SUPPLEMENTARY INFORMATION

Text S1. Wind Rose Data

A wind rose was constructed to guide initial bay site selection. Wind records over a two-year period (i.e., January 2015 – December 2016) were first obtained from the Bon Secour Bay weather station maintained by Dauphin Island Sea Lab (https://arcos.disl.org/stations/disl_stations?stationnew=106). Wind roses were then constructed for each month using the windRose function of the openair package in R (Carslaw and Ropkins 2012). Overall, wind records illustrate a gradient in both direction and speed (Figure S1.1).

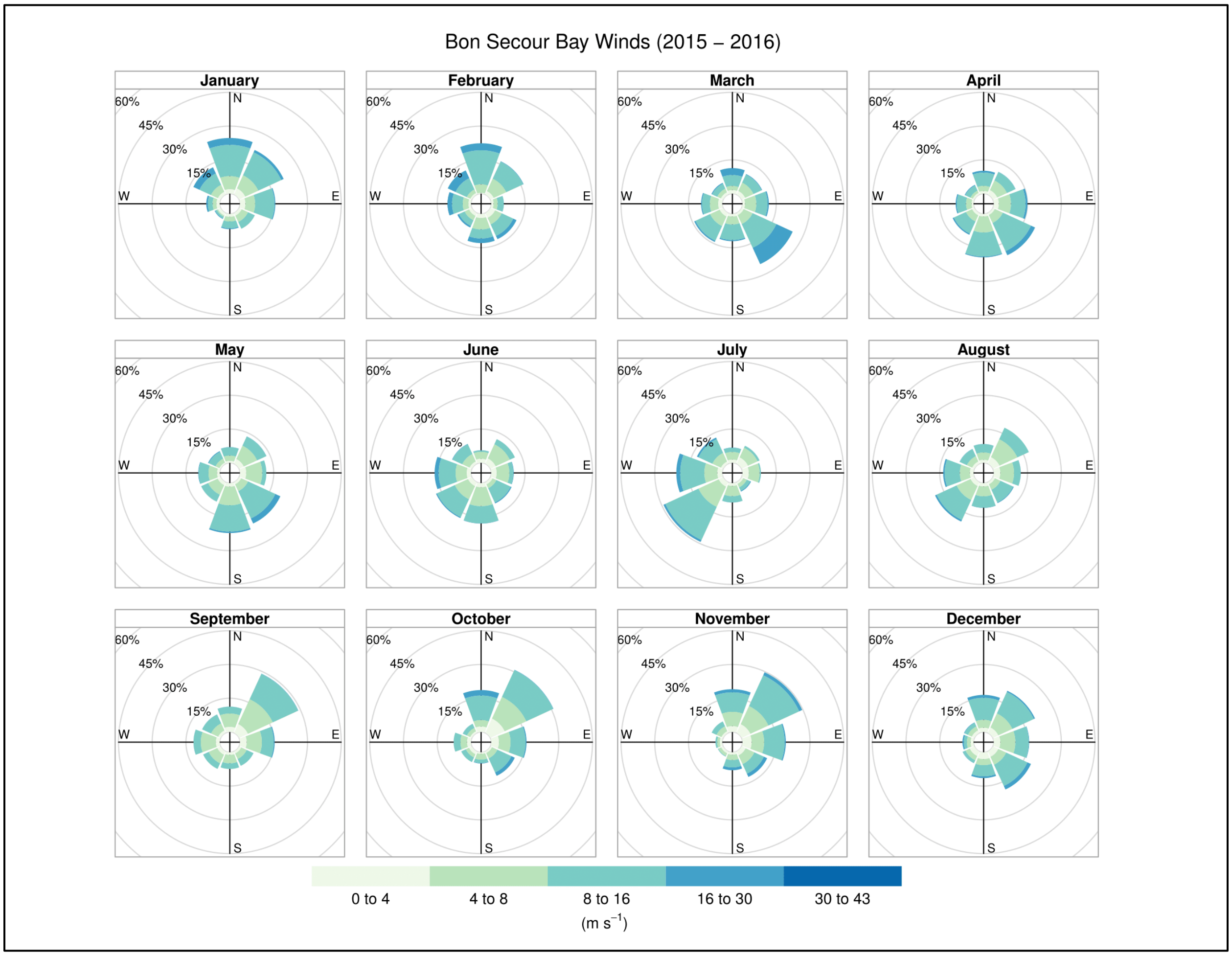

Figure S1.1. Monthly average speed (m/s) and direction of winds in Bon Secour Bay, Alabama, USA. For each month, the spokes protruding from the center indicate how often winds came out of a particular direction (i.e., longer spokes indicate winds blew more frequently from that direction). Different colors indicate how frequently winds were within a range of speeds (0-4, 4-8, 8-16, 16-30, 30-43; bottom legend). As a whole, Bon Secour Bay winds fluctuated seasonally in both speed and direction.

Text S2. Custom Corer Description and Methods

The corer was custom fabricated at the Mississippi State University Coastal Research and Extension Center using steel pipe and featured a metal hole saw (~6.5 cm) welded to one side of the corer and a "T" handle at the other (Figures S2.1). These features were designed to maximize the cutting action of the corer and to minimize compaction of the sediment layers. The corer was rotated into the sediment using a circular cutting motion until 50 cm depth or refusal was achieved. At that point, the core and its contents were removed and transported back to the boat for furthering processing. Using a knife, cores were then cut into four subsections starting from the top of the core (i.e., at the sediment surface) and every 10 cm along the core depth profile to 40 cm or, in the case of shallow refusal, the maximum depth. The trap door on the corer relieves pressure and allowed for easy extraction of the core.

Figure S2.1. Photograph of the custom fabricated corer used in this study. The corer is made from ~6.6cm steel pipe and measures nearly 64 cm in total length. A ~6.5 cm holesaw is welded to end of one side of the pipe and the other side features a removeable "T" handle that allows for cutting through root layers without compacting soil layers in the core. In addition, a trap door approximately at the center of the corer allows for easy core extraction.

Text S3. Correlation Matrices of Environmental Factors Affecting Plant Responses

Several environmental characteristics can have direct and indirect effects on plant responses (Kirwan & