SUPPLEMENTARY ELECTRONIC MATERIAL

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SEX-SPECIFIC CONTRIBUTIONS TO REPRODUCTION IN WHISKERED TERN *CHLIDONIAS HYBRIDA* COLONIES OF VARYING BREEDING DENSITY

CONTRIBUCI N SEGÚN EL SEXO A LA REPRODUCCI N DEL FUMAREL CARIBLANCO *CHLIDONIAS HYBRIDA* EN COLONIAS CON DENSIDADES VARIABLES DE PAREJAS REPRODUCTORAS

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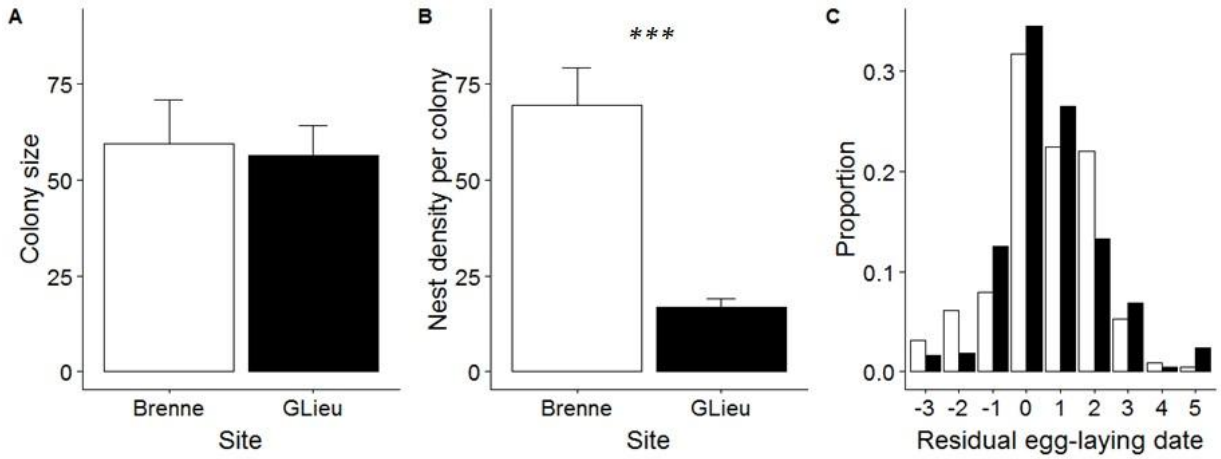
Appendix 1. Between-region comparisons of Whiskered Tern colonies

The number of active nests was routinely counted in a representative sample of colonies in the two breeding regions (including some of the colonies where focals were carried out) at the peak of the breeding season over the study period: 20 colonies in Brenne in 2002–2004, and 19 colonies at GLieu in 2004–2005. Mean colony size (± SE) did not differ between the two regions: 59.4 ± 11.5 and 56.3 ± 7.7 nests per colony in Brenne and GLieu, respectively (permutation t-test: $t = 0.22$, $P = 0.88$). By contrast, nest density was significantly higher in Brenne (69.3 ± 9.8 nests/ha per colony) than at GLieu (16.7 ± 2.2 nests/ha per colony, t-test with Welch correction: $t = 5.26$, $P < 0.001$). This difference was all the greater as nest density was underestimated in Brenne, where it was calculated by dividing the number of active nests in a pond by the surface area of aquatic plant beds, whereas Whiskered Terns rarely settle on all plant beds. At GLieu, all active nests were located using a GPS, and the assessment of nest density was derived from the area enclosed by the outermost nests of each colony (i.e. the minimum convex polygon measured using ArcView ver. 3.2 (Environmental Science Research Institute)). Finally, based on egg-biometry (from 13 colonies for each study region, totalling 227 and 597 complete clutches in Brenne and GLieu, respectively), we compared reproductive synchrony between the two study regions. In short, egg volume was calculated based on egg length and width (Coulson, 1963). Then, using the linear equation of egg density against egg age published in a previous work (Paillisson *et al.,* 2007), we estimated the initiation date of each clutch (the laying date of the first egg of a clutch), and we identified complete clutches with certainty based on egg age estimation (see a complete description of the methodology in Paillisson *et al.,* 2007). Estimated clutch initiation dates were expressed in pentades (five-day time intervals, beginning May 15). To control for colony and year effects, we calculated residual laying dates by subtracting each individual clutch-laying date (in pentades) from the peak laying date of all nests over a given year in each study region: pentades 5, 1, and 4 in 2002, 2003 and 2004 in Brenne, and pentades 5 and 4 in 2004 and 2005 at GLieu, respectively. No difference in egg-laying synchrony was found between regions based on the Cramér-von Mises test to test the distribution of residual egg-laying date data between regions ($T = 1.67$, $P = 0.12$), and the Fligner-Policello test to test the position of the distribution of residual egg-laying dates between regions ($U = -0.23$, $P = 0.82$).



