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Hurricane-induced selection on the morphology of an island lizard

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Supplemental Information 1: Description of lizard behavior on a perch in hurricane-force winds

Nothing is known about the behavior of anoles in hurricane-force winds. We conducted an experiment to determine (1) if lizards remained on artificial perches when faced with high winds or sought shelter (jumped off the perch to the ground), and (2) were capable of maintaining grip on a wooden perch at high wind speeds.

To determine how *A. scriptus* individuals react to hurricane force winds, we used a Toro leaf blower (51619: Ultra Blower), a two-cm diameter wooden dowel, and a high-speed video camera. The dowel was set vertically with the opening of the leaf blower set 70 cm from the perch. On the other side of the perch we set a large net and protective padding to ensure that lizards landed unharmed should they be blown off the perch. Each lizard was placed on the dowel head up at the same place, orthogonal to the flow of wind. The leaf blower was then turned on and the speed of the wind slowly but steadily increased (Fig.1) until the lizard was unable to maintain grip on the perch, at which point the leaf blower was turned off. The cone of wind created by the leaf blower encompassed the entirety of the experimental perch. All trials were recorded with a Phantom Miro high speed camera recording at 400Hz. Each lizard experienced one trial and a total of 47 lizards were recorded. All lizards were released unharmed after the experiment at their point of capture.

Once the fan was turned on, instead of fleeing the perch all lizards immediately pivoted to the lee side, grasping it with their forelimbs tucked in close to their bodies and their feet on the perch in such a way that their femurs jutted out to either side. All lizards eventually lost their grip to the perch, and in the majority of cases, the hind limbs lost contact before the forelimbs (see figure), suggesting the possibility that faced with high winds on a small perch, hind limbs will catch wind, leading to a lizard's eventual ultimate loss of grip. Further studies employing more rigorous laboratory conditions, however, will be needed to definitively test the trait-performance association of lizards on perches experiencing hurricane-force winds.

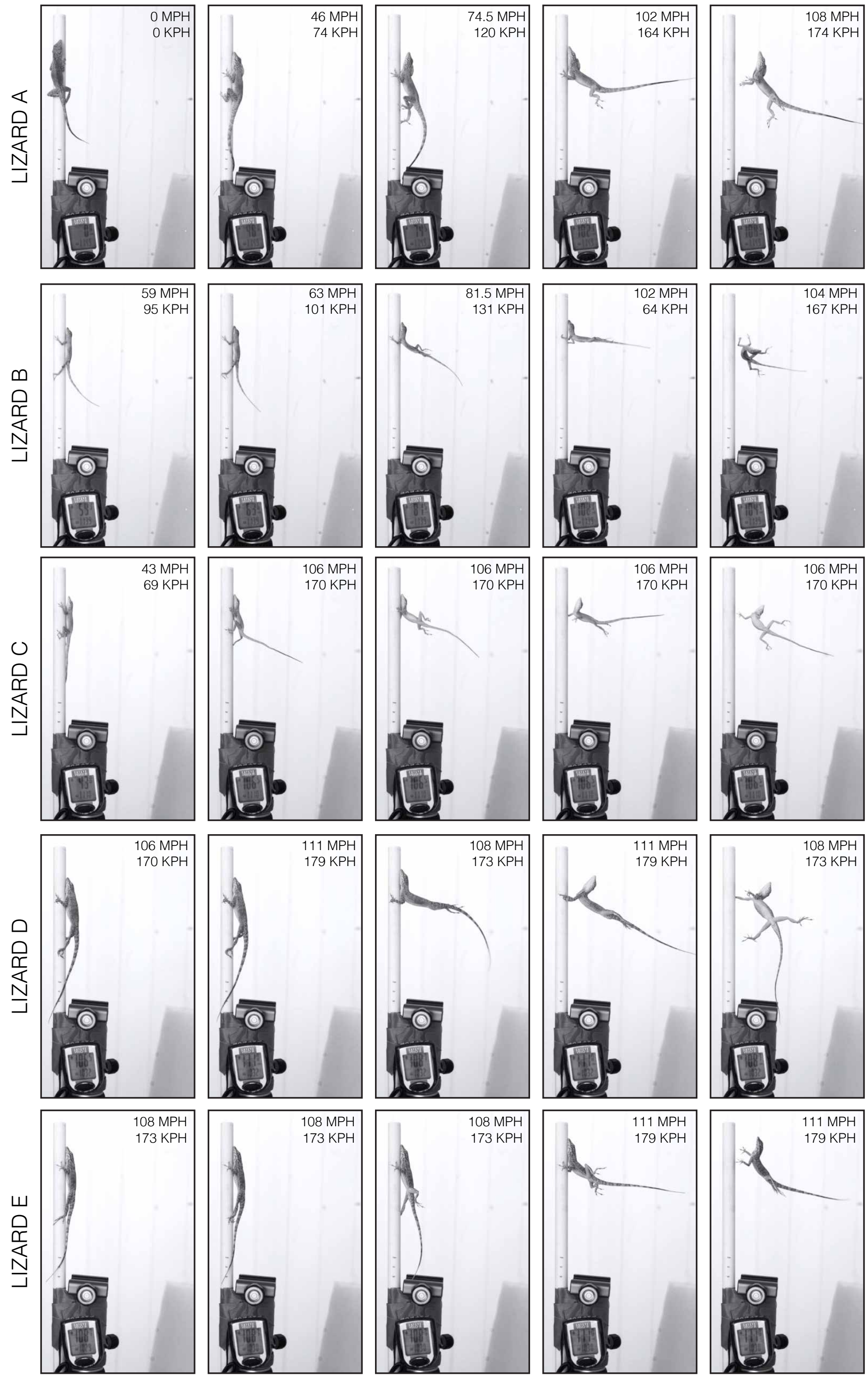

Figure 1: A representative sequence of five lizards experiencing high winds. Note, the oscillations in wind speed in the fourth row (Lizard D) reflect variation in the leaf blower at maximum output. These five lizards were selected to illustrate the characteristic perching position in the lee of the perch with forelimbs tucked close to the body and hind limbs extended on either side of the perch.

