Supplementary Materials for

A general pattern of trade-offs between ecosystem resistance and resilience to tropical cyclones

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The PDF file includes:

- Supplementary text
- Figs. S1 to S4
- Tables S1 to S4
- Legends for data S1 and S2
- Legends for codes S1 and S2

Other Supplementary Material for this manuscript includes the following:

- Data S1 and S2
- Codes S1 and S2
Simulation Model

Observed resistance and resilience are calculated from different aspects of the temporal trajectory of an ecosystem response variable following a disturbance event (Fig S1). The resistance equation includes the effect size of the response and the magnitude of the stressor, whereas the resilience equation includes the effect size of the response and the time until the variable returns to baseline conditions (see methods). The resistance equation is multiplied by -1 to flip the axis and make it conform to an intuitive directionality: low resistance = low metric value. Given the shared numerator of these two equations and the flipped axis on the resistance equation, there is a bias for these two metrics to be negatively related to one another.

To evaluate the degree to which the formulas for observed resistance and resilience influences the relationship between these variables, independent of the biological processes of interest, we developed a series of simulation models and compared these models to each other and to our data. We designed one set of simulation models to be based on the processes in our a priori conceptional model of how intrinsic resistance and resilience drive ecosystem response to a disturbance. We used these models to evaluate how different relationships between intrinsic resistance and resilience affect observed resistance and resilience when the system works as we predict. For our second set of simulation models, we compared our observed patterns in the data to different null models of simulated random data to determine whether our dataset could have been the product of random chance. We explain each set of simulations, the results, and our interpretation of the results in the following sections.

Process Based Simulations

Our conceptual model states that each variable of interest has an intrinsic resistance and resilience that is dictated by characteristics such as functional traits for organisms or the degree of biological control for ecosystem processes. We predict that the maximum change measured in a variable following a disturbance is positively related to stressor magnitude, but that the slope of that relationship declines with increasing intrinsic resistance (Fig S2A). Similarly, the time until a variable returns to its baseline condition is positively related to the magnitude of the response following the disturbance, but the slope of that relationship declines with increasing resilience (Fig S2B). Observed resistance and resilience serve as indicators of intrinsic resistance and resilience and are calculated from stressor intensity, maximum change following disturbance, and the return time to baseline (Fig S2C).

We had three sets of models designed to simulate the process in the aforementioned conceptual model. In each model we set either a positive, negative, or no relationship between intrinsic resistance and resilience. Each set of models consisted of simulating 500 datasets each with 1000 time series (n=1500 datasets, 1.5-million-time series). For each dataset, we started by generating 1000 random stressor values from a uniform distribution from 30 to 300 (approximating the distribution of the rainfall data), 1000 intrinsic resistance values drawn randomly from a uniform distribution from 1 to 100, and 1000 pre-storm values drawn randomly from a uniform distribution from 70 to 130. In simulations with no relationship between intrinsic resistance and resilience, intrinsic resistance values were also drawn randomly from a uniform distribution from 1 to 100. In simulations with a positive relationship between intrinsic resistance and resilience, we calculated resistance by taking the corresponding resilience value and adding a random number drawn from a uniform distribution from -5 to 5 to add random noise. Lastly, for simulations with a negative relationship between intrinsic resistance and resilience, we calculated resistance as 100 minus the corresponding resilience value and adding a random number drawn from a uniform distribution from -5 to 5 to add random noise. For each observation i in each dataset, the maximum observed change ($max \Delta_i$) was calculated as:

$$max \Delta_i = \frac{Str_i \times B_i}{IR_i} + B_i + \epsilon$$

Where $Str$ is stressor intensity, $B$ is baseline value, $IR_t$ is intrinsic resistance, and $\epsilon$ is a random number drawn from a uniform distribution from -20 to 20. For each observation i in each dataset, the return time to baseline ($RT_t$) was calculated as:

$$RT_i = \left(\frac{max \Delta_i - B_i}{B_i}\right) \times \left(1 - \frac{IR_i}{100}\right) + \epsilon$$

Where $IR_t$ is the intrinsic resilience. The natural log response ration ($LRR$), observed resistance ($OR_t$), and resilience ($OR_i$) were all calculated from these values using the equations in the main text (see methods). For each simulated dataset of 1000 values, we fit a simple linear regression between observed resistance and resilience and saved the p-value, slope, and $R^2$ value of the relationship (n=500 fitted regression models per set of simulations).