Comparisons of (**A**) colony size (mean number of active nests per colony ± SE), (**B**) nest density per colony (mean number of nests/ha per colony ± SE), and (**C**) egg-laying synchrony between regions (Brenne: white bars; GLieu: black bars). ***: P < 0.001, otherwise differences were not significant.

*[Comparaciones del (**A**) tamaño de la colonia (número medio de nidos ocupados ± ES), (**B**) densidad de nidos por colonia (número medio de nidos/ha en cada colonia ± ES), y (**C**) sincronía en la fecha de puesta entre localidades (Brenne: columnas blancas; GLieu: colunas Negras). ***: P < 0.001, las diferencias no fueron significativas si no hay indicación de lo contrario.]*

Table A1. Basic behaviours recorded at the nest (first column) and their combination to describe a series of behavioural variables (expressed in duration or occurrence) used to document the parental effort of mates throughout breeding. Behaviours considered include: nest building (the time a bird spent shaping the nesting platform), vigilance (the resting time spent scanning the close environment), self-care (the time spent sleeping, cleaning feathers or occasionally consuming a prey item), partner/offspring care (the time devoted to incubating and replacing eggs, brooding, feeding or protecting nestlings, or feeding the partner, depending on the breeding stage), social interactions (mainly agonistic calls against conspecifics), together representing nest-attendance, and material or food delivery or empty trip (arrival with neither material nor food).

[Comportamientos básicos observados en el nido (primera columna) y su combinación para describir una serie de variables comportamentales (teniendo en cuenta tanto la duración como la manifestación del comportamiento) usadas para mostrar el esfuerzo de cría de cada miembro de la pareja a lo largo de la temporada de cría. Los comportamientos incluidos fueron: construcción del nido (el tiempo que un ave pasa dando le forma a la plataforma del nido), vigilancia (el tiempo que el ave pasa posada vigilando el entorno próximo), cuidado individual (el tiempo que el ave pasa durmiendo, limpiando el plumaje o consumiendo una presa), cuidados hacia la pareja o crías (el tiempo consagrado a incubar y recolocar los huevos, calentar, alimentar o proteger a los pollos, o alimentar a la pareja, dependiendo del momento durante la época de cría), interacciones sociales (principalmente graznidos de amenaza hacia otros individuos de la misma especie), resto de comportamiento incluyendo la presencia en el nido, aporte de material de construcción o de alimento o vuelos en vacío (llegada al nido sin material ni alimento).]

Basic behaviours	**Duration (% time)**					**Occurrence (probability or rate)**			
	Nest attendance	Nest building	Vigilance	Self-care	Partner/ offspring care	Material delivery	Food delivery	Empty trip	Social interaction
Resting	X		X						
Feather cleaning	X			X					
Sleeping	X			X					
Sleeping while providing egg/chick care	X			X	X				
Feather cleaning while providing egg/chick care	X			X	X				
Nest shaping	X	X							
Nest shaping while providing egg/chick care	X	X			X				
Egg/chick care	X				X				
Calls	X								X
Calls while providing egg/chick care	X				X				X
Arrival with material						X			
Arrival with food for partner/chick							X		
Arrival without material/food								X	

Table A2. GLMMs testing the influence of sex and breeding region on the duration of a series of behaviours during each of the three breeding stages. Different link functions were used depending on the model adjustment. Significant models (with at least one significant effect) explaining more than or equal to 10% of the variance (when all fixed terms are considered, R^2) are shown in bold.

