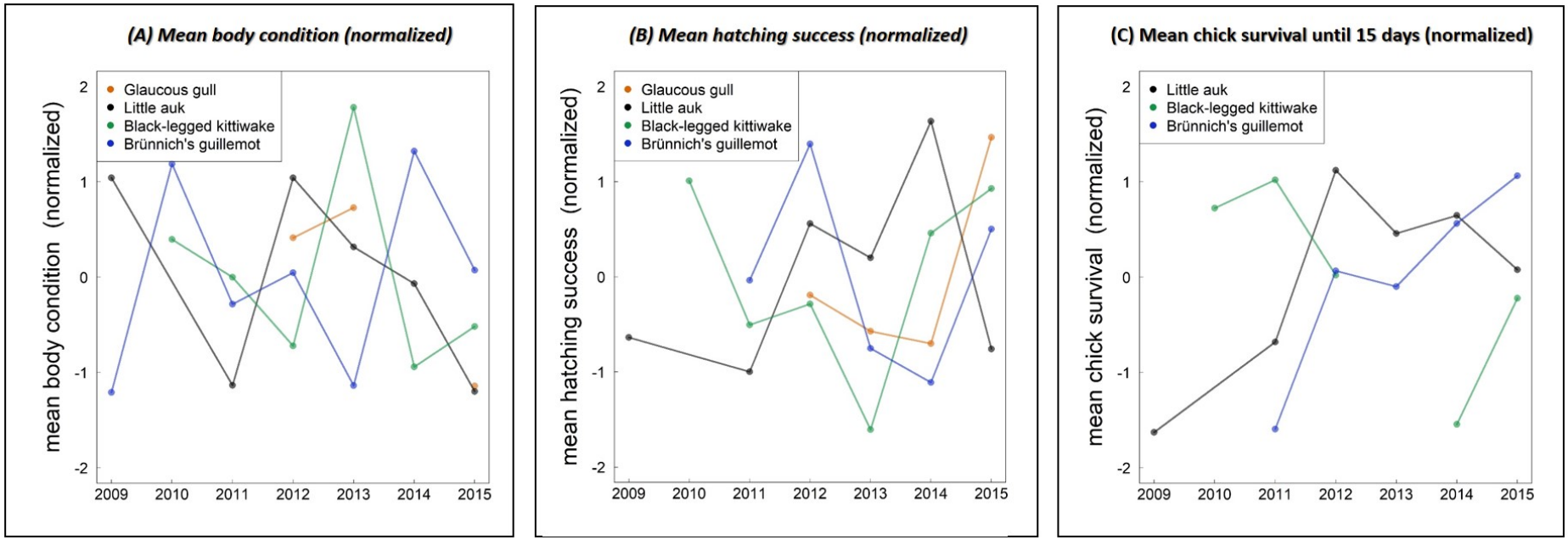


Figure S6. *Inter-annual variation in Svalbard seabird isotopic ratios (a) and condition or breeding success (b). In (a), the left (A) and central (B) panels represent the average carbon (top) and nitrogen (bottom) isotopic ratios for the breeding season (blood samples) and right panels (C) represent the non-breeding season (feather samples). In panels (B), isotopic ratios have been adjusted for sampling date (see details in the Method section and Suppl. Mat. 5). In (b), panels represent the body condition (A), hatching success (B) and chick survival until 15 days of age (C). All variables were normalized (centered on the mean and divided by the SD).*