Supplemental Information 2: Additional analysis details and results

Extended analysis methods:

As described in our Methods, we visited Pine Cay and Water Cay twice in the span of six weeks and in the interim two hurricanes hit the area. We sought to determine whether the lizard populations we surveyed on both islands experienced strong directional selection, thereby shifting population means of a suite of traits associated with clinging capacity; specifically, limb lengths and toepad characteristics.

We used a MANCOVA approach for trait analyses using lizard body size – snout-to-vent length (SVL) – as a covariate with each limb element as a dependent variable. We also included as a fixed effect "Hurricane," corresponding to "Before" or "After" the hurricanes. This was the primary effect of interest. We sampled two islands and included them as a fixed factor interacting with the hurricane effect to determine whether the response of the populations from the two islands differed. To improve the distribution of the residuals, all morphological measurements (the response and SVL) were natural-log transformed before analysis. We initially evaluated all interactions in the model and if no significant interactions were found, the interaction was subsequently removed. Consequently, our MANCOVA took the form:

*log(Humerus, Radius, Metacarpal, LongestFinger, Femur, Tibia, Metatarsal, LongestToe, FingerArea, ToeArea, FingerCount, ToeCount) ~ Hurricane*Origin + Sex + log(SVL)*

The MANCOVA was used to assess overall significance of the hurricane effect and the hurricane × island of origin interaction in the model. For the MANCOVA, we calculated a structure matrix corresponding to the pooled-within-groups correlations between the descriminating variables and standardized canonical discriminant functions (Table 2). Following the MANCOVA, we performed a series of univariate ANCOVAs to determine which traits significantly differed. These comparisons are less conservative than generalized linear models, and so we tested all traits shown to significantly differ in the post-hoc ANCOVA with GLMs. We first tested all interactions and then removed them if they were not significant, thus, our models generally took the form:

log(Morphological trait) ~ log(SVL) + Hurricane + Island of Origin + Sex

We conducted all analyses in R[1] using the *lm()* function. For all models, we used the *lsmeans()* function in the eponymous package[2] to calculate the least squares means and confidence intervals for the before/after hurricane comparison. We then used the pairwise *contrast()* function in the lsmeans package to assign *P*-values to the comparison and type III ANOVAs to test the significance of the factors of each model. We used the same model structure to test for differences in SVL between the two populations before and after the hurricanes, again testing all interactions and removing them until all factor were significant.

Because many of these morphological traits are highly correlated with each other, we performed a principal components analysis to generate uncorrelated morphological response variables – principal component axes – reflecting the shape of the lizards. This principal component analysis was conducted on size-corrected residual values for the five limb elements with an observed mean-shift in the previous analysis: humerus, femur, and longest hind limb toe length; forelimb and hind limb toepad surface area. We conducted the PC analysis on the pooled lizards from both islands to enable us to test for an island × hurricane effect. Differences in PC scores between the before-hurricane and after-hurricane populations were tested using the linear model structure described above.

Results:

We found significant differences in the body size, limb length, and toepad area between the lizards measured before and after the hurricanes. Lizards after the hurricanes were smaller, and for their body size, had relatively longer humeri, shorter femora and shorter hind limb toes. They also had significantly larger toepads (Table 1).

	Pine Cay				**Water Cay**			
	Before		**After**		**Before**		**After**	
	Male	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**
n =	*18*	*15*	*29*	*17*	*20*	*18*	*25*	*22*
Snout-to-Vent Length	56.91 ± 0.89	44.11 ± 0.4	53.68 ± 0.75	43.52 ± 0.49	54.71 ± 0.63	42.51 ± 0.4	52.94 ± 0.68	43.68 ± 0.51
Femur	12.99 ± 0.21	9.9 ± 0.19	11.81 ± 0.19	9.31 ± 0.12	12.7 ± 0.17	9.22 ± 0.11	11.64 ± 0.23	8.94 ± 0.17
Tibia	13.95 ± 0.17	10.56 ± 0.19	13.03 ± 0.18	10.36 ± 0.1	13.56 ± 0.15	10.12 ± 0.09	13.07 ± 0.16	10.4 ± 0.15
Metatarsal	8.75 ± 0.11	6.74 ± 0.11	8.19 ± 0.1	6.62 ± 0.07	8.3 ± 0.11	6.4 ± 0.07	8.12 ± 0.08	6.56 ± 0.12
Longest Toe	8.72 ± 0.16	6.58 ± 0.1	7.8 ± 0.14	6.31 ± 0.11	8.17 ± 0.13	6.19 ± 0.1	7.65 ± 0.12	6.27 ± 0.1
Humerus	10.3 ± 0.2	7.76 ± 0.11	9.97 ± 0.18	7.65 ± 0.09	9.92 ± 0.16	7.34 ± 0.09	10.01 ± 0.17	7.89 ± 0.13
Radius	8.92 ± 0.14	7.02 ± 0.1	8.53 ± 0.13	6.75 ± 0.07	8.77 ± 0.11	6.64 ± 0.07	8.54 ± 0.11	6.84 ± 0.09
Metacarpal	3.02 ± 0.08	2.48 ± 0.07	2.93 ± 0.07	2.47 ± 0.06	3.1 ± 0.06	2.41 ± 0.06	3.06 ± 0.06	2.59 ± 0.06
Longest Finger	4.38 ± 0.09	3.44 ± 0.07	4.09 ± 0.09	3.3 ± 0.05	4.24 ± 0.08	3.16 ± 0.07	4.27 ± 0.08	3.3 ± 0.08
Forelimb Lamellae Count	12.22 ± 0.22	10.87 ± 0.17	12.18 ± 0.18 §	11.06 ± 0.18	12.15 ± 0.17	10.33 ± 0.16	12.36 ± 0.18	11.36 ± 0.22
Hind Limb Lamellae Count	14.94 ± 0.25	13.33 ± 0.25	14.5 ± 0.21 §	12.94 ± 0.23	14.6 ± 0.13	12.56 ± 0.23	15 ± 0.14	13.18 ± 0.23
Forelimb Toepad Area	1.98 ± 0.09	1 ± 0.03	1.96 ± 0.08 §	1.15 ± 0.04	1.93 ± 0.06	0.93 ± 0.03	2.03 ± 0.07	1.13 ± 0.05
Hind Limb Toepad Area	3.38 ± 0.14	1.68 ± 0.05	3.24 ± 0.14 §	1.81 ± 0.08	3.05 ± 0.09	1.44 ± 0.05	3.1 ± 0.1	1.76 ± 0.07

Table 1: Summary values for each of the tested traits for male and female lizards from both Pine Cay and Water Cay, before and after the hurricanes struck the islands. The first row indicates the number of animals in a given category with the exception of the four values denoted by §; these values were calculated on 28 animals. All values are means ± the standard error. Statistical significance of the comparison between the before and after sampling was assessed using GLMs (see below and main text). Those traits showing a significant difference ($P < 0.05$) are labeled in bold.

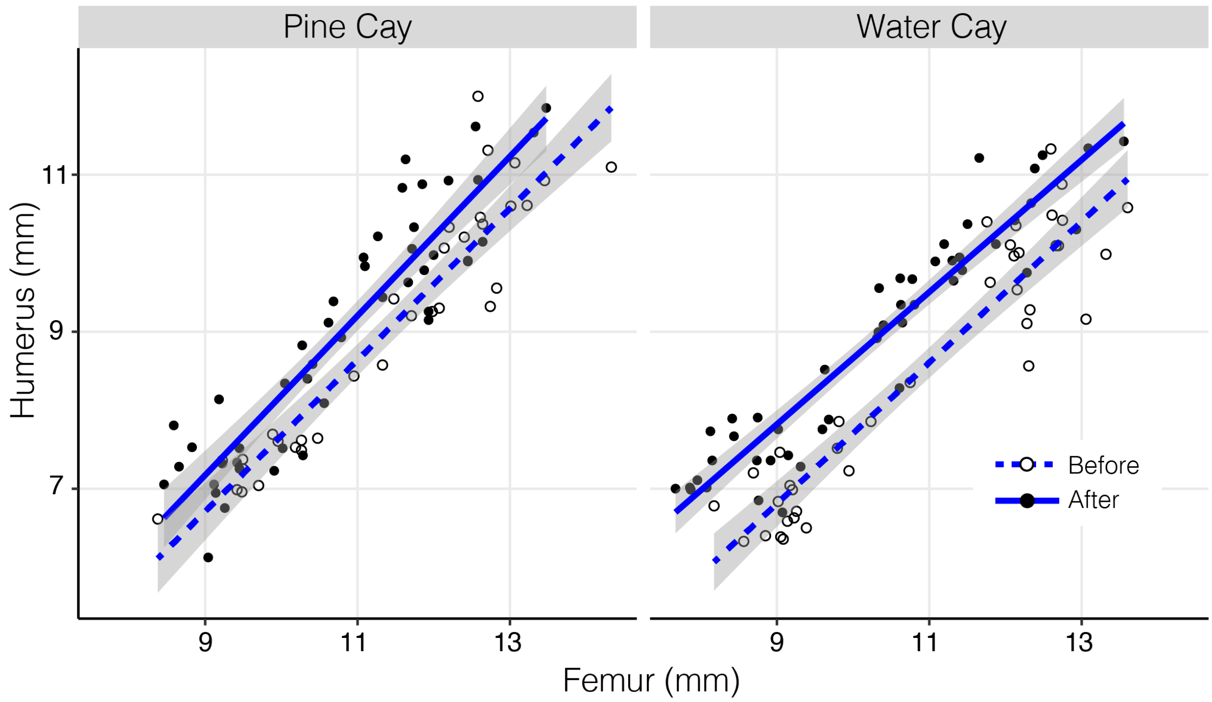

Figure 1: To further illustrate the morphological shifts presented in the figure 2 of the manuscript, we have included an additional figure showing the shift in humerus to femur ratio in the lizard populations on Pine Cay and Water Cay before and after the hurricanes. Dashed lines are the linear best fit of lizards measured before the hurricane, represented with open circles. Filled circles are lizards from after the hurricane with solid lines of best fit. The grey shaded areas correspond to 95% confidence intervals.