[GLMM utilizados para comprobar la influencia de los factores sexo y área de cría sobre la duración de la ejecución de distintos comportamientos durante las tres fases de época de cría. Se usaron diferentes funciones link en función del ajuste de los modelos. En negrita aparecen los modelos significativos (con al menos un factor significativo) que explicaban al menos 10% de la varianza (cuando todas las variables fijas son tenidas en cuenta, R^2).]

Stage	Response variable	Link function	Effect	χ^2	d.f.	P	R^2
Nest building	**Nest attendance**	**Logit**	**Sex**	**116.65**	**1**	**< 0.001**	**0.28**
			Breeding region	1.59	1	0.21	
			Sex × Breeding region	0.98	1	0.32	
	Vigilance	**Logit**	**Sex**	**143.11**	**1**	**< 0.001**	**0.32**
			Breeding region	0.70	1	0.40	
			Sex × Breeding region	0.02	1	0.89	
	Self-care	Logit	Sex	11.55	1	< 0.001	0.04
			Breeding region	0.34	1	0.56	
			Sex × Breeding region	2.30	1	0.13	
	Partner/offspring care	Logit	Sex	0.07	1	0.80	0.01
			Breeding region	< 0.01	1	0.96	
			Sex × Breeding region	0.08	1	0.78	
Egg incubation	**Nest attendance**	**Logit**	Sex	123.44	1	< 0.001	**0.23**
			Breeding region	0.11	1	0.75	
			Sex × Breeding region	**9.32**	**1**	**< 0.01**	
	Vigilance	**Cauchit**	Sex	2.70	1	0.10	**0.11**
			Breeding region	0.30	1	0.58	
			Sex × Breeding region	**37.47**	**1**	**< 0.001**	
	Self-care	Cauchit	Sex	1.33	1	0.25	0.03
			Breeding region	4.53	1	0.03	
			Sex × Breeding region	4.31	1	0.04	
	Partner/offspring care	**Logit**	Sex	159.93	1	< 0.001	**0.30**
			Breeding region	2.45	1	0.12	
			Sex × Breeding region	**35.55**	**1**	**< 0.001**	
Chick rearing	**Nest attendance**	**Logit**	Sex	360.00	1	< 0.001	**0.10**
			Breeding region	0.02	1	0.88	
			Sex × Breeding region	**4.19**	**1**	**0.04**	
	Vigilance	Log	Sex	33.28	1	< 0.001	0.07
			Breeding region	3.08	1	0.08	
			Sex × Breeding region	5.21	1	0.02	
	Self-care	Cauchit	Sex	9.62	1	< 0.01	0.06
			Breeding region	0.84	1	0.36	
			Sex × Breeding region	9.20	1	< 0.01	
	Partner/offspring care	Log	Sex	81.20	1	< 0.001	0.08
			Breeding region	4.45	1	0.04	
			Sex × Breeding region	3.73	1	0.06	

Table A3. GLMMs testing the influence of sex and breeding region on the probability of occurrence of a series of behaviours during each of the three breeding stages. Different link functions were used depending on the model adjustment. Significant models (with at least one significant effect) explaining more than or equal to 10% of the variance (when all fixed terms are considered, R^2) are shown in bold.

[GLMM utilizados para comprobar la influencia de los factores sexo y área de cría en la probabilidad de aparición de diversos comportamientos en cada una de las tres fases de la cría. Se usaron diferentes funciones link en función del ajuste de los modelos. En negrita aparecen los modelos significativos (con al menos un factor significativo) que explicaban al menos 10% de la varianza (cuando todas las variables fijas son tenidas en cuenta, R^2).]