Randomization Simulations

To test if the patterns we found were due to our formula choice, we ran three different sets of simulations with randomly generated observations. Each set of models consisted of simulating 500 datasets each with 1000 time series. For each set of models, we compared our observed patterns in the data to different null models of simulated random data to determine whether our dataset could have been the product of random chance.
series (n=1500 datasets, 1.5-million time series). In all three sets of simulations we randomly generated the baseline value, stressor value, maximum proportional change, and return time for each time series. We then calculated LRR, ORL, and ORL using the equations in the main text. For the first set of simulations, we drew all of the random values from uniform distributions. In the second set of simulations, we randomly selected the values for baseline, stressor, maximum proportional change, and return time from the observations in our dataset; we performed the random selection process separately for each variable. For the third set of simulations, we randomly selected values from our dataset, however, the stressor and maximum proportional change values were drawn from the same observation; all other variables were selected independently. This third version of the model preserved the likely link between stressor intensity and response magnitude while breaking any non-random association between response magnitude and return time. For each simulated dataset of 1000 values, we fit a simple linear regression between observed resistance and observed resilience and saved the p-value, slope, and $R^2$ value of the relationship (n=500 fitted regression models per set of simulations).

We compared the parameters from the null models to the parameters from a simple linear regression model fit to the entire observed dataset as well as regressions fit to random subsets of the data to consider the effect of potential outliers on the shape of the relationship in our data. Following a similar approach to the simulations, we randomly selected 500 observations without replacement from our dataset 500 times and fit a regression model to each random subset. The distributions of the model coefficients and goodness of fit metrics from the subsets of the dataset were compared to the distributions obtained from the simulations.

Results

Process Based Simulations

The relationship between observed resistance and resilience was different for each of the three process-based simulations. The version with no relationship between intrinsic resistance and resilience generated slightly positive observed relationships on average (slope: 0.026 ± 0.017 SD), explained very little variation ($R^2$: 0.002 ± 0.003 SD), and most outcomes were not statistically significant (65.8% had $p$-value > 0.05). For the simulations with a positive relationship between intrinsic resistance and resilience, relationships between observed resistance and resilience were all positive (slope: 0.322 ± 0.015 SD), explained 0.299 ± 0.019 SD variation, and were all statistically significant at an $\alpha$ of 0.05. Lastly, the simulations that had a negative relationship between intrinsic resistance and resilience generated negative relationships between observed resistance and resilience (slope: -0.709 ± 0.019 SD), which explained 0.732 ± 0.017 SD of the variation, and were all statistically significant at an $\alpha$ of 0.05.

In conclusion, the process-based simulations demonstrate two important points. First, despite the bias toward a negative relationship between observed resistance and resilience in our equations, it is not a forgone conclusion that these metrics are negatively related in nature. Our process-based simulations showed that the relationship between observed resistance and resilience could be positive, negative, or nonexistent (Fig. S3).

Secondly, the simulation demonstrates that if our conceptual model (Fig. S2) accurately represents natural, biological processes, then the relationship between observed resistance and resilience that we measure is indicative of the relationship between intrinsic resistance and intrinsic resilience.

Random Simulations

The random simulations all produced negative relationships between observed resistance and resilience (Fig. S4), however, all outputs were significantly different from our observed relationships in terms of slope (observed dataset slope: -0.375) and variation explained (observed dataset $R^2$: 0.429) by the linear regression model. The simulations that used randomly generated data had a very poor fit, exhibiting a mean slope of -0.075 ± 0.025 SD and a mean $R^2$ value of 0.010 ± 0.007 SD (Fig. S4). The models based on random draws from our observed data had better fits but still had significantly shallow slopes (all random: -0.246 ± 0.020 SD, partial random: -0.245 ± 0.019 SD) as well as lower explanatory power than the observed data (all random: 0.134 ± 0.029 SD, partial random: 0.130 ± 0.027 SD).

The random simulations demonstrate that in a completely random world, there is, as we expected, a bias toward negatively relationships between observed resistance and resilience. However, it is extremely unlikely that the relationships in our dataset were produced by this alone. First, the completely random simulation (Fig. 4, Row 1) suggests that the bias toward negatively relationships with completely random data may be very subtle in terms of slope and explanatory power. Second, in a direct test of the alternate hypothesis that patterns in our dataset were generated by chance, we found that the simulated data failed to capture the shape of the relationship between observed resistance and resilience. The simulations which drew random values from our observed data explained
roughly 30% less variation (observed data: 42.9% vs. randomized data: 13.4%) and the slopes were significantly shallower than what we observed (observed data: -0.375 vs. randomized data: -0.245). This latter comparison may also be very conservative. The data we randomized in the second and third simulations were, in all likelihood, created by biologically important processes and so the distributions we drew from had a higher chance of reproducing the observed patterns than completely randomly generated observations.

**Conclusions**

We interpret the results of the simulations to indicate that a variety of relationships between observed resistance and observed resilience are possible and that the patterns in our data could not have been generated solely by random chance and must have been the result of deterministic processes. We use this premise as justification to use standard statistical tools to quantify the relationships and attempt to infer process from the observed patterns.
Fig. S1. Simple diagram showing the temporal trajectory of a measured variable before, during, and after a hurricane disturbance. Two of the key variables we use to measure observed resistance (effect size) and resilience (return time, effect size) are labeled in the diagram. Figure was modified from Hogan et al. 2020 with permission from the American Institute of Biological Sciences and Oxford University Press (8).
**Fig. S2.** Conceptual model of how the latent variables, intrinsic resistance and intrinsic resilience, influence the effect of stressor magnitude on maximum change and maximum change on return time. The diagram also shows how log response ratio, observed resistance, and observed resilience are calculated from the observations of stressor magnitude, maximum change, and return time. The conceptual model treats observed resistance and resilience as measurable indicators of the latent variable’s intrinsic resistance and resilience.
**Fig. S3.** Summarized results of process-based simulation models. Columns show different outputs from the three types of simulations (rows). Outer columns show example relationships between intrinsic resistance and intrinsic resilience (left) and observed resistance and resilience (right). The center three columns are distributions of fitted model parameters (slope, $R^2$, $p$-value) across all simulations for each set.
Figure S4. Summarized results of randomized simulation models. Each row corresponds to a different set of models. The columns show different outputs from the simulations. In each graph, blue denotes our dataset and red denotes randomized data. In the histograms, solid lines are means and dotted lines are the 95% confidence intervals. From left to right, columns 1-3 display distributions of model parameters (slope, $R^2$, p-value) from across simulation runs. The right column shows the relationship between observed resistance and resilience for the observed dataset (blue points) and for one example of the randomized data (red points). The lines in the scatterplots are best fit lines (light blue = observed data, pink = randomized data).
Table S1.
Mixed Effects Model Significance Tests. Each row corresponds to a model to fit to the entire dataset with the response and fixed effect corresponding to the response and predictor columns. For the first two rows, variable category within ecosystem type was treated as a random intercept effect (reported in Table S2). For the remaining rows corresponding to models linking ecosystem sensitivity to stressor intensity, variable category was treated as a random slope effect (reported in Table S2).

| Response                     | Predictor            | DF   | F     | P-value | Marginal R² | Conditional R² |
|------------------------------|----------------------|------|-------|---------|-------------|----------------|
| ln(Resistance to Wind Speed) | Resilience           | 1,10 | 48.78 | < 0.001 | 0.493       | 0.672          |
| ln(Resistance to Rainfall)   | Resilience           | 1,9  | 22.73 | < 0.001 | 0.389       | 0.657          |
| Resilience                   | Max Wind             | 1,5  | 0.28  | 0.617   | 0.012       | 0.276          |
| Resilience                   | Max Rain             | 1,3  | 0.012 | 0.923   | 0.002       | 0.291          |
| Resilience                   | Total Rain           | 1,3  | 0.207 | 0.680   | 0.002       | 0.291          |
| Resistance to Wind Speed     | Max Wind             | 1,5  | 18.59 | 0.005   | 0.051       | 0.197          |
| Resistance to Rainfall       | Max Rain             | 1,7  | 24.38 | 0.002   | 0.189       | 0.365          |
| Resistance to Rainfall       | Total Rain           | 1,8  | 24.42 | < 0.001 | 0.170       | 0.337          |
Table S2.
Mixed Effects Model Coefficients. For all models referenced in Table S1, the corresponding model coefficients including fixed intercept, fixed slope, random intercept, and where applicable, random slope are reported here as well as the categorical groupings (ecosystem type, variable category) to which these coefficients correspond.