MANCOVA Model Output:

```
                      Df  Pillai approx F num Df den Df    Pr(>F)
Hurricane              1 0.60037   18.278     12    146 < 2.2e-16 ***
Origin                 1 0.40777    8.377     12    146 6.491e-12 ***
Sex                    1 0.96109  300.547     12    146 < 2.2e-16 ***
log(SVL)               1 0.82213   56.237     12    146 < 2.2e-16 ***
Hurricane:Origin       1 0.10165    1.377     12    146    0.1833
Residuals            157
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

MANCOVA Structure Matrix

Trait	**Correlation**
Femur	-0.192
Finger Count	0.164
Longest Toe	-0.155
Finger Area	0.109
Tibia	-0.071
Toe Area	0.068
Metatarsal	-0.06

Radius	-0.048
Humerus	0.046
Toe Count	0.042
Metacarpal	0.031
Longest Finger	-0.031

Table 2: Pooled within-groups correlations between discriminating variables and standardized canonical discriminant functions.

Summary ANCOVA of each morphometric within the MANCOVA:

```
Response Humerus :
                  Df  Sum Sq Mean Sq   F value    Pr(>F)    
Hurricane          1 0.01673 0.01673    6.6817 0.0106507 *  
Origin             1 0.03270 0.03270   13.0627 0.0004052 ***
Sex                1 2.87099 2.87099 1146.9031 < 2.2e-16 ***
log(SVL)           1 0.53159 0.53159  212.3594 < 2.2e-16 ***
Hurricane:Origin   1 0.00803 0.00803    3.2067 0.0752643 .  
Residuals        157 0.39301 0.00250                        
---

 Response Radius :
                  Df  Sum Sq Mean Sq   F value    Pr(>F)    
Hurricane          1 0.00355 0.00355    3.1821   0.07638 .  
Origin             1 0.02777 0.02777   24.9090 1.581e-06 ***
Sex                1 2.33923 2.33923 2098.3944 < 2.2e-16 ***
log(SVL)           1 0.45166 0.45166  405.1563 < 2.2e-16 ***
Hurricane:Origin   1 0.00137 0.00137    1.2302   0.26907    
Residuals        157 0.17502 0.00111                        
---

 Response Metacarpal :
                  Df  Sum Sq Mean Sq  F value    Pr(>F)    
Hurricane          1 0.00722 0.00722   0.8661    0.3535    
Origin             1 0.00834 0.00834   1.0010    0.3186    
Sex                1 1.51476 1.51476 181.7187 < 2.2e-16 ***
log(SVL)           1 0.51768 0.51768  62.1040 5.099e-13 ***
Hurricane:Origin   1 0.00141 0.00141   0.1687    0.6818    
Residuals        157 1.30871 0.00834                       
---

 Response LongestFinger :
                  Df  Sum Sq Mean Sq  F value    Pr(>F)    
Hurricane          1 0.00133 0.00133   0.2111   0.64657    
Origin             1 0.02893 0.02893   4.5894   0.03371 *  
Sex                1 2.50338 2.50338 397.1367 < 2.2e-16 ***
log(SVL)           1 0.40839 0.40839  64.7866 1.933e-13 ***
Hurricane:Origin   1 0.02774 0.02774   4.4003   0.03754 *  
Residuals        157 0.98966 0.00630                       
---

 Response Femur :
```

```
                  Df  Sum Sq Mean Sq F value    Pr(>F)    
Hurricane          1 0.13971 0.13971  45.873 2.389e-10 ***
Origin             1 0.10807 0.10807  35.486 1.629e-08 ***
Sex                1 2.96189 2.96189 972.544 < 2.2e-16 ***
log(SVL)           1 0.43992 0.43992 144.448 < 2.2e-16 ***
Hurricane:Origin   1 0.00134 0.00134   0.440    0.5081    
Residuals        157 0.47814 0.00305                      
---

 Response Tibia :
                  Df  Sum Sq Mean Sq   F value    Pr(>F)    
Hurricane          1 0.00904 0.00904    7.2348  0.007924 ** 
Origin             1 0.03282 0.03282   26.2509 8.694e-07 ***
Sex                1 2.58328 2.58328 2066.2954 < 2.2e-16 ***
log(SVL)           1 0.35394 0.35394  283.1103 < 2.2e-16 ***
Hurricane:Origin   1 0.00162 0.00162    1.2928  0.257265    
Residuals        157 0.19628 0.00125                        
---

 Response Metatarsal :
                  Df  Sum Sq Mean Sq   F value    Pr(>F)    
Hurricane          1 0.00531 0.00531    3.2522   0.07324 .  
Origin             1 0.06953 0.06953   42.5646 8.929e-10 ***
Sex                1 2.19217 2.19217 1342.0114 < 2.2e-16 ***
log(SVL)           1 0.32661 0.32661  199.9455 < 2.2e-16 ***
Hurricane:Origin   1 0.00415 0.00415    2.5433   0.11277    
Residuals        157 0.25646 0.00163                        
---

 Response LongestToe :
                  Df  Sum Sq Mean Sq  F value    Pr(>F)    
Hurricane          1 0.07136 0.07136  21.4159 7.693e-06 ***
Origin             1 0.09954 0.09954  29.8749 1.776e-07 ***
Sex                1 2.24927 2.24927 675.0576 < 2.2e-16 ***
log(SVL)           1 0.43457 0.43457 130.4237 < 2.2e-16 ***
Hurricane:Origin   1 0.00504 0.00504   1.5136    0.2204    
Residuals        157 0.52312 0.00333                       
---