Stage	Response variable	Link function	Effect	χ^2	d.f.	P	R^2
Nest building	**Material delivery**	**Probit**	**Sex**	**14.90**	**1**	**< 0.001**	**0.10**
			Breeding region	0.03	1	0.97	
			Sex × Breeding region	< 0.001	1	0.98	
	Food delivery	**Logit**	**Sex**	**21.61**	**1**	**< 0.001**	**0.15**
			Breeding region	**10.36**	**1**	**0.001**	
			Sex × Breeding region	0.01	1	0.92	
	Empty trip	Probit	Sex	7.51	1	< 0.01	0.04
			Breeding region	0.57	1	0.45	
			Sex × Breeding region	0.74	1	0.39	
	Social interaction	**Logit**	**Sex**	**4.61**	**1**	**0.03**	**0.16**
			Breeding region	**10.10**	**1**	**0.001**	
			Sex × Breeding region	2.57	1	0.11	
Egg incubation	Material delivery	Logit	Sex	15.77	1	< 0.001	0.07
			Breeding region	4.10	1	0.04	
			Sex × Breeding region	1.01	1	0.32	
	Food delivery	Logit	Sex	13.10	1	< 0.001	0.04
			Breeding region	4.57	1	0.03	
			Sex × Breeding region	0.05	1	0.83	
	Empty trip	Cloglog	Sex	12.79	1	< 0.001	0.03
			Breeding region	0.40	1	0.53	
			Sex × Breeding region	3.00	1	0.08	
	Social interaction	Logit	Sex	57.34	1	< 0.001	0.06
			Breeding region	0.03	1	0.86	
			Sex × Breeding region	0.48	1	0.49	
Chick rearing	Material delivery	Logit	Sex	0.03	1	0.87	0.02
			Breeding region	5.06	1	0.03	
			Sex × Breeding region	2.66	1	0.10	
	Food delivery	Logit	Sex	3.23	1	0.07	0.03
			Breeding region	2.24	1	0.13	
			Sex × Breeding region	6.05	1	0.01	
	Empty trip	Logit	Sex	0.86	1	0.35	< 0.01
			Breeding region	< 0.01	1	0.95	
			Sex × Breeding region	0.07	1	0.78	
	Social interaction	Logit	Sex	36.07	1	< 0.001	0.03
			Breeding region	0.66	1	0.42	
			Sex × Breeding region	0.88	1	0.35	

Table A4. GLMMs testing the influence of sex and breeding region on the rate of a series of behaviours during each of the three breeding stages. Different link functions were used depending on the model adjustment. Significant models (with at least one significant effect) explaining more than or equal to 10% of the variance (when all fixed terms are considered, R^2) are shown in bold. A dash (-) indicates that no model was run (due to a small sample size or an unbalanced sample size among the factor levels).

[GLMM utilizados para comprobar la influencia de los factores sexo y área de cría en la tasa de diversos comportamientos en cada una de las tres fases de la cría. Se usaron diferentes funciones link en función del ajuste de los modelos. En negrita aparecen los modelos significativos (con al menos un factor significativo) que explicaban al menos 10% de la varianza (cuando todas las variables fijas son tenidas en cuenta, R^2). Un guion (-) indica que no pudo establecerse ningún modelo (debido al pequeño tamaño muestral o al desigualdad del tamaña muestral entre los diferentes niveles de un determinado factor).]

Stage	Response variable	Link function	Effect	χ^2	d.f.	P	R^2
Nest building	Material delivery	-	Sex	-	-	-	-
			Breeding region	-	-	-	
			Sex × Breeding region	-	-	-	
	Food delivery	-	Sex	-	-	-	-
			Breeding region	-	-	-	
			Sex × Breeding region	-	-	-	
	Empty trip	-	Sex	-	-	-	-
			Breeding region	-	-	-	
			Sex × Breeding region	-	-	-	
	Social interaction	-	Sex	-	-	-	-
			Breeding region	-	-	-	
			Sex × Breeding region	-	-	-	
Egg incubation	**Material delivery**	**Log**	Sex	1.69	1	0.19	**0.11**
			Breeding region	0.54	1	0.46	
			Sex × Breeding region	**13.32**	**1**	**< 0.001**	
	Food delivery	-	Sex	-	-	-	-
			Breeding region	-	-	-	
			Sex × Breeding region	-	-	-	
	Empty trip	Identity	Sex	0.93	1	0.33	0.02
			Breeding region	4.47	1	0.03	
			Sex × Breeding region	1.43	1	0.23	
	Social interaction	**Identity**	Sex	2.41	1	0.12	**0.12**
			Breeding region	**10.04**	**1**	**0.001**	
			Sex × Breeding region	0.02	1	0.89	
Chick rearing	**Material delivery**	**Square root**	Sex	38.95	1	< 0.001	**0.17**
			Breeding region	0.00	1	0.99	
			Sex × Breeding region	**16.53**	**1**	**< 0.001**	
	Food delivery	Log	Sex	1.21	1	0.27	0.08
			Breeding region	12.38	1	< 0.001	
			Sex × Breeding region	0.69	1	0.41	
	Empty trip	-	Sex	-	-	-	-
			Breeding region	-	-	-	
			Sex × Breeding region	-	-	-	
	Social interaction	-	Sex	-	-	-	-
			Breeding region	-	-	-	
			Sex × Breeding region	-	-	-	

Table A5. Mean estimates (± SE, based on estimated marginal means from GLMMs) for a series of behaviours displayed by Whiskered Terns throughout breeding. NB: nest-building stage, EI: egg-incubation stage, and CR: chick-rearing stage. Estimates are provided for various bird groups according to significant effects: F (females) and M (males) whatever the breeding region, B (Brenne) and GL (GLieu) whatever the sex, FB and MB (Females and Males from Brenne), and FGL and MGL (Females and Males from GLieu) in the case of a significant effect of the interaction term. The letters in brackets correspond to results of pairwise post-hoc comparisons when a significant effect of the interaction term occurs. The last column indicates whether the significant effects described here were retained (R, at least one significant effect with $R^2 \geq 0.10$), not retained (NR, at least one significant effect but $R^2 < 0.10$), whether no significant effect was found (NS, in this case, values are estimates resulting from the interaction term), and whether the candidate factors were not tested due to a small sample size or an unbalanced sample size among the factor levels (NT, a dash means that no estimate is provided for the behavioural variable).

[Estimaciones de las medias (± ES, basadas en las medias marginales estimadas en los GLMM) de los descriptores de los distintos comportamientos desplegados por los fumareles cariblancos a largo del periodo de cría. NB: fase de construcción del nido, EI: fase de incubación, y CR: fase de cría de los pollos). Se muestran los valores estimados para varios grupos de aves en función de factores significativos: F (hembras), y M (machos) para ambas áreas de cría, B (Brenne) y GL (GLieu) independientemente del sexo, FB y MB (hembras y machos respectivamente de Brenne), y FGL y MGL (hembras y machos respectivamente de GLieu) cuando la interacción de ambos factores fue significativa. Las letras entre paréntesis corresponden a los contrastes post-hoc cuando en los casos en los que la interacción entre ambos factores fue significativa. La última columna muestra si los efectos significativos descritos más arriba fueron considerados (R, al menos un efecto significativo con valor de $R^2 \geq 0,10$), no considerado (NR, al menos un efecto significativo pero el valor de $R^2 < 0,10$) si no se produjo un efecto significativo (NS, en este caso, se muestran los valores estimados del término de la interacción), cuando no se pudo comprobar el efecto de los factores debido al pequeño tamaño muestral o a las diferencias en el tamaño mistral entre los diferentes niveles de un determinado factor (NT, un guion indica no hay valor estimado para dicha variable comportamental).]