| Response                          | Predictor | Fixed Intercept | Fixed Slope | System       | Variable Category | Random Intercept | Random Slope |
|-----------------------------------|-----------|-----------------|-------------|--------------|-------------------|------------------|--------------|
| ln(Resistance to Wind Speed)      | Resilience| 1.089           | -0.095      | Freshwater   | Biogeochemistry   | 1.534            | -0.003       |
|                                   |           |                 |             | Freshwater   | Hydrography       | 1.304            | -0.081       |
|                                   |           |                 |             | Freshwater   | Mobile Biota      | 0.864            | -0.146       |
|                                   |           |                 |             | Saline       | Biogeochemistry   | 1.039            | -0.101       |
|                                   |           |                 |             | Saline       | Hydrography       | 1.165            | -0.068       |
|                                   |           |                 |             | Saline       | Mobile Biota      | 1.173            | -0.078       |
|                                   |           |                 |             | Saline       | Sedentary Fauna   | 0.943            | -0.122       |
|                                   |           |                 |             | Saline       | Vascular Plant    | 0.787            | -0.165       |
|                                   |           |                 |             | Terrestrial  | Biogeochemistry   | 0.950            | -0.114       |
|                                   |           |                 |             | Terrestrial  | Hydrography       | 1.026            | -0.113       |
|                                   |           |                 |             | Terrestrial  | Vascular Plant    | 1.265            | -0.059       |
|                                   |           |                 |             | Wetland      | Mobile Biota      | 1.039            | -0.094       |
|                                   |           |                 |             | Wetland      | Vascular Plant    | 1.061            | -0.096       |
|                                   |           |                 |             | -           | Biogeochemistry   | 1.063            | -0.096       |
|                                   |           |                 |             | -           | Hydrography       | 1.132            | -0.094       |
|                                   |           |                 |             | -           | Mobile Biota      | 1.074            | -0.096       |
|                                   |           |                 |             | -           | Sedentary Fauna   | 1.082            | -0.096       |
|                                   |           |                 |             | -           | Vascular Plant    | 1.092            | -0.095       |
| ln(Resistance to Rainfall)        | Resilience| 1.397           | -0.076      | Freshwater   | Biogeochemistry   | 1.783            | 0.009        |
|                                   |           |                 |             | Freshwater   | Hydrography       | 1.712            | -0.037       |
|                                   |           |                 |             | Freshwater   | Mobile Biota      | 1.187            | -0.130       |
|                                   |           |                 |             | Saline       | Biogeochemistry   | 1.426            | -0.070       |
|                                   |           |                 |             | Saline       | Hydrography       | 1.544            | -0.047       |
|                                   |           |                 |             | Saline       | Mobile Biota      | 1.130            | -0.104       |
|                                   |           |                 |             | Saline       | Sedentary Fauna   | 1.200            | -0.115       |
|                                   |           |                 |             | Saline       | Vascular Plant    | 0.989            | -0.158       |
|                                   |           |                 |             | Terrestrial  | Biogeochemistry   | 1.223            | -0.101       |
|                                   |           |                 |             | Terrestrial  | Hydrography       | 1.285            | -0.105       |
|                                   |           |                 |             | Terrestrial  | Vascular Plant    | 1.751            | 0.004        |
|                                   |           |                 |             | Wetland      | Mobile Biota      | 1.593            | -0.050       |
|                                   |           |                 |             | Wetland      | Vascular Plant    | 1.343            | -0.083       |
|                                   |           |                 |             | -           | Biogeochemistry   | 1.395            | -0.076       |
|                                   |           |                 |             | -           | Hydrography       | 1.402            | -0.076       |
|                                   |           |                 |             | -           | Mobile Biota      | 1.397            | -0.076       |
|                                   |           |                 |             | -           | Sedentary Fauna   | 1.397            | -0.076       |
|                                   |           |                 |             | -           | Vascular Plant    | 1.397            | -0.076       |
| Resilience                        | Max Wind  | -4.331          | -0.227      | Freshwater   | Biogeochemistry   | -4.007           | 0.021        |
|                                   |           |                 |             | Freshwater   | Hydrography       | -1.405           | -0.492       |
|                                   |           |                 |             | Freshwater   | Mobile Biota      | -4.686           | -0.187       |
|                                   |           |                 |             | Saline       | Biogeochemistry   | -4.779           | -0.173       |
|                                   |           |                 |             | Saline       | Hydrography       | -5.622           | -0.023       |
|                                   |           |                 |             | Saline       | Mobile Biota      | -5.073           | 0.115        |
|                                   |           |                 |             | Saline       | Sedentary Fauna   | -4.665           | -0.218       |
|                                   |           |                 |             | Saline       | Vascular Plant    | -3.028           | -0.465       |
|                                   |           |                 |             | Terrestrial  | Biogeochemistry   | -7.941           | 0.055        |
|                                   |           |                 |             | Terrestrial  | Hydrography       | -4.355           | -0.314       |
|                                   |           |                 |             | Terrestrial  | Vascular Plant    | -3.881           | -0.262       |
|                                   |           |                 |             | Wetland      | Mobile Biota      | -1.322           | -1.017       |
|                                   |           |                 |             | Wetland      | Vascular Plant    | -5.535           | -0.095       |
| Resilience                        | Max Rain  | -4.915          | -0.048      | Freshwater   | Biogeochemistry   | -4.831           | 0.191        |
|                                   |           |                 |             | Freshwater   | Hydrography       | -4.370           | 0.170        |
|                                   |           |                 |             | Freshwater   | Mobile Biota      | -5.406           | 0.019        |
| Residence       | Total Rain | -5.046 | 0.041 |
|-----------------|------------|--------|-------|
| Freshwater      | Biogeochemistry | -5.558 | 0.158 |
| Freshwater      | Hydrography | -4.465 | 0.193 |
| Freshwater      | Mobile Biota | -5.344 | 0.021 |
| Saline          | Biogeochemistry | -5.608 | 0.113 |
| Saline          | Hydrography | -5.912 | 0.087 |
| Saline          | Mobile Biota | -4.885 | 0.042 |
| Saline          | Sedentary Fauna | -5.280 | 0.063 |
| Saline          | Vascular Plant | -4.062 | 0.346 |
| Terrestrial     | Biogeochemistry | -5.836 | 0.334 |
| Terrestrial     | Hydrography | -5.057 | 0.153 |
| Terrestrial     | Vascular Plant | -5.609 | 0.163 |
| Wetland         | Mobile Biota | -3.095 | 0.324 |
| Wetland         | Vascular Plant | -5.891 | 0.008 |

