SUPPORTING INFORMATION for

Nest initiation and flooding in response to season and semi-lunar spring tides in a ground-nesting shorebird

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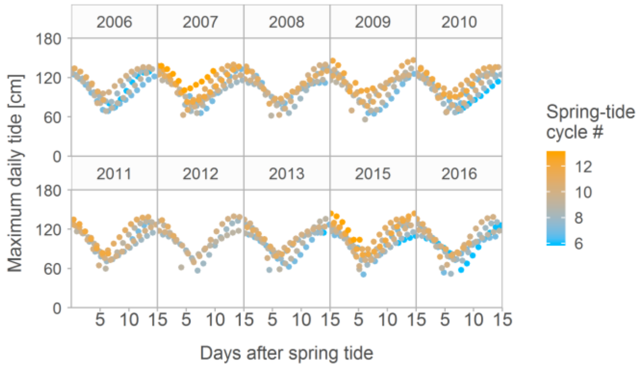

Figure S1 | Changes in the daily high tide levels at Ceuta, Mexico. Each point depicts one day and its color indicates spring tide cycle # (1 refers to the 1st spring tide cycle of the year). Depicted are only spring tide cycles for the breeding season (i.e. period between first and last initiated clutch in a given year). The tide height data were downloaded from mobilegeographics.com (see Methods for details).

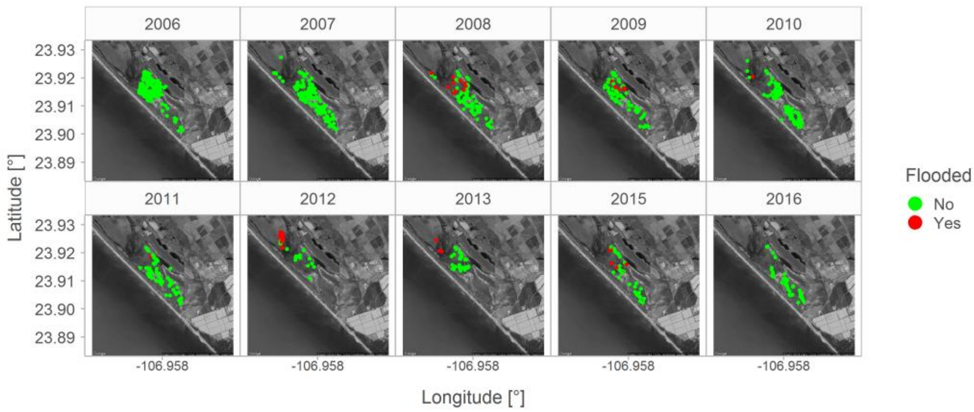

Figure S2 | Spatial variation in Snowy Plover nest locations and flooding across years at Ceuta, Mexico. Each point depicts one nest, its color indicates whether the nest was flooded (red) or not (green). The map was created with 'ggmap' R package (1).

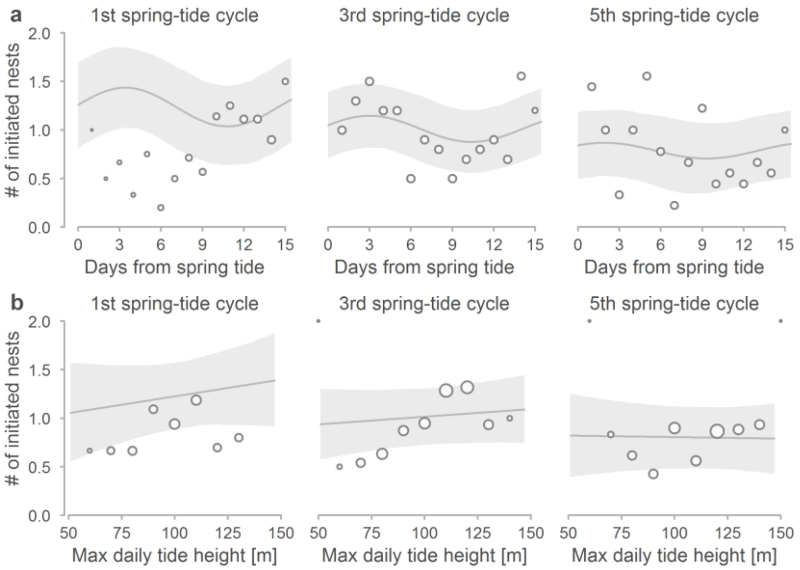

Figure S3 | Changes in the number of initiated Snowy Plover nests across the breeding season. Number of initiated nests over the breeding season (as indicated by spring tide cycle #) and over the spring tide cycle (**a**), or in relation to maximum daily high tide (**b**). Circles represent the mean number of initiated nests within each day of a spring tide cycle (**a**), and for each 10 m tide height interval (**b**). Circle size indicates number of years. The lines and the shaded areas represent model predictions with 95% CI based on a posterior distribution of 5,000 simulated values generated from 'complex Gaussian model' outputs (Table S2 and S3) using the 'sim' function in R (2). *N* = 776 days from ten breeding seasons encompassing 62 spring tide cycles.

Table S1 | Nest flooding in relation to nest initiation day during the semi-lunar spring tide cycle.

Model	Response variable	Effect type	Effect	Estimate	95% CI Lower	95% CI Upper
Gaussian	Flooded	Fixed	Intercept	0.155	-0.005	0.317
	(0 = no, 1 = yes)		Nest latitude	-0.078	-0.099	-0.055
			Spring tide cycle number	0.164	0.052	0.275
			Cos (Day of spring tide cycle)	-0.01	-0.038	0.017
			Sin (Day of spring tide cycle)	-0.03	-0.058	-0.002
		Random	Female ID (intercept)	1 %		
		(variance)	Year (intercept)	17 %		
			Spring tide cycle number (intercept)	33 %		
			Residual	49 %		
Binomial	Flooded	Fixed	Intercept	-9.3	-13.4	-5.2
	(0 = no, 1 = yes)		Nest latitude	-2.8	-4.4	-1.2
			Spring tide cycle number	4.9	3	6.9
			Cos (Day of spring tide cycle)	-0.7	-1.8	0.4
			Sin (Day of spring tide cycle)	-1.2	-2.2	-0.1
		Random	Year (intercept)	100 %		
			Spring tide cycle number (intercept)	0 %		

The posterior estimates (medians) of the effect sizes with the 95% Cis derived from a posterior distribution of 5,000 simulated values generated by the 'sim' function in R. Variance components were estimated by the 'lmer' function in R (3). To account for non-independence of data points, 'Female ID', 'Year' and 'Spring tide cycle number' within the breeding season (i.e. time within the breeding season) were fitted as random intercepts. 'Spring tide cycle number' is standardized within the year so that the first spring tide cycle in the given year corresponds to the cycle when the first nest was initiated. This variable, as well as 'Nest latitude', were z-transformed (mean-centred and divided by standard deviation). 'Day of spring tide cycle' was transformed to radians (2 * number of days after the last spring tide * π / length of the given spring tide cycle [~14.75]) and fitted as sine and cosine of radians. Note that despite violating some model assumptions our 'Gaussian model' fits the data better and, unlike our 'Binomial model', also accounts for spatial auto-correlation in residuals. The 'Binomial model' lacks female identity as random intercept because model with female identity did not converge.

N = 476 nests (413 hatched, 20 unhatched, 43 flooded) initiated by 266 females over 10 years and 6 spring tide cycles. As the 7th cycle contained only one nest, we assigned this nest to the 6th cycle.

Table S2 | Nest initiation within the spring tide cycle.

Model	Response variable	Effect type	Effect	Estimate	95% CI Lower	95% CI Upper
Gaussian complex	# of initiated nests (count)	Fixed	Intercept	0.943	0.64	1.247
			Spring tide cycle number	-0.195	-0.325	-0.065
			Cos (Day of spring tide cycle)	0.105	0.002	0.208
			Sin (Day of spring tide cycle)	0.043	-0.09	0.174
			Cos × Spring tide cycle	-0.06	-0.163	0.041
			Sin × Spring tide cycle	0.016	-0.122	0.147
		Random (variance)	First or second half : Spring tide cycle : Year (intercept)	9 %		
			Spring tide cycle : Year (intercept)	7 %		
			Year (intercept)	13 %		
			Residual	71 %		
Gaussian simple	# of initiated nests (count)	Fixed	Intercept	1.349	0.954	1.747
			Spring tide cycle number	-0.11	-0.188	-0.034
			Cos (Day of spring tide cycle)	0.104	0.001	0.211
			Sin (Day of spring tide cycle)	0.04	-0.098	0.17
		Random (variance)	First or second half : Spring tide cycle : Year (intercept)	9 %		
			Spring tide cycle : Year (intercept)	7 %		
			Year (intercept)	13 %		
			Residual	72 %		
Poisson complex	# of initiated nests (count)	Fixed	Intercept	-0.302	-0.591	-0.02
			Spring tide cycle number	-0.236	-0.375	-0.105
			Cos (Day of spring tide cycle)	0.096	-0.016	0.202
			Sin (Day of spring tide cycle)	0.038	-0.103	0.176
			Cos × Spring tide cycle	-0.048	-0.168	0.069
			Sin × Spring tide cycle	0.019	-0.127	0.168
		Random (variance)	Observation (intercept)	12 %		
			First or second half : Spring tide cycle : Year (intercept)	29 %		
			Spring tide cycle : Year (intercept)	19 %		
			Year (intercept)	40 %		
Poisson simple	# of initiated nests (count)	Fixed	Intercept	0.205	-0.193	0.575
			Spring tide cycle number	-0.138	-0.216	-0.059
			Cos (Day of spring tide cycle)	0.033	-0.114	0.171
			Sin (Day of spring tide cycle)	0.108	0.002	0.214
		Random (variance)	Observation (intercept)	12 %		
			First or second half : Spring tide cycle : Year (intercept)	30 %		
			Spring tide cycle : Year (intercept)	19 %		
			Year (intercept)	40 %		

