Appendix: **Variation In Shape And Consistency Of Selection Between Populations Of The New Zealand Hihi.**

Supplementary Information 1: Descriptions of the breeding dataset.

Note that the number of breeding attempts also correspond to the number of females reproducing each year as all clutches from a same female are considered as a combined annual breeding attempt (see main manuscript). A breeding attempt value of e.g., 15 therefore means that 15 females tried to reproduce at least once.

Table S.1. Breeding attempts recorded each year

	Tiritiri Mātangi	Kārori
Year	Number of breeding attempts	Number of breeding attempts
1997	14	NA
1998	12	NA
1999	17	NA
2000	26	NA
2001	32	NA
2002	30	NA
2003	42	NA
2004	52	NA
2005	53	17
2006	64	15
2007	63	12
2008	70	18
2009	77	16
2010	94	18
2011	64	20
2012	75	13
2013	55	17
2014	53	27
2015	51	32
2016	62	25
2017	54	26
2018	67	19
2019	77	13

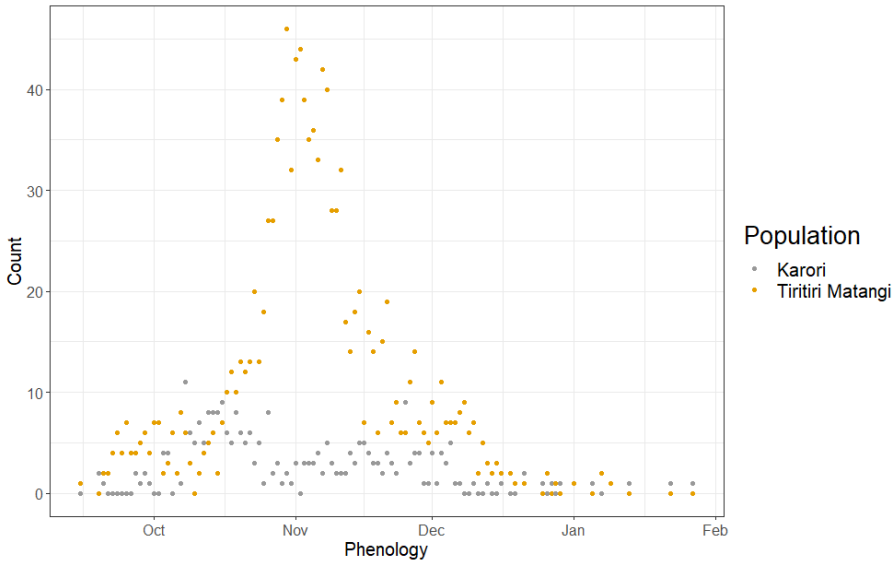

Fig.S.1.a. Number of laying events per date across the years in Tiritiri Mātangi and Kārori hihi populations.

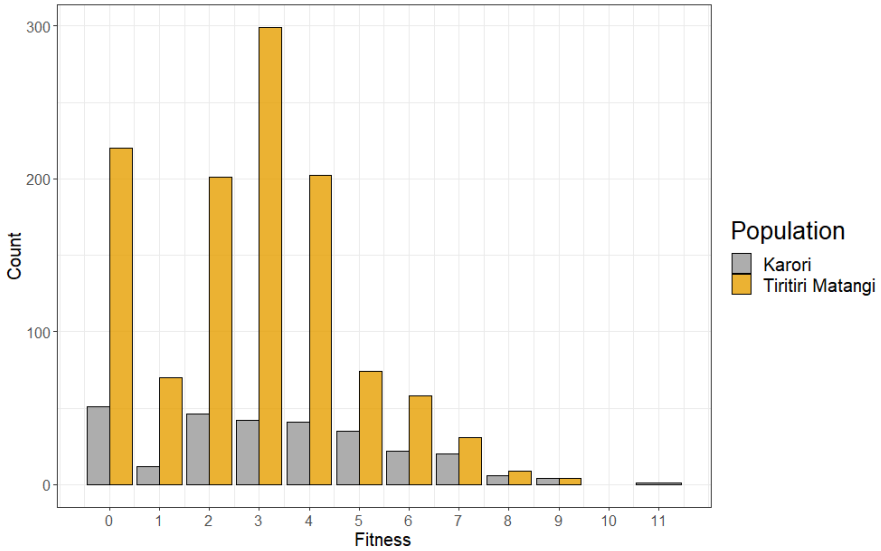

Fig.S.1.b. Fitness (calculated as the number of fledglings produced by each female over one season) in Tiritiri Mātangi and Kārori populations. In both populations, fitness data follow zero-inflated Poisson distributions.

Supplementary Information 2: Power analysis for Kārori

Table S.2: Relative support for models of selection after subsampling the Tiritiri Mātangi dataset. Support is averaged across 10 subsamples of the Tiritiri Mātangi dataset.

Selection model	Relative support (standard error)
ConstOpt	0.193 (0.041)
FluctDir	0.185 (0.051)
FluctCorrDir	0.182 (0.047)
NoSel	0.162 (0.063)
FluctCorrOpt	0.116 (0.024)
FluctOpt	0.109 (0.023)
ConstDir	0.051 (0.012)

With a smaller number of individuals in Kārori (n=168) compared to Tiritiri Mātangi (n=804), models may lack power to distinguish between selective regimes. To test this, we sub-sampled the Tiritiri Mātangi lay date dataset (total number of breeding attempts= 1204) to match the Kārori sample size (total number of breeding attempts = 606), and tested the fit of all models to this dataset.