Descriptor	Behaviour	Stage	Whiskered Tern groups								Model relevance
			F	M	B	GL	FB	MB	FGL	MGL	
Duration	Nest attendance	NB	79 ± 2	39 ± 3							R
		EI					86 ± 2 (c)	43 ± 3 (a)	76 ± 3 (b)	51 ± 4 (a)	R
		CR					48 ± 3 (c)	23 ± 3 (a)	40 ± 6 (bc)	31 ± 5 (ab)	R
	Vigilance	NB	60 ± 2	24 ± 2							R
		EI					5 ± 1 (a)	11 ± 1 (bc)	12 ± 1 (c)	8 ± 1 (b)	R
		CR					27 ± 2 (b)	12 ± 2 (a)	14 ± 3 (a)	13 ± 3 (a)	NR
	Self-care	NB	16 ± 1	11 ± 1							NR
		EI					11 ± 1 (b)	12 ± 1 (b)	7 ± 1 (a)	10 ± 1 (ab)	NR
		CR					10 ± 1 (b)	4 ± 1 (a)	6 ± 1 (ab)	6 ± 1 (ab)	NR
	Partner/offspring care	NB					3 ± 3	2 ± 1	1 ± 1	3 ± 3	NS
		EI					77 ± 2 (d)	21 ± 2 (a)	54 ± 4 (c)	34 ± 4 (b)	R
		CR	11 ± 2	3 ± 1	4 ± 1	8 ± 2					NR

Table A5. Continued.

Descriptor	Behavioural variable	Stage	Whiskered Terns groups								Model relevance
			F	M	B	GL	FB	MB	FGL	MGL	
Probability	Material delivery	NB	0.04 ± 0.01	0.20 ± 0.01							R
		EI	0.09 ± 0.03	0.23 ± 0.06	0.19 ± 0.05	0.11 ± 0.04					NR
		CR			0.13 ± 0.03	0.24 ± 0.06					NR
	Food delivery	NB	0.01 ± 0.01	0.38 ± 0.05	0.02 ± 0.01	0.09 ± 0.04					R
		EI	0.02 ± 0.01	0.11 ± 0.02	0.03 ± 0.01	0.06 ± 0.02					NR
		CR					0.42 ± 0.05 (a)	0.59 ± 0.05 (b)	0.47 ± 0.08 (ab)	0.34 ± 0.07 (a)	NR
	Empty trip	NB	0.84 ± 0.04	0.70 ± 0.04							NR
		EI	0.49 ± 0.03	0.65 ± 0.03							NR
		CR					0.53 ± 0.06	0.48 ± 0.06	0.51 ± 0.09	0.49 ± 0.09	NS
	Social interaction	NB	0.02 ± 0.02	0.10 ± 0.06	0.01 ± 0.01	0.24 ± 0.12					R
		EI					< 0.01	< 0.01	< 0.01	< 0.01	NS
		CR					< 0.01	< 0.01	< 0.01	< 0.01	NS
Rate	Material delivery	NB	-	-	-	-	-	-	-	-	NT
		EI					3.9 ± 0.8 (b)	3.6 ± 0.7 (b)	0.9 ± 0.4 (a)	3.7 ± 0.9 (b)	R
		CR					3.6 ± 1.3 (ab)	6.1 ± 1.9 (bc)	0.7 ± 0.7 (a)	12.4 ± 2.9 (c)	R
	Food delivery	NB	-	-	-	-	-	-	-	-	NT
		EI	-	-	-	-	-	-	-	-	NT
		CR			1.8 ± 0.2	3.5 ± 0.5					NR
	Empty trip	NB	-	-	-	-	-	-	-	-	NT
		EI	2.2 ± 0.1	1.8 ± 0.1							NR
		CR	-	-	-	-	-	-	-	-	NT
	Social interaction	NB	-	-	-	-	-	-	-	-	NT
		EI			1.7 ± 0.2	2.7 ± 0.3					R
		CR	-	-	-	-	-	-	-	-	NT

REFERENCES

Coulson, J.C. (1963). Egg size and shape in the Kittiwake (*Rissa tridactyla*) and their use in estimating age composition of populations. *Proceedings of the Zoological Society of London*, 140: 211-227.

Paillisson, J.-M., Reeber, S., Carpentier, A. & Marion, L. (2007). Reproductive parameters in relation to food supply in the Whiskered Tern (*Chlidonias hybrida*). *Journal of Ornithology*, 148: 69-77.