| Resistance to Wind Speed | Max Wind | 4.052 | 0.252 |
|---------------------------|---------|------|------|
| Freshwater                | Biogeochemistry | 3.269 | 0.291 |
| Freshwater                | Hydrography | 4.509 | 0.170 |
| Freshwater                | Mobile Biota | 4.010 | 0.238 |
| Saline                    | Biogeochemistry | 3.923 | 0.293 |
| Saline                    | Hydrography | 3.757 | 0.361 |
| Saline                    | Mobile Biota | 3.862 | 0.388 |
| Saline                    | Sedentary Fauna | 4.083 | 0.235 |
| Saline                    | Vascular Plant | 3.202 | 0.471 |
| Terrestrial               | Biogeochemistry | 5.467 | 0.153 |
| Terrestrial               | Hydrography | 4.103 | 0.297 |
| Terrestrial               | Vascular Plant | 3.927 | 0.241 |
| Wetland                   | Mobile Biota | 3.680 | 0.263 |
| Wetland                   | Vascular Plant | 4.879 | 0.075 |

| Resistance to Rainfall    | Max Rain | 5.031 | 0.253 |
|---------------------------|---------|------|------|
| Freshwater                | Biogeochemistry | 4.496 | 0.230 |
| Freshwater                | Hydrography | 5.553 | 0.165 |
| Freshwater                | Mobile Biota | 5.108 | 0.217 |
| Saline                    | Biogeochemistry | 5.744 | 0.111 |
| Saline                    | Hydrography | 5.643 | 0.149 |
| Saline                    | Mobile Biota | 4.044 | 0.353 |
| Saline                    | Sedentary Fauna | 4.931 | 0.204 |
| Saline                    | Vascular Plant | 3.835 | 0.656 |
| Terrestrial               | Biogeochemistry | 5.472 | 0.355 |
| Terrestrial               | Hydrography | 4.848 | 0.345 |
| Terrestrial               | Vascular Plant | 4.893 | 0.242 |
| Wetland                   | Mobile Biota | 5.743 | 0.071 |
| Wetland                   | Vascular Plant | 5.183 | 0.214 |