The support for each model was computed by transforming the LOOIC in model weight in a similar fashion to Akaike weight, i.e.:

$$w_i = \exp(-0.5 * \Delta\text{LOOIC\_i}) \,/\, \text{sum}(\exp(-0.5 * \Delta\text{LOOIC})).$$

Across 10 replicate samples, we found comparable support for all models of directional (42%) or stabilizing selection (42%), the model with no selection receiving the lowest support (16%) (See Table S2). We hypothesise that model fitting is sensitive to the random presence or absence of early reproductions in the dataset, hence smaller sample sizes do not correctly represent the reality of the Tiritiri Mātangi dataset and fail to detect trends observed with the full dataset (See Fig.S2).

In contrast to Kārori (Fig.S1), a close examination of the predicted shape of the models clearly suggests the presence of an optimum (Fig.S2, right panel), and not directional selection (Fig.S1, left panel).

Overall, these analyses suggest that the sample size for Kārori is well-powered to detect directional selection when present.

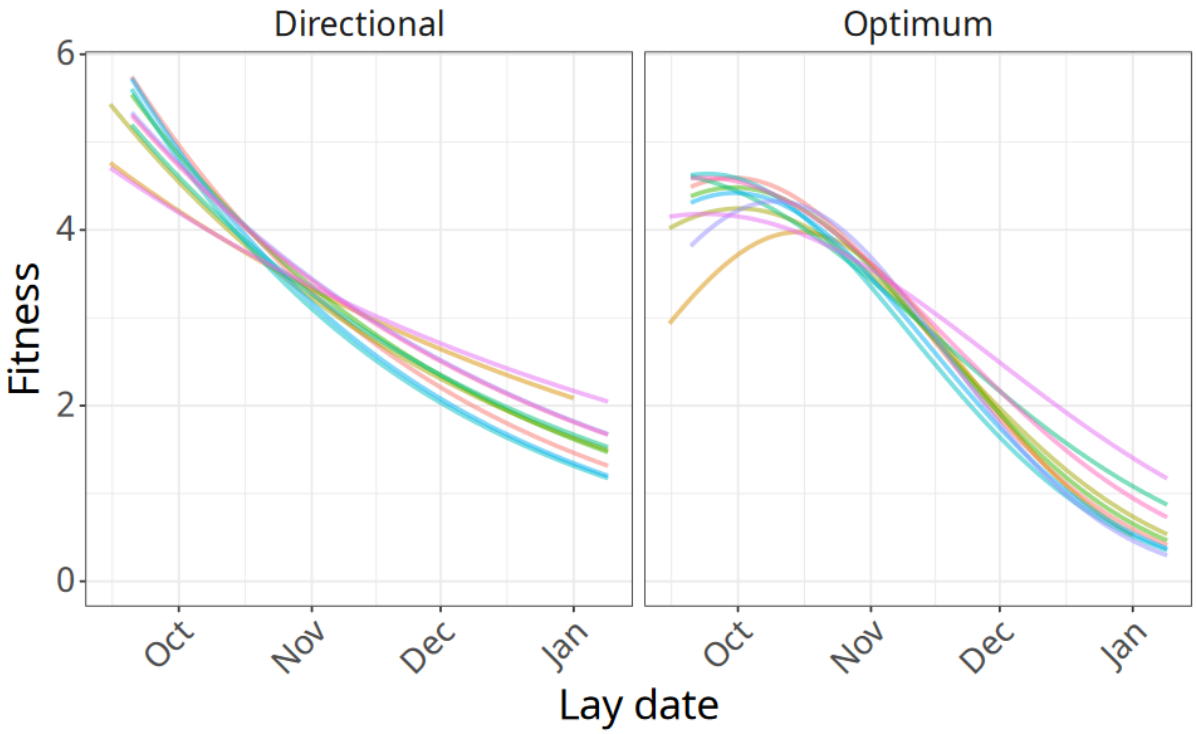

Figure S.2.a: comparison of directional (ConstDir) and optimum (ConstOpt) models in a Tiritiri Mātangi dataset sampled to the same size as Kārori. Each colour represents one of the ten sub-samples.