The posterior estimates (medians) of the effect sizes with the 95% credible intervals (CI) derived from a posterior distribution of 5,000 simulated values generated by the 'sim' function in R. Variance components were estimated by the 'lmer' function in R. To account for non-independence of data points 'Year', 'Spring tide cycle number' within year and indication whether the nest was initiated in the 'First or Second half' of the spring tide cycle where fitted as random intercepts. Overdispersion was modelled by adding 'Observation' level as random intercept. 'Spring tide cycle number' is standardized within the year so that first spring tide cycle in the given year corresponds to the cycle when the first nest was initiated. 'Day of spring tide cycle' was transformed to radians (2 * number of days after the last spring tide * π / length of the given spring tide cycle [~14.75]) and fitted as sine and cosine of radians.
N = 776 days from 10 years encompassing 62 spring tide cycles.

Table S3 | Nest initiation according to maximum daily tide height.

Model	Response variable	Effect type	Effect	Estimate	95% CI Lower	95% CI Upper
Gaussian complex	# of initiated nests (count)	Fixed	Intercept	0.952	0.647	1.242
			Spring tide cycle number	-0.192	-0.325	-0.061
			Maximum daily tide height	0.033	-0.044	0.113
			Maximum daily tide height × Spring tide cycle	-0.028	-0.107	0.052
		Random (variance)	First or second half : Spring tide cycle : Year (intercept)	9 %		
			Spring tide cycle : Year (intercept)	7 %		
			Year (intercept)	12 %		
			Residual	72 %		
Gaussian simple	# of initiated nests (count)	Fixed	Intercept	0.945	0.65	1.23
			Spring tide cycle number	-0.193	-0.321	-0.063
			Maximum daily tide height	0.036	-0.042	0.113
		Random (variance)	First or second half : Spring tide cycle : Year (intercept)	9 %		
			Spring tide cycle : Year (intercept)	7 %		
			Year (intercept)	12 %		
			Residual	72 %		
Poisson complex	# of initiated nests (count)	Fixed	Intercept	-0.297	-0.586	-0.009
			Spring tide cycle number	-0.237	-0.37	-0.102
			Maximum daily tide height	0.029	-0.055	0.115
			Maximum daily tide height × Spring tide cycle	-0.033	-0.121	0.059
		Random (variance)	Observation (intercept)	13 %		
			First or second half : Spring tide cycle : Year (intercept)	30 %		
			Spring tide cycle : Year (intercept)	19 %		
			Year (intercept)	38 %		
Poisson simple	# of initiated nests (count)	Fixed	Intercept	-0.3	-0.589	-0.032
			Spring tide cycle number	-0.237	-0.378	-0.109
			Maximum daily tide height	0.037	-0.044	0.116
		Random (variance)	Observation (intercept)	13 %		
			First or second half : Spring tide cycle : Year (intercept)	30 %		
			Spring tide cycle : Year (intercept)	19 %		
			Year (intercept)	38 %		

The posterior estimates (medians) of the effect sizes with the 95% CIs derived from a posterior distribution of 5,000 simulated values generated by the 'sim' function in R. Variance components were estimated by the 'lmer' function in R. To account for non-independence of data points 'Year', 'Spring tide cycle number' within year and indication whether the nest was initiated in the 'First or Second half' of the spring tide cycle where fitted as random intercepts. Overdispersion was modelled by adding 'Observation' level random intercept. 'Spring tide cycle number' is standardized within the year so that first spring tide cycle in the given year corresponds to the cycle when the first nest was initiated. 'Day of spring tide cycle' was transformed to radians (2 * number of days after the last spring tide * π / length of the given spring tide cycle [~14.75]) and fitted as sine and cosine of radians. Note that despite violating model assumptions our 'Gaussian model' fits the data better and unlike our 'Binomial model' also accounts for spatial auto-correlation in residuals.
N = 776 days from 10 years encompassing 62 spring tide cycles.

References

1. Kahle D, Wickham H. Spatial visualization with ggplot2. The R Journal. 2013;5(1):144-61.
2. Gelman A, Su Y. arm: Data analysis using regression and multilevel/hierarchical models [Online]. R package version 1.8-6. 2015.
3. Bates D, Mächler M, Bolker B, Walker S. Fitting Linear Mixed-Effects Models using lme4. 2015. 2015;67(1):48.