| Resistance to Rainfall    | Total Rain | 5.195 | 0.241 |
|---------------------------|------------|------|------|
| Freshwater                | Biogeochemistry | 4.641 | 0.240 |
| Freshwater                | Hydrography | 5.608 | 0.170 |
| Freshwater                | Mobile Biota | 5.117 | 0.219 |
| Saline                    | Biogeochemistry | 5.882 | 0.082 |
| Saline                    | Hydrography | 5.720 | 0.139 |
| Saline                    | Mobile Biota | 3.991 | 0.424 |
| Saline                    | Sedentary Fauna | 4.902 | 0.242 |
| Saline                    | Vascular Plant | 4.399 | 0.558 |
| Terrestrial               | Biogeochemistry | 5.761 | 0.336 |
| Terrestrial               | Hydrography | 5.080 | 0.302 |
|          |                 |         |   |
|--------|----------------|---------|---|
| Terrestrial | Vascular Plant | 5.219   | 0.145 |
| Wetland | Mobile Biota    | 5.378   | 0.169 |
| Wetland | Vascular Plant  | 5.841   | 0.110 |
Table S3.
Output from ANOVA models testing whether ecosystem sensitivity metrics vary significantly among variable categories and system categories. Post-hoc comparison tests are reported in Table S4. * indicates significant at an adjusted α of 0.006

| Response               | Predictor                        | Sum of Squares | DF   | F          | p-value |
|------------------------|----------------------------------|----------------|------|------------|---------|
| Resilience             | Biogeochemistry across Systems   | 704.743        | 2    | 69.306     | < 0.001*|
|                        | Residuals                        | 13005.545      | 2558 |            |         |
| Resilience             | Hydrography across Systems       | 266.285        | 2    | 44.339     | < 0.001*|
|                        | Residuals                        | 3645.404       | 1214 |            |         |
| Resilience             | Mobile Biota across Systems      | 9.457          | 2    | 0.497      | 0.609   |
|                        | Residuals                        | 1903.520       | 200  |            |         |
| Resilience             | Vascular Plant across Systems    | 10.081         | 2    | 2.452      | 0.090   |
|                        | Residuals                        | 283.726        | 138  |            |         |
| Resistance to Wind Speed| Biogeochemistry across Systems  | 124.999        | 2    | 35.234     | < 0.001*|
|                        | Residuals                        | 4537.536       | 2558 |            |         |
| Resistance to Wind Speed| Hydrography across Systems     | 11.052         | 2    | 4.714      | 0.009   |
|                        | Residuals                        | 1423.265       | 1214 |            |         |
| Resistance to Wind Speed| Mobile Biota across Systems    | 7.252          | 2    | 3.048      | 0.050   |
|                        | Residuals                        | 237.920        | 200  |            |         |
| Resistance to Wind Speed| Vascular Plant across Systems | 4.243          | 2    | 1.702      | 0.186   |
|                        | Residuals                        | 171.955        | 138  |            |         |
| Resistance to Rainfall | Biogeochemistry across Systems  | 145.135        | 2    | 42.352     | < 0.001*|
|                        | Residuals                        | 4382.938       | 2558 |            |         |
| Resistance to Rainfall | Hydrography across Systems       | 12.517         | 2    | 5.285      | 0.005*  |
|                        | Residuals                        | 1437.573       | 1214 |            |         |
| Resistance to Rainfall | Mobile Biota across Systems      | 54.876         | 2    | 14.561     | < 0.001*|
|                        | Residuals                        | 376.878        | 200  |            |         |
| Resistance to Rainfall | Vascular Plant across Systems    | 4.963          | 2    | 1.474      | 0.233   |
|                        | Residuals                        | 232.367        | 138  |            |         |
| Resilience             | Freshwater across Variables      | 65.535         | 2    | 8.281      | < 0.001*|
|                        | Residuals                        | 910.142        | 230  |            |         |
| Resilience             | Saline across Variables          | 168.320        | 4    | 9.167      | < 0.001*|
|                        | Residuals                        | 16699.022      | 3638 |            |         |
| Resilience             | Terrestrial across Variables     | 26.337         | 2    | 4.723      | 0.012   |
|                        | Residuals                        | 192.401        | 69   |            |         |
| Resilience             | Wetland across Variables         | 96.922         | 1    | 17.232     | < 0.001*|
|                        | Residuals                        | 1057.390       | 188  |            |         |
| Resistance to Wind Speed| Freshwater across Variables     | 14.224         | 2    | 8.088      | < 0.001*|
|                        | Residuals                        | 202.238        | 230  |            |         |
| Resistance to Wind Speed| Saline across Variables         | 20.441         | 4    | 3.175      | 0.013   |
|                        | Residuals                        | 5854.516       | 3638 |            |         |
| Resistance to Wind Speed| Terrestrial across Variables    | 7.076          | 2    | 1.707      | 0.189   |
|                        | Residuals                        | 143.053        | 69   |            |         |
| Resistance to Wind Speed| Wetland across Variables        | 28.680         | 1    | 28.717     | < 0.001*|
| Resistance to Rainfall | Variables               | Residuals | DF | F      | p       |
|------------------------|-------------------------|-----------|----|--------|---------|
|                        |                         | 187.752   | 188|        |         |
| Freshwater across      |                         | 22.439    | 2  | 10.091 | < 0.001*|
|                        | Residuals               | 255.724   |    |        |         |
| Saline across Variables|                         | 79.228    | 4  | 12.394 | < 0.001*|
|                        | Residuals               | 5814.140  | 3638|        |         |
| Terrestrial across     |                         | 17.228    | 2  | 3.881  | 0.025   |
|                        | Residuals               | 153.133   | 69 |        |         |
| Wetland across         |                         | 0.574     | 1  | 0.456  | 0.501   |
|                        | Residuals               | 236.716   | 188|        |         |
Table S4.