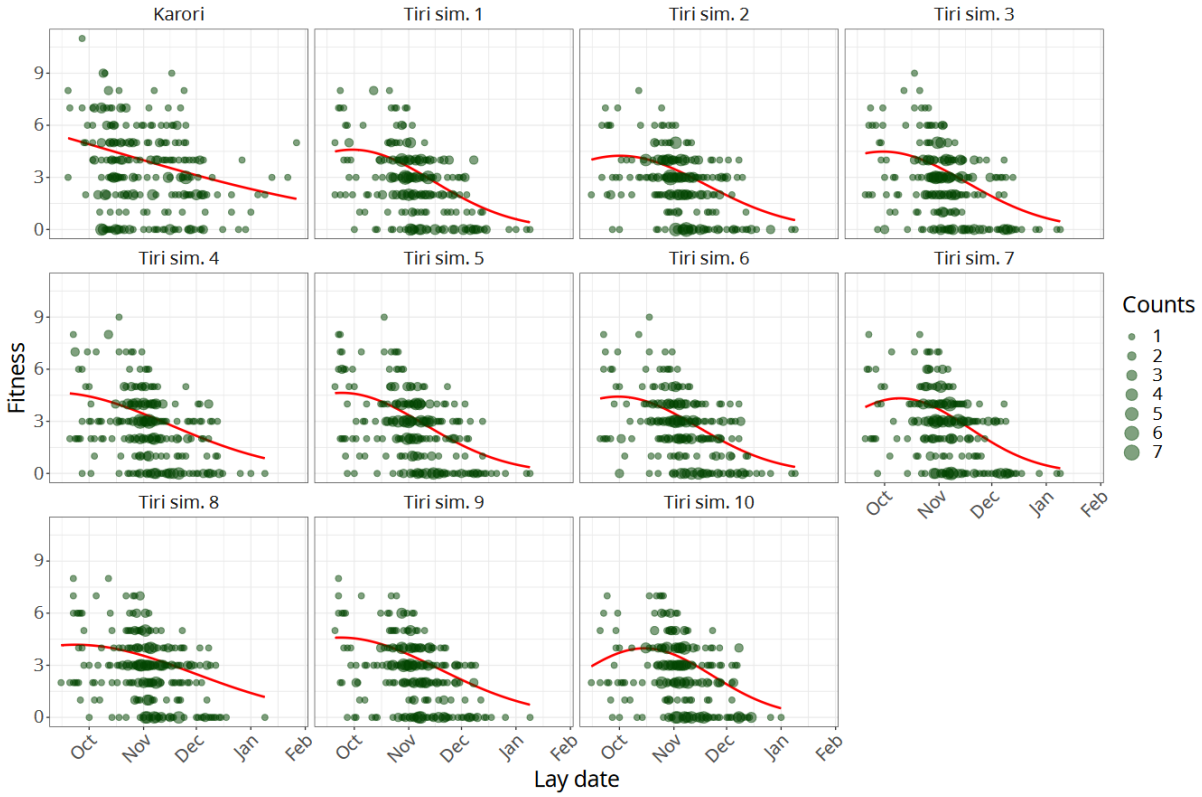

Figure S.2.b – Graphical results of the power analyses. We found support for directional selection in the Kārori population (top left panel) where both the *Dir.* (not represented here) and the *Opt.* models (red curve) are characterized by a linear trend. In contrast, although stabilizing selection was the best supported model in only half of the simulations performed in our power analyses (panels 2 to 11), all the *Opt.* models for sub-sampled Tiritiri Matangi datasets (red curves) display an optimum shape (i.e., a peak). These two findings provide reassurance for the results found for Kārori.

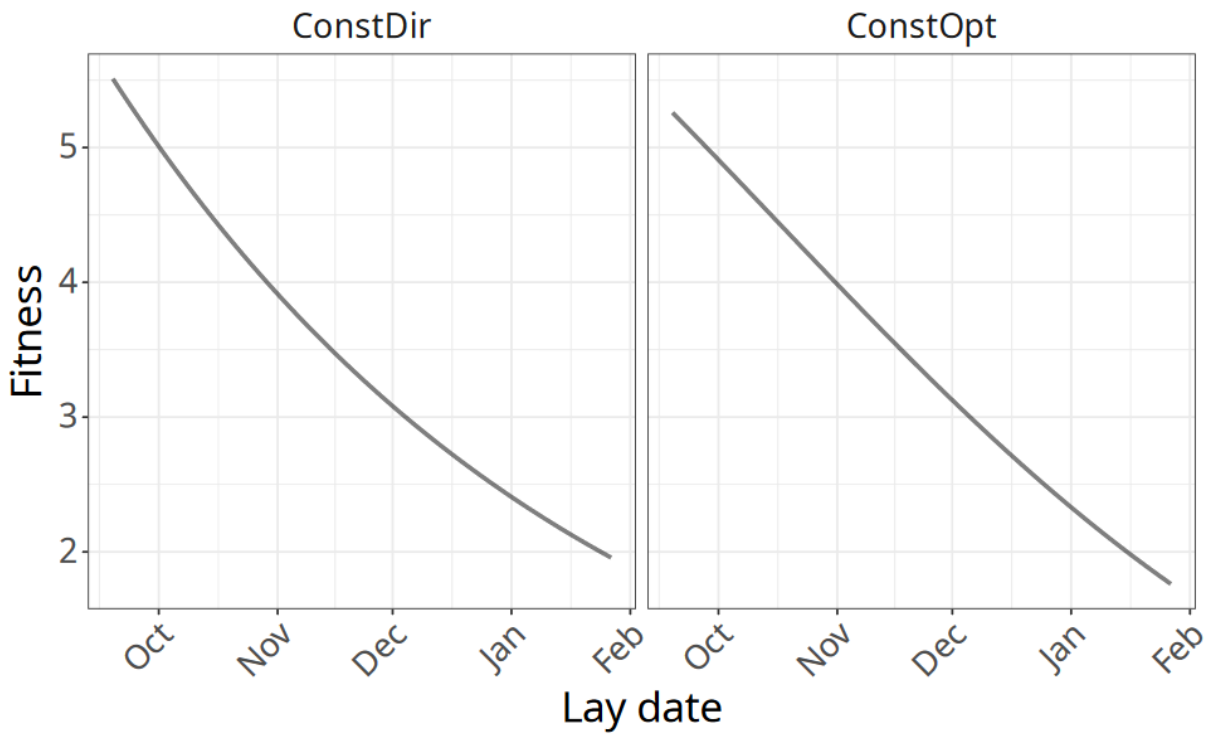

Figure S.2.c: comparison of directional (ConstDir) and optimum (ConstOpt) models in Kārori

In the Kārori population, our results provide mixed support for the shape of the election the shape of selection (stabilizing vs directional; See Table 1). However, a closer comparison of the directional model (ConstDir) and the model with an optimum (ConstOpt) reveals that the inferred shape is also largely directional (no clear optimum is visible), and very similar to the purely directional model, providing support for directional selection.