 Response FingerArea :
                  Df  Sum Sq Mean Sq   F value    Pr(>F)    
Hurricane          1  0.4624  0.4624   42.9537 7.638e-10 ***
Origin             1  0.0867  0.0867    8.0527  0.005144 ** 
Sex                1 15.4621 15.4621 1436.3936 < 2.2e-16 ***
log(SVL)           1  3.1165  3.1165  289.5180 < 2.2e-16 ***
Hurricane:Origin   1  0.0011  0.0011    0.1031  0.748604    
Residuals        157  1.6900  0.0108                        
---

 Response ToeArea :
                  Df  Sum Sq Mean Sq   F value    Pr(>F)    
Hurricane          1  0.2438  0.2438   26.9454 6.394e-07 ***
Origin             1  0.4647  0.4647   51.3505 2.833e-11 ***
Sex                1 16.1503 16.1503 1784.7953 < 2.2e-16 ***
log(SVL)           1  3.4459  3.4459  380.8082 < 2.2e-16 ***
Hurricane:Origin   1  0.0045  0.0045    0.5026    0.4794    
Residuals        157  1.4207  0.0090                        
```

```
---

 Response FingerCount :
                  Df  Sum Sq Mean Sq F value    Pr(>F)    
Hurricane          1 0.04712 0.04712  9.1604 0.0028911 ** 
Origin             1 0.00153 0.00153  0.2978 0.5860416    
Sex                1 0.49982 0.49982 97.1723 < 2.2e-16 ***
log(SVL)           1 0.06759 0.06759 13.1411 0.0003899 ***
Hurricane:Origin   1 0.01395 0.01395  2.7115 0.1016278    
Residuals        157 0.80755 0.00514                      
---

 Response ToeCount :
                  Df  Sum Sq Mean Sq  F value    Pr(>F)    
Hurricane          1 0.00376 0.00376   0.8006  0.372288    
Origin             1 0.00303 0.00303   0.6454  0.422984    
Sex                1 0.64460 0.64460 137.4201 < 2.2e-16 ***
log(SVL)           1 0.03588 0.03588   7.6484  0.006364 ** 
Hurricane:Origin   1 0.03707 0.03707   7.9020  0.005568 ** 
Residuals        157 0.73645 0.00469                       
---

1 observation deleted due to missingness
```

Linear Model Output:

```
lm(formula = log(SVL) ~ Sex * Hurricane + Origin, data = dat)

Residuals:
      Min        1Q    Median        3Q       Max 
-0.132167 -0.038484  0.002117  0.034045  0.150616 

Coefficients:
                         Estimate Std. Error t value Pr(>|t|)    
(Intercept)              3.785418   0.010585 357.617  < 2e-16 ***
SexMale                  0.198172   0.012194  16.252  < 2e-16 ***
HurricaneBefore         -0.008604   0.013687  -0.629  0.53052    
OriginWater Cay         -0.020089   0.009073  -2.214  0.02824 *  
SexMale:HurricaneBefore  0.054697   0.018384   2.975  0.00338 ** 
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Humerus:

```
lm(formula = log(Humerus) ~ log(SVL) + Hurricane + Origin + Sex, 
    data = dat)

Residuals:
      Min        1Q    Median        3Q       Max 
-0.137012 -0.032837 -0.006019  0.029860  0.189515 

Coefficients:
                 Estimate Std. Error t value Pr(>|t|)    
(Intercept)     -1.719344   0.253212  -6.790 2.11e-10 ***
log(SVL)         0.998054   0.067114  14.871  < 2e-16 ***
HurricaneBefore -0.029128   0.008073  -3.608 0.000413 ***
OriginWater Cay  0.008553   0.007985   1.071 0.285738    
```

```
SexMale          0.044499   0.016896   2.634 0.009280 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Radius:

```
lm(formula = log(Radius) ~ log(SVL) + Hurricane + Origin + Sex,
    data = dat)

Residuals:
      Min        1Q    Median        3Q       Max
-0.091751 -0.019855 -0.002547  0.022387  0.114716

Coefficients:
                 Estimate Std. Error t value Pr(>|t|)
(Intercept)     -1.531979   0.167661  -9.137 2.85e-16 ***
log(SVL)         0.913414   0.044438  20.555  < 2e-16 ***
HurricaneBefore  0.001057   0.005345   0.198 0.843521
OriginWater Cay  0.007139   0.005287   1.350 0.178843
SexMale          0.037619   0.011187   3.363 0.000967 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Metacarpal:

```
lm(formula = log(Metacarpal) ~ log(SVL) + Hurricane + Origin +
    Sex, data = dat)

Residuals:
      Min        1Q    Median        3Q       Max
-0.274400 -0.061752  0.009136  0.062051  0.213999

Coefficients:
                Estimate Std. Error t value Pr(>|t|)
(Intercept)     -2.87839    0.45861  -6.276 3.16e-09 ***
log(SVL)         1.00040    0.12156   8.230 6.38e-14 ***
HurricaneBefore -0.02548    0.01462  -1.742  0.08339 .
OriginWater Cay  0.04767    0.01446   3.296  0.00121 **
SexMale         -0.02995    0.03060  -0.979  0.32924
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Longest Finger:

```
lm(formula = log(LongestFinger) ~ log(SVL) + Hurricane * Origin +
    Sex, data = dat)

Residuals:
      Min        1Q    Median        3Q       Max
-0.183161 -0.047144 -0.002277  0.046687  0.202230

Coefficients:
                                Estimate Std. Error t value Pr(>|t|)
(Intercept)                     -1.99341    0.40180  -4.961 1.79e-06 ***
log(SVL)                         0.83975    0.10671   7.869 5.30e-13 ***
HurricaneBefore                  0.02741    0.01858   1.476   0.1421
OriginWater Cay                  0.02895    0.01647   1.758   0.0807 .
```