Results of post-hoc Tukey HSD tests on significant ANOVA models of differences in ecosystems sensitivity among variable categories within ecosystem types and among ecosystem types within variables.

| Response            | Classification | Dataset | Comparison                  | Difference | SE  | df  | t-ratio | p-value |
|---------------------|----------------|---------|------------------------------|------------|-----|-----|---------|---------|
| Resilience          | Ecosystem      | Biogeochemistry across Systems | Freshwater - Saline | 1.525      | 0.199 | 2558 | 7.667   | < 0.001 |
|                     |                |         | Freshwater - Terrestrial     | 3.954      | 0.338 | 2558 | 11.689  | < 0.001 |
|                     |                |         | Saline - Terrestrial         | 2.429      | 0.281 | 2558 | 8.632   | < 0.001 |
|                     |                | Hydrography across Systems    | Freshwater - Saline | 2.271      | 0.243 | 1214 | 9.331   | < 0.001 |
|                     |                |         | Freshwater - Terrestrial     | 3.444      | 1.028 | 1214 | 3.349   | 0.002   |
|                     |                |         | Saline - Terrestrial         | 1.173      | 1.002 | 1214 | 1.171   | 0.471   |
| Resistance to Wind Speed | Ecosystem | Biogeochemistry across Systems | Freshwater - Saline | -0.286    | 0.117 | 2558 | 2.438   | 0.039   |
|                     |                |         | Freshwater - Terrestrial     | -1.605     | 0.200 | 2558 | 8.033   | < 0.001 |
|                     |                |         | Saline - Terrestrial         | -1.319     | 0.166 | 2558 | 7.933   | < 0.001 |
| Resistance to Rainfall | Ecosystem | Biogeochemistry across Systems | Freshwater - Saline | -0.363    | 0.115 | 2558 | 3.145   | 0.005   |
|                     |                |         | Freshwater - Terrestrial     | -1.755     | 0.196 | 2558 | 8.938   | < 0.001 |
|                     |                | Hydrography across Systems    | Freshwater - Saline | 0.269      | 0.153 | 1214 | 1.760   | 0.184   |
|                     |                |         | Freshwater - Terrestrial     | -1.462     | 0.646 | 1214 | 2.264   | 0.061   |
|                     |                |         | Saline - Terrestrial         | -1.731     | 0.629 | 1214 | 2.752   | 0.017   |
| Mobile Biota across Systems | Ecosystem | Biogeochemistry across Systems | Freshwater - Saline | 1.104      | 0.254 | 200  | 4.349   | < 0.001 |
|                     |                |         | Freshwater - Wetland         | 0.090      | 0.263 | 200  | 0.342   | 0.937   |
|                     |                |         | Saline - Wetland             | -1.014     | 0.219 | 200  | 4.638   | < 0.001 |
| Resilience          | Variable Category | Biogeochemistry across Variables | Biogeochemistry - Hydrography | -0.432  | 0.322 | 230  | 1.342   | 0.374   |
|                     |                |         | Biogeochemistry - Mobile Biota | 1.158      | 0.345 | 230  | 3.357   | 0.003   |
|                     |                |         | Hydrography - Mobile Biota   | 1.590      | 0.406 | 230  | 3.920   | < 0.001 |
|                     |                |         | Biogeochemistry - Hydrography | 0.314      | 0.077 | 3638 | 4.091   | < 0.001 |
|                     |                |         | Biogeochemistry - Mobile Biota | -0.920     | 0.234 | 3638 | 3.933   | 0.001   |
|                     |                |         | Biogeochemistry - Sedentary Fauna | 0.467      | 0.537 | 3638 | 0.870   | 0.908   |
|                     |                |         | Biogeochemistry - Vascular Plant | -0.005     | 0.481 | 3638 | -0.011  | 1.000   |