Supplementary Information 3: Models Estimates

See Tables S3.a-c for Tiritiri Mātangi models and Tables S3.d-f for Kārori.

a.

	Tiritiri Mātangi – No selection					
No Selection	NoSel					
	Parameter	Median	Mode	SE	Low	Up
	Intercept	1.29	1.28	0.0415	1.2	1.36
	St. Dev. Of the intercept	0.143	0.133	0.0374	0.0785	0.223
	Female identity	0.129	0.12	0.0402	0.0347	0.198
	Young	-0.408	-0.397	0.0461	-0.498	-0.315
	Old	-0.489	-0.474	0.125	-0.745	-0.258
	Probability of ZI values (p_{zi})	0.125	0.121	0.0132	0.0999	0.152

b.

directional selection	Tiritiri Mātangi –**ConstDir**					
	Parameter	Median	Mode	SE	Low	Up
	Intercept	1.17	1.16	0.0366	1.09	1.24
	St. Dev. Of the intercept	0.0979	0.093	0.0341	0.0333	0.169
	Slope (b)	-0.202	-0.2	0.0212	-0.247	-0.163
	Female identity	0.0833	0.0918	0.0414	9.09e-4	0.149
	Young	-0.268	-0.253	0.047	-0.359	-0.175
	Old	-0.363	-0.351	0.119	-0.606	-0.139
	Probability of ZI values (p_{zi})	0.0997	0.098	0.0134	0.0747	0.126
	Tiritiri Mātangi – F**luctdir**					
	Parameter	Median	Mode	SE	Low	Up
	Intercept	1.16	1.15	0.0353	1.09	1.23
	St. Dev. Of the intercept	0.0795	0.0823	0.0372	6.4e-4	0.142
	Slope (b)	-0.247	-0.253	0.0388	-0.327	-0.176
	St. Dev. Of the slope (σb)	0.133	0.129	0.0353	0.0702	0.208
	Female identity	0.0787	0.061	0.0415	3.18e-5	0.146
	Young	-0.258	-0.262	0.0468	-0.347	-0.165
	Old	-0.364	-0.376	0.118	-0.603	-0.146
	Probability of ZI values (p_{zi})	0.0927	0.0928	0.0132	0.0668	0.118
	Tiritiri Mātangi – F**luctcorrdir**					
	Parameter	Median	Mode	SE	Low	Up
	Intercept	1.16	1.15	0.035	1.08	1.22
	St. Dev. Of the intercept	0.0791	0.0698	0.036	0.00425	0.144
	Slope (b)	-0.249	-0.243	0.032	-0.311	-0.184
	St. Dev. Of the slope (σb)	0.138	0.126	0.0545	0.06	0.247
	Auto-correlation (ϕ)	-0.551	-0.658	0.247	-0.95	-0.0407
	Female identity	0.0776	0.0899	0.0413	3.82e-5	0.145

	Young	-0.256	-0.273	0.0481	-0.354	-0.166
	Old	-0.364	-0.331	0.116	-0.599	-0.147
	Probability of ZI values (p_{zi})	0.0921	0.0959	0.0132	0.0664	0.118

c.

stabilizing section						
	Tiritiri Mātangi – **ConstOpt**					
	Parameter	Median	Mode	SE	Low	Up
	Intercept	1.51	1.51	0.0532	1.41	1.62
	St. Dev. Of the intercept	0.0958	0.0798	0.033	0.0344	0.167
	Omega (ω)	2.83	2.7	0.274	2.39	3.41
	Theta (Θ)	-2.13	-2.02	0.38	-2.93	-1.56
	Female identity	0.0886	0.104	0.0426	5.42e-5	0.154
	Young	-0.268	-0.255	0.0469	-0.36	-0.179
	Old	-0.38	-0.417	0.12	-0.611	-0.142
	Probability of ZI values (p_{zi})	0.0883	0.0862	0.0124	0.0635	0.111
	Tiritiri Mātangi – **FluctOpt**					
	Parameter	Median	Mode	SE	Low	Up
	Intercept	1.5	1.5	0.0435	1.42	1.59
	St. Dev. Of the intercept	0.0737	0.073	0.0396	2.62e-5	0.143
	Omega (ω)	2.47	2.37	0.249	2.06	2.97
	Theta (Θ)	-1.81	-1.73	0.308	-2.42	-1.26
	St. Dev of theta (σΘ)	0.404	0.376	0.142	0.139	0.708
	Female identity	0.0904	0.0997	0.0425	6.6e-4	0.155
	Young	-0.266	-0.281	0.0471	-0.36	-0.178
	Old	-0.371	-0.355	0.115	-0.599	-0.146
	Probability of ZI values (p_{zi})	0.0828	0.0826	0.013	0.0574	0.109
	Tiritiri Mātangi – **FluctCorrOpt**					
	Parameter	Median	Mode	SE	Low	Up
	Intercept	1.49	1.5	0.0441	1.41	1.58
	St. Dev. Of the intercept	0.0831	0.0909	0.0405	2.42e-4	0.152
	Omega (ω)	2.4	2.38	0.223	2.01	2.86
	Theta (Θ)	-1.75	-1.7	0.268	-2.28	-1.28
	St. Dev of theta (σΘ)	0.445	0.452	0.221	0.0889	0.879
	Auto-correlation (ϕ)	-0.564	-0.583	0.324	-0.985	0.126
	Female identity	0.0911	0.088	0.0419	0.00157	0.156
	Young	-0.266	-0.259	0.0465	-0.351	-0.173
	Old	-0.37	-0.358	0.116	-0.609	-0.163
	Probability of ZI values (p_{zi})	0.0822	0.084	0.0126	0.0599	0.109

d.

	Kārori - **NoSel**					
No Selection	NoSel					
	Parameter	Median	Mode	SE	Low	Up
	Intercept	1.39	1.41	0.076	1.24	1.54
	St. Dev. Of the intercept	0.167	0.167	0.0755	0.00605	0.304
	Female identity	0.189	0.196	0.0637	0.0531	0.309
	Young	-0.0734	-0.0764	0.0818	-0.228	0.0873
	Old	-0.432	-0.463	0.488	-1.41	0.453
	Probability of ZI values (p_{zi})	0.157	0.154	0.0245	0.114	0.21

e.

directional selection	Kārori – **ConstDir**					
	Parameter	Median	Mode	SE	Low	Up
	Intercept	1.36	1.35	0.0604	1.25	1.48
	St. Dev. of the intercept	0.0685	0.0233	0.0535	6.20E-06	0.174
	Slope (b)	-0.151	-0.15	0.0343	-0.22	-0.0852
	Female identity	0.168	0.178	0.0625	0.031	0.281
	Young	-0.039	-0.023	0.0759	-0.187	0.11
	Old	-0.501	-0.51	0.495	-1.52	0.403
	Probability of ZI values (p_{zi})	0.157	0.155	0.0246	0.109	0.204
	Kārori – F**luctdir**					
	Parameter	Median	Mode	SE	Low	Up
	Intercept	1.37	1.37	0.0604	1.24	1.48
	St. Dev. Of the intercept	0.0618	0.00747	0.0508	2.49E-04	0.166
	Slope (b)	-0.15	-0.144	0.0376	-0.223	-0.0745
	St. Dev. Of the slope (σb)	0.0449	0.00683	0.0394	8.58E-05	0.125
	Female identity	0.168	0.189	0.0613	0.0326	0.275
	Young	-0.0528	-0.0365	0.0769	-0.204	0.0941
	Old	-0.53	-0.328	0.494	-1.51	0.374
	Probability of ZI values (p_{zi})	0.157	0.161	0.0243	0.109	0.205
	Kārori – F**luctcorrdir**					
	Parameter	Median	Mode	SE	Low	Up
	Intercept	1.37	1.37	0.0597	1.25	1.48
	St. Dev. Of the intercept	0.0607	0.0428	0.052	2.95E-05	0.167
	Slope (b)	-0.151	-0.161	0.0411	-0.223	-0.0677
	St. Dev. Of the slope (σb)	0.0448	0.00208	0.0467	5.98E-05	0.14
	Auto-correlation (ϕ)	-0.224	-0.541	0.479	-0.967	0.672
	Female identity	0.169	0.19	0.0618	0.0281	0.274
	Young	-0.053	-0.0298	0.0771	-0.203	0.0957
	Old	-0.515	-0.399	0.485	-1.48	0.371
	Probability of ZI values (p_{zi})	0.157	0.158	0.0237	0.112	0.203

f.

stabilizing selection

Kārori – **ConstOpt**

Parameter	Median	Mode	SE	Low	Up
Intercept	2.04	1.75	0.795	1.35	3.85
St. Dev. Of the intercept	0.0694	0.0425	0.0563	3.21E-05	0.182
Omega (ω)	7.98	7.54	2.7	4	13.8
Theta (Θ)	-9.08	-5.53	8.71	-28.8	-1.09
Female identity	0.167	0.189	0.063	0.0221	0.276
Young	-0.0384	-0.0133	0.0758	-0.197	0.0993
Old	-0.518	-0.471	0.482	-1.54	0.328
Probability of ZI values (p_{zi})	0.158	0.166	0.0242	0.114	0.207

Kārori – **FluctOpt**

Parameter	Median	Mode	SE	Low	Up
Intercept	1.87	1.67	0.599	1.38	3.16
St. Dev. Of the intercept	0.0676	0.0266	0.058	9.86E-06	0.185
Omega (ω)	7.35	6.99	2.46	3.61	12.7
Theta (Θ)	-7.14	-5.37	6.83	-22.4	-0.889
St. Dev of theta (σΘ)	0.412	0.0795	0.476	4.26E-05	1.44
Female identity	0.165	0.169	0.0638	0.018	0.271
Young	-0.0461	-0.0529	0.0764	-0.189	0.104
Old	-0.489	-0.282	0.487	-1.54	0.365
Probability of ZI values (p_{zi})	0.156	0.156	0.0238	0.111	0.205

Kārori – **FluctCorrOpt**

Parameter	Median	Mode	SE	Low	Up
Intercept	1.88	1.64	0.589	1.4	3.3
St. Dev. Of the intercept	0.0723	0.00236	0.0586	7.40E-05	0.19
Omega (ω)	7.46	6.78	2.47	3.97	12.9
Theta (Θ)	-7.32	-4.61	6.85	-23.4	-0.962
St. Dev of theta (σΘ)	0.427	0.0373	0.56	3.25E-04	1.62
Auto-correlation (ϕ)	-0.198	-0.584	0.465	-0.968	0.67
Female identity	0.164	0.153	0.0622	0.0306	0.279
Young	-0.0491	-0.0272	0.0776	-0.196	0.105
Old	-0.521	-0.365	0.489	-1.55	0.358
Probability of ZI values (p_{zi})	0.158	0.16	0.0243	0.109	0.206

Supplementary Information 4: Comparison of Tiritiri Mātangi and Kārori's environments.