```
SexMale                           0.06330    0.02687   2.356   0.0197 *
HurricaneBefore:OriginWater Cay -0.05344    0.02527  -2.115   0.0360 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Femur:

```
lm(formula = log(Femur) ~ log(SVL) + Hurricane + Origin + Sex,
    data = dat)

Residuals:
      Min        1Q    Median        3Q       Max
-0.110862 -0.038613 -0.001311  0.029196  0.210533

Coefficients:
                 Estimate Std. Error t value Pr(>|t|)
(Intercept)     -1.205823   0.276605  -4.359 2.33e-05 ***
log(SVL)         0.906389   0.073314  12.363  < 2e-16 ***
HurricaneBefore  0.052848   0.008819   5.993 1.34e-08 ***
OriginWater Cay -0.016398   0.008723  -1.880 0.061953 .
SexMale          0.069291   0.018457   3.754 0.000243 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Tibia:

```
lm(formula = log(Tibia) ~ log(SVL) + Hurricane + Origin + Sex,
    data = dat)

Residuals:
      Min        1Q    Median        3Q       Max
-0.076795 -0.021904 -0.002749  0.017972  0.165430

Coefficients:
                 Estimate Std. Error t value Pr(>|t|)
(Intercept)     -0.734413   0.177807  -4.130 5.84e-05 ***
log(SVL)         0.812610   0.047128  17.243  < 2e-16 ***
HurricaneBefore  0.009419   0.005669   1.662   0.0986 .
OriginWater Cay  0.003696   0.005607   0.659   0.5107
SexMale          0.072307   0.011864   6.094 7.99e-09 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Metatarsal:

```
lm(formula = log(Metatarsal) ~ log(SVL) + Hurricane + Origin +
    Sex, data = dat)

Residuals:
      Min        1Q    Median        3Q       Max
-0.097655 -0.026495 -0.000641  0.025552  0.138497

Coefficients:
                 Estimate Std. Error t value Pr(>|t|)
(Intercept)     -1.009803   0.204103  -4.948 1.90e-06 ***
log(SVL)         0.767725   0.054098  14.191  < 2e-16 ***
HurricaneBefore  0.005818   0.006507   0.894   0.3726
```

```
OriginWater Cay -0.011987   0.006437  -1.862   0.0644 .
SexMale          0.062823   0.013619   4.613 8.13e-06 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Longest Toe:

```
lm(formula = log(LongestToe) ~ log(SVL) + Hurricane + Origin +
    Sex, data = dat)

Residuals:
      Min        1Q    Median        3Q       Max
-0.142090 -0.032275  0.003146  0.038218  0.127727

Coefficients:
                 Estimate Std. Error t value Pr(>|t|)
(Intercept)     -1.586320   0.290891  -5.453 1.86e-07 ***
log(SVL)         0.907410   0.077101  11.769  < 2e-16 ***
HurricaneBefore  0.034814   0.009274   3.754 0.000244 ***
OriginWater Cay -0.016067   0.009173  -1.752 0.081786 .
SexMale          0.033817   0.019410   1.742 0.083402 .
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Forelimb Toepad Area:

```
lm(formula = log(FingerArea) ~ log(SVL) + Hurricane + Origin +
    Sex, data = dat)

Residuals:
     Min       1Q   Median       3Q      Max
-0.33276 -0.07118  0.00129  0.07744  0.23263

Coefficients:
                Estimate Std. Error t value Pr(>|t|)
(Intercept)     -8.94919    0.52954 -16.900  < 2e-16 ***
log(SVL)         2.39407    0.14030  17.064  < 2e-16 ***
HurricaneBefore -0.13054    0.01661  -7.860 5.59e-13 ***
OriginWater Cay  0.04006    0.01651   2.427   0.0164 *
SexMale          0.08671    0.03537   2.451   0.0153 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Hind limb Toepad Area:

```
lm(formula = log(ToeArea) ~ log(SVL) + Hurricane + Origin + Sex,
    data = dat)

Residuals:
     Min       1Q   Median       3Q      Max
-0.34453 -0.05926  0.00288  0.05857  0.31115

Coefficients:
                Estimate Std. Error t value Pr(>|t|)
(Intercept)     -8.93378    0.48613 -18.377  < 2e-16 ***
log(SVL)         2.51738    0.12880  19.545  < 2e-16 ***
HurricaneBefore -0.10162    0.01525  -6.665 4.18e-10 ***
```

```
OriginWater Cay -0.01732    0.01516  -1.143   0.2549
SexMale          0.07283    0.03247   2.243   0.0263 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Forelimb lamellae count:

```
glm(formula = FingerCount ~ log(SVL) + Hurricane + Origin + Sex,
    family = poisson(link = "log"), data = dat)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-0.56782  -0.16965  -0.02309   0.14960   0.74644

Coefficients:
                 Estimate Std. Error z value Pr(>|z|)
(Intercept)      1.098186   1.484818   0.740    0.460
log(SVL)         0.346110   0.393319   0.880    0.379
HurricaneBefore -0.036485   0.047173  -0.773    0.439
OriginWater Cay  0.008709   0.046744   0.186    0.852
SexMale          0.033943   0.099655   0.341    0.733
```