|                     |                |         | Hydrography - Mobile Biota   | -1.234     | 0.238 | 3638 | 5.182   | < 0.001 |
|                     |                |         | Hydrography - Sedentary Fauna | 0.153      | 0.539 | 3638 | 0.284   | 0.999   |
|                     |                |         | Hydrography - Vascular Plant  | -0.320     | 0.483 | 3638 | 0.662   | 0.964   |
|                     |                |         | Mobile Biota - Sedentary Fauna | 1.387      | 0.583 | 3638 | 2.380   | 0.121   |
|                     |                |         | Mobile Biota - Vascular Plant | 0.914      | 0.531 | 3638 | 1.721   | 0.421   |
|                     |                |         | Sedentary Fauna - Vascular Plant | -0.473     | 0.719 | 3638 | -0.658  | 0.965   |
| Wetland across Variables |          |            | Mobile Biota - Vascular Plant | 1.472      | 0.355 | 188  | 4.151   | < 0.001 |
| Resistance to Wind Speed | Variable Category | Freshwater across Variables | Biogeochemistry - Hydrography | -0.602    | 0.152 | 230  | 3.963   | < 0.001 |
|                     |                |         | Biogeochemistry - Mobile Biota | -0.277     | 0.163 | 230  | 1.702   | 0.207   |
|                     |                |         | Hydrography - Mobile Biota   | 0.325      | 0.191 | 230  | 1.699   | 0.208   |
| Wetland across Variables |          |            | Mobile Biota - Vascular Plant | -0.801    | 0.149 | 188  | 5.359   | < 0.001 |
| Resistance to Rainfall | Variable Category | Freshwater across Variables | Biogeochemistry - Hydrography | -0.676    | 0.171 | 230  | 3.960   | < 0.001 |
|                     |                |         | Biogeochemistry - Mobile Biota | -0.564     | 0.183 | 230  | 3.084   | 0.006   |
|                     |                |         | Hydrography - Mobile Biota   | 0.112      | 0.215 | 230  | 0.522   | 0.861   |
|                     |                |         | Biogeochemistry - Hydrography | -0.044     | 0.045 | 3638 | -0.974  | 0.374   |
|                     |                |         | Biogeochemistry - Mobile Biota | 0.903      | 0.138 | 3638 | 6.546   | < 0.001 |
|                     |                |         | Biogeochemistry - Sedentary Fauna | -0.455     | 0.317 | 3638 | -1.435  | 0.605   |
|                     |                |         | Biogeochemistry - Vascular Plant | -0.367     | 0.284 | 3638 | -1.292  | 0.696   |
|                     |                |         | Hydrography - Mobile Biota   | 0.948      | 0.141 | 3638 | 6.743   | < 0.001 |
|                     |                |         | Hydrography - Sedentary Fauna | -0.411     | 0.318 | 3638 | -1.291  | 0.697   |
|                     |                |         | Hydrography - Vascular Plant  | -0.323     | 0.285 | 3638 | -1.131  | 0.790   |
|                     |                |         | Mobile Biota - Sedentary Fauna | -1.358     | 0.344 | 3638 | -3.950  | 0.001   |
|                     |                |         | Mobile Biota - Vascular Plant | -1.270     | 0.313 | 3638 | -4.052  | < 0.001 |
|                     |                |         | Sedentary Fauna - Vascular Plant | 0.088    | 0.424 | 3638 | 0.208   | 1.000   |
Data S1. (separate file)
Excel document with the hurricane response data and meta-data describing variable names

Data S2. (separate file)
CSV document with the hurricane response data used in the analyses

Code S1. (separate file)
R script with the code for reproducing analyses reported in the main text and the figures

Code S2. (separate file)
R script with the code for reproducing the simulation model analyses and figures reported in the supplement