Tiritiri Mātangi sanctuary is located on an offshore island in Tikipa Moana / Hauraki Gulf (36°36'8"S, 174°53'13"E), a sub-tropical climatic zone. The Kārori population is located in Zealandia urban eco-sanctuary, within Wellington city (41°17'26"S, 174°45'10"E). This region is exposed to Cook Strait meteorological conditions and, compared to Tiritiri Mātangi is situated within an oceanic climatic zone. To describe the average environmental conditions prior to breeding, we first calculated the grand mean of the start of the breeding season across years in each population. We then compared the average ambient temperature and amount of precipitation recorded over the 35 days prior to this date (See Supplementary Information 5 for a justification of this timing). Data were downloaded from the New Zealand National Climate Database (https://cliflo.niwa.co.nz; "Tiritiri Mātangi Lighthouse" and "Wellington, Kelburn Aws" stations for Tiritiri Mātangi and Kārori, respectively).

Student tests revealed a significant difference between the average temperature recorded over the 30 days before the grand mean start of the breeding season, Tiritiri Mātangi habitat being approximately 20% warmer than Kārori (Tiritiri Mātangi: 17.21 ± 0.46°C Kārori: 14.49 ± 0.71 °C; $t_{24.31}$=-12.3; p-value < 0.001; Fig.S.6). Similarly, we found a significant difference in the amount of precipitation, Tiritiri Mātangi being almost 70% drier than Kārori (Tiritiri Mātangi: 78.37 ± 25.06 mm; Kārori: 131.73 ± 61.25 mm; $t_{24.36}$=-12.3; $t_{18.21}$=3.11; p-value = 0.006; Fig.S3.c).

Interestingly, the minimum temperatures recorded in Tiritiri seems to be always warmer than the warmest temperatures recorded in Kārori. This difference could be explained by the latitude difference between both populations (more than 500km separates them, See Fig.1 of the main manuscript). Also note that Tiritiri Mātangi Island is located in Hauraki Gulf, while Zealandia Sanctuary (hosting the Kārori population) is located in a valley within Wellington and exposed to the Cook Strait climatic conditions.

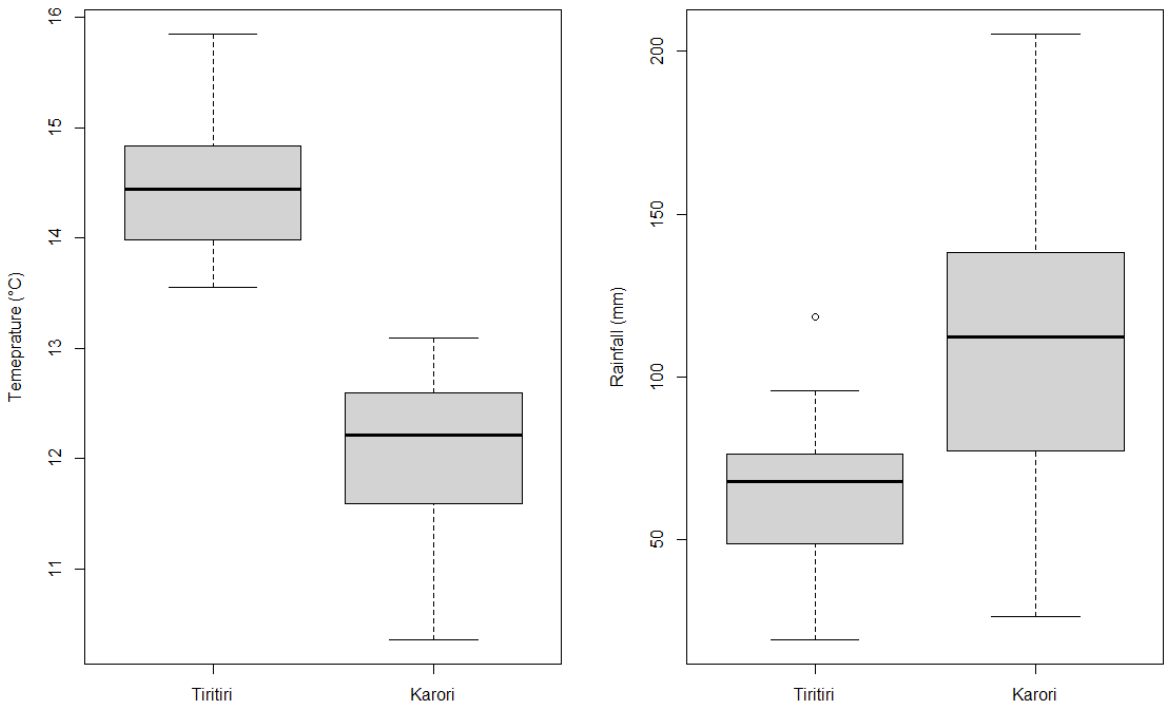

Fig.S.4 Comparison of average temperature and rainfall amount between Tiritiri Mātangi and Kārori. Both temperatures (left panel) and rainfall amounts (right panel) are recorded during a 30 days' time-window preceding the average start of the breeding season.

Supplementary Information 5: Relationship between environmental conditions and laying date in the hihi

To check the existence of phenotypic plasticity in laying date in response to environmental cues, we explored the relationship between different parameters of environmental conditions and the start of the breeding season. More specifically, we used a sliding-window method to test temperature and precipitation as potential cues for the start of breeding season (Brommer, Rattiste, & Wilson, 2008). For each site, the grand mean of the start of the breeding season across years was correlated to the average ambient temperature and amount of precipitation recorded over twelve temporal windows preceding the start of the breeding season (ranging from 5 to 60 days, with an increment of five days). Data were downloaded from the New Zealand National Climate Database (https://cliflo.niwa.co.nz).