Hind limb lamellae count:

```
glm(formula = ToeCount ~ log(SVL) + Hurricane + Origin + Sex,
    family = poisson(link = "log"), data = dat)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-0.79313  -0.21005   0.02227   0.16567   0.72077

Coefficients:
                 Estimate Std. Error z value Pr(>|z|)
(Intercept)      1.598890   1.356113   1.179    0.238
log(SVL)         0.256760   0.359266   0.715    0.475
HurricaneBefore -0.009879   0.043035  -0.230    0.818
OriginWater Cay  0.004383   0.042698   0.103    0.918
SexMale          0.068420   0.091097   0.751    0.453
```

Body Condition Analysis:

Body condition residuals were calculated from the relationship of Mass and SVL.

```
bodycondition_residuals <- residuals(lm(log(dat$Mass)~log(dat$SVL)))
```

In general, there was no difference in body condition from the populations before and after the hurricanes. There were differences between the two populations however; Body condition was higher on Pine than on Water Cay.

```
lm(formula = bodycondition_residuals ~ Hurricane + Origin, data = dat)

Residuals:
     Min       1Q   Median       3Q      Max
-0.33012 -0.07394 -0.00836  0.06736  0.54059
```

```
Coefficients:
                Estimate Std. Error t value Pr(>|t|)
(Intercept)      0.04040    0.01625   2.486   0.0139 *
HurricaneBefore  0.01704    0.01966   0.867   0.3874
OriginWater Cay -0.09218    0.01949  -4.729 4.89e-06 ***
```

We did detect a significant interaction in the change of body condition post-hurricane between the islands. Body condition improved on Water Cay and decreased slightly on Pine Cay.

```
lm(formula = bodycondition_residuals ~ Hurricane * Origin, data = dat)

Residuals:
     Min       1Q   Median       3Q      Max
-0.37538 -0.06474 -0.00235  0.06633  0.49533

Coefficients:
                                 Estimate Std. Error t value Pr(>|t|)
(Intercept)                      0.007929   0.017600   0.451 0.652942
HurricaneBefore                  0.094771   0.027232   3.480 0.000646 ***
OriginWater Cay                 -0.027928   0.024758  -1.128 0.260989
HurricaneBefore:OriginWater Cay -0.148823   0.037679  -3.950 0.000117 ***
```

PCA Model Output:

```
Importance of components:
                          PC1     PC2     PC3     PC4     PC5
Standard deviation     0.1512 0.07803 0.06754 0.05141 0.04540
Proportion of Variance 0.5983 0.15929 0.11933 0.06914 0.05393
Cumulative Proportion  0.5983 0.75759 0.87692 0.94607 1.00000

                       PC1    PC2    PC3    PC4    PC5
femur_residuals      0.014 -0.358  0.649 -0.538  0.401
humerus_residuals    0.154 -0.195  0.237 -0.255 -0.904
longtoe_residuals    0.063 -0.380  0.460  0.800 -0.013
fingerarea_residuals 0.771  0.563  0.285  0.044  0.072
toearea_residuals    0.614 -0.610 -0.479 -0.061  0.128
```

PC1:

```
lm(formula = PC1 ~ Hurricane * Origin + Sex, data = dat)

Residuals:
     Min       1Q   Median       3Q      Max
-0.32504 -0.08545 -0.00608  0.08820  0.38992

Coefficients:
                                Estimate Std. Error t value Pr(>|t|)
(Intercept)                      0.04087    0.02212   1.848   0.0665 .
HurricaneBefore                 -0.17343    0.02841  -6.103 7.72e-09 ***
OriginWater Cay                  0.02739    0.02588   1.058   0.2916
SexMale                          0.03582    0.01959   1.828   0.0694 .
HurricaneBefore:OriginWater Cay  0.00168    0.03920   0.043   0.9659
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

PC2:

```
lm(formula = PC2 ~ Hurricane + Origin + Sex, data = dat)

Residuals:
      Min        1Q    Median        3Q       Max 
-0.263973 -0.044529 -0.003565  0.043396  0.252605 

Coefficients:
                 Estimate Std. Error t value Pr(>|t|)    
(Intercept)     -0.004332   0.012080  -0.359 0.720343    
HurricaneBefore -0.033979   0.011738  -2.895 0.004326 ** 
OriginWater Cay  0.040287   0.011662   3.454 0.000707 ***
SexMale         -0.003359   0.011738  -0.286 0.775097    
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

PC3:

```
lm(formula = PC3 ~ Hurricane + Origin + Sex, data = dat)

Residuals:
      Min        1Q    Median        3Q       Max 
-0.166373 -0.038463 -0.000524  0.040468  0.227868 

Coefficients:
                 Estimate Std. Error t value Pr(>|t|)    
(Intercept)     -0.032814   0.010259  -3.199  0.00167 ** 
HurricaneBefore  0.049987   0.009968   5.015 1.41e-06 ***
OriginWater Cay  0.007583   0.009904   0.766  0.44505    
SexMale          0.012693   0.009968   1.273  0.20476    
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

PC4:

```
lm(formula = PC4 ~ Hurricane + Origin + Sex, data = dat)

Residuals:
      Min        1Q    Median        3Q       Max 
-0.122426 -0.033247 -0.000023  0.037308  0.121484 

Coefficients:
                 Estimate Std. Error t value Pr(>|t|)
(Intercept)      0.001923   0.008393   0.229    0.819
HurricaneBefore  0.008705   0.008156   1.067    0.287
OriginWater Cay -0.005169   0.008103  -0.638    0.524
SexMale         -0.005409   0.008156  -0.663    0.508
```

PC5:

```
lm(formula = PC5 ~ Hurricane + Origin + Sex, data = dat)

Residuals:
     Min       1Q   Median       3Q      Max 
-0.11513 -0.03004 -0.00224  0.02546  0.13581 

Coefficients:
                 Estimate Std. Error t value Pr(>|t|)
```

```
(Intercept)      -0.002805   0.007113  -0.394  0.69384    
HurricaneBefore   0.024484   0.006911   3.543  0.00052 ***
OriginWater Cay  -0.012732   0.006867  -1.854  0.06558 .  
SexMale          -0.002187   0.006911  -0.316  0.75213    
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Works Cited:

1. R Core Team. R: A language and environment for statistical computing. (R Foundation for Statistical Computing, Vienna, Austria 2017)
2. Lenth R. V. Least-squares means: The R package lsmeans. *J. of Stat. Soft.* **69**, 1–33 (2016).

Supplemental Information 3: Variance estimates

One prediction of directional selection is a decrease in trait variance after the selection event[1]. We tested this prediction by investigating body size-corrected residuals of the suite of morphological traits with significant mean shifts from before and after the hurricanes hit the islands (Supplemental 2). For all animals, we calculated residuals of the log transformed morphological trait and snout-to-vent length (SVL) using the *lm()* function in R[2]. Across the whole dataset we found that trait variation decreased after the hurricanes. This was consistently the case on Pine Cay. We observed small increases in two traits on Water Cay, but decreases in the other four (Table 1).

	Pine Cay	Water Cay
Snout-vent Length	**-14.45**	**-12.97**
Humerus Residuals	**-0.0018**	0.0003
Femur Residuals	**-0.0014**	**-0.0002**
Longest Toe Residuals	**-0.0002**	**-0.0015**
Forelimb Toe Pad Residuals	**-0.0078**	0.0060
Hind Limb Toe Pad Residuals	**-0.0018**	**-0.0034**

Table 1: The change in trait variance in snout-to-vent length and five limb traits with significant mean shifts. Decreases in variance are indicated in bold.

The variance in all six of these measurements decreased among the survivors on Pine Cay and decreased in four of the six traits on Water Cay, a result unlikely to have occurred by chance (the probability of 10 out of 12 being negative is P=0.019 using a binomial test).

To control for the fact that these morphological traits are correlated, we also conducted a principal analysis on the five size-corrected limb traits that showed a significant mean shift (Table 2) and used the resulting PC axes, which by definition are independent of each other. These PCAs were calculated independently for the animals on Pine Cay and Water Cay.

```
Pine Cay Loadings:
                        PC1    PC2    PC3    PC4    PC5
femur_residuals       0.011  0.198 -0.802 -0.244 -0.508
humerus_residuals     0.157  0.234 -0.181 -0.642  0.689
longtoe_residuals     0.100  0.473 -0.341  0.707  0.386
fingerarea_residuals  0.770 -0.579 -0.223  0.127  0.081
toearea_residuals     0.611  0.589  0.397 -0.106 -0.333

Water Cay Loadings:
                        PC1    PC2    PC3    PC4    PC5
femur_residuals       0.011  0.198 -0.802 -0.244 -0.508
humerus_residuals     0.157  0.234 -0.181 -0.642  0.689
longtoe_residuals     0.100  0.473 -0.341  0.707  0.386
fingerarea_residuals  0.770 -0.579 -0.223  0.127  0.081
toearea_residuals     0.611  0.589  0.397 -0.106 -0.333
```

	Pine Cay	Water Cay
PC1	**-0.0105**	0.0034
PC2	**-0.0025**	**-0.0008**
PC3	**-0.0002**	**-0.0004**
PC4	0	**-0.0005**
PC5	0.0004	**-0.0006**

Table 2: Change in the variance of PC axes one through 5 for animals on Pine Cay and Water Cay following the hurricanes. Decreases in variance are indicated in bold.

Seven of these 10 axes showed a decrease in variance and one showed no change. Considered in conjunction with SVL, the probability of nine of 11 (not counting the tie) traits showing a decrease in variance is P=0.033 (binomial test).

Finally, we examined skewness for each trait before and after the hurricanes to determine if hurricane-related mortality would result in skewed trait distributions. We found no general pattern (Table 3). In most cases, the skew did not significantly differ from normal before or after the hurricanes (evaluated using the D'Agostino test). In some cases, a trait showed a change in mean and a reduction in variance, but skewness did not change, or changed in the direction opposite to the mean shift.

	Pine Cay			Water Cay		
	Before Skew	After Skew	Magnitude	Before Skew	After Skew	Magnitude
Snout-vent length	0.15	0.15	-	0.07	0.19	0.12
Humerus Residuals	0.76	0.76*	-	0.18	0.21	0.03
Femur Residuals	1.21*	-0.03	-1.24	-0.27	0.21	0.48
Longest Toe Residuals	0.04	-0.07	-0.11	-0.03	-0.83*	-0.80
Forelimb Toe Pad Residuals	-0.28	-0.43	-0.15	0.21	-0.54	-0.75
Hind Limb Toe Pad Residuals	0.74	-0.78*	-1.52	-0.31	-0.21	0.10

Table 3: Skewness values for SVL and five relative morphological traits from before and after the hurricanes on Pine and Water Cay. Normality of the distributions was evaluated using the D'Agostino test, and those that were significantly skewed ($P < 0.05$) have been marked with an (*).

Works Cited:

1. Endler, J. A. *Natural Selection in the Wild*. (Princeton Univ. Press, 1986).
2. R Core Team. R: A language and environment for statistical computing. (R Foundation for Statistical Computing, Vienna, Austria 2017).