1. Tiritiri Mātangi

Unfortunately, the weather forecast was only recorded on the island until 2010 and after 2015 (Tiritiri Mātangi Lighthouse Station), as the station was closed for several years. As a consequence, we could only use the data for 18 seasons (from 1997 to 2010 and 2016 to 2020), the next closest station (Whangaparaoa Aws) being situating on the mainland, 5.8 km away.

First, for each time window, we performed a linear regression between the environmental cue (Temperature (T) and Rainfall (RF)) recorded over the specific time window and the annual average date of breeding season. Second, in an attempt to better understand the relationship between temperature and rainfall, we also performed a linear regression between the two parameters. Because we performed multiple tests, we used a Bonferroni correction to take into account the probability to reject the null hypothesis by chance. Specifically, as we used twelve time-windows (and therefore performed twelve tests on each data sets), we chose a significance cut-off for the p-value at 0.004 (0.05/12). Model coefficients and p-values are reported in Table S5.a.

Our results suggest a clear association between temperature and the start of the breeding season (see Figure S5.a), the warmer the period (and the longer the warm period) before the grand mean of the start of the breeding season across years, the earlier the start of the season. This result is not surprising and was already found by de Villemereuil et al. (2019). We found no support for a relationship between the start of the breeding season and the amount of precipitation, and temperature and precipitations seem uncorrelated in this population.

Table S5.a Relationship between start of the breeding season and Temperature or Rainfall in Tiritiri Mātangi. Provided are the coefficients and p-value of linear regressions between the start of the breeding season and Temperature (T) or rainfall (RF) recorded over twelve temporal windows. After Bonferroni correction, significant p-values are provided in blue.

	Temperature		**Rainfall**		**T-RF**	
Temporal window	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
5 days	-5.2124	0.0046	-0.4786	0.0969	0.0317	0.3825
10 days	-6.9765	0.0014	-0.1122	0.5689	-0.0087	0.6581
15 days	**-9.5142**	**0.0000**	-0.1421	0.1624	0.0104	0.2396
20 days	**-10.8325**	**0.0003**	0.0075	0.9424	0.0047	0.5149
25 days	**-9.4125**	**0.0012**	-0.0903	0.3471	0.0092	0.1935
30 days	**-8.6527**	**0.0013**	-0.0440	0.6087	0.0073	0.2856
35 days	**-8.8344**	**0.0021**	-0.0004	0.9956	0.0028	0.6395
40 days	-8.6655	0.0057	0.0463	0.4214	-0.0004	0.9265
45 days	-9.2024	0.0045	0.0288	0.5740	-0.0010	0.7717
50 days	**-9.5078**	**0.0033**	0.0053	0.8982	0.0001	0.9643
55 days	-10.3620	0.0046	0.0145	0.7340	-0.0012	0.6405
60 days	-10.5982	0.0048	0.0266	0.5244	-0.0015	0.5525

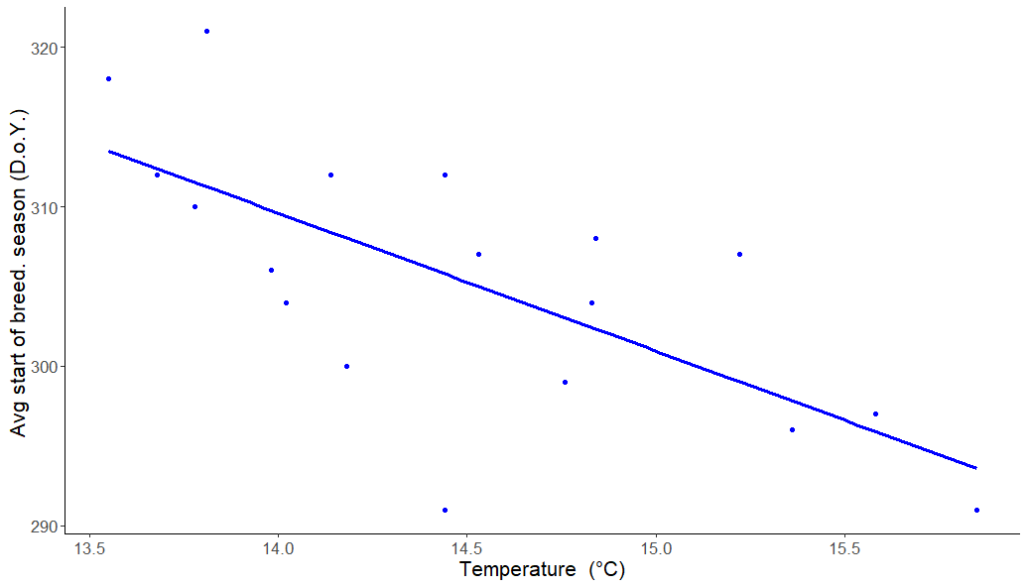

Figure S5.a Relationship between temperature and average start of the breeding season in Tiritiri Mātangi, for a time-window of 30 days. The significant relationship suggests a plastic response of laying date to temperature, the warmer the environment, the earlier the breeding.

2. Kārori

We used a similar approach in Kārori, using the "Wellington, Kelburn Aws" weather forecast station located ~2 km away from the sanctuary. Again, we tested the relationship between temperature (T) and amount of rainfall (RF) and the start of the breeding session. We also tested the relationship between T and RF. Again, we applied a Bonferroni correction to the p-value cut-off threshold. Results are summarized in Table S5.b.

In contrast to Tiritiri Mātangi, we found no association between environmental parameters and the start of the breeding season across years, suggesting a lack of climatic-based plastic response (See Figure S5.b). Yet, we found significant and negative correlations between temperature and rainfall for three temporal windows tested, suggesting that the most humid years are also the coldest.

Table S5.b Relationship between start of the breeding season and Temperature or Rainfall in Kārori. Provided are the coefficients and p-value of linear regressions between the start of the breeding season and Temperature (T) or rainfall (RF) recorded over twelve temporal windows. After Bonferroni correction, significant p-values are provided in blue.

	Temperature		**Rainfall**		**T-RF**	
Temporal window	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
5 days	0.2462	0.9148	0.0829	0.6988	-0.0265	0.3054
10 days	0.2462	0.8406	-0.0067	0.9482	-0.0136	0.1107
15 days	0.2462	0.9488	0.0083	0.9320	-0.0148	0.0458
20 days	0.2462	0.8969	-0.0108	0.9113	-0.0099	0.0875
25 days	0.2462	0.6277	-0.0335	0.6329	**-0.0133**	**0.0002**
30 days	0.2462	0.5448	-0.0600	0.3651	**-0.0131**	**0.0005**
35 days	0.2462	0.3967	-0.0386	0.5062	**-0.0100**	**0.0007**
40 days	0.2462	0.4065	-0.0472	0.3973	-0.0077	0.0051
45 days	0.2462	0.4199	-0.0304	0.6160	-0.0054	0.0612
50 days	0.2462	0.4137	-0.0213	0.7138	-0.0046	0.0756
55 days	0.2462	0.4136	-0.0134	0.8112	-0.0032	0.1823
60 days	0.2462	0.4207	-0.0258	0.6384	-0.0028	0.2120

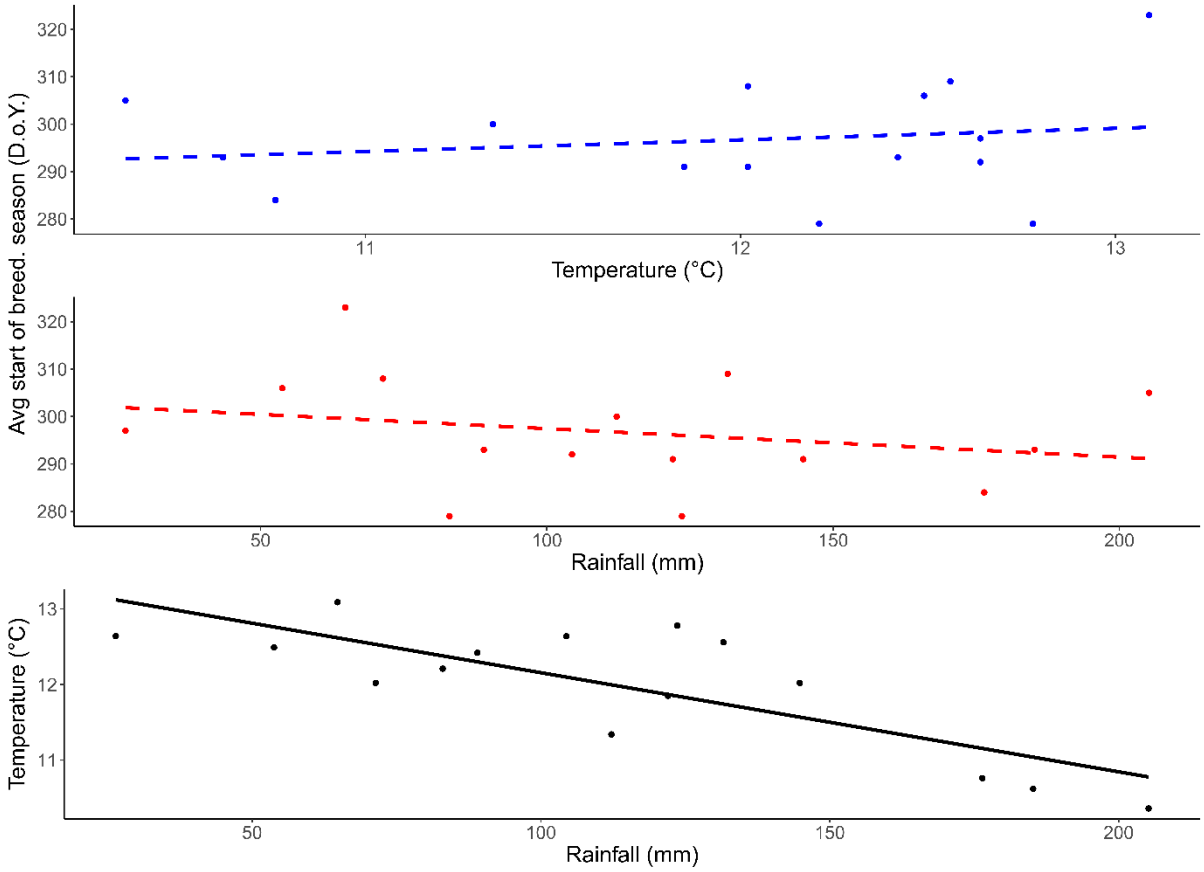

Figure S5.b Relationship between environmental parameters and the average start of the breeding season in Kārori, for a time-window of 30 days. Top panel represents the relationship between temperatures and the **average start of the breeding** season. Middle panel represents the relationship between the total amount of rainfall and the **average start of the breeding** season. The bottom panel represents the relationship between temperature and total rainfall. Significant relationships are represented with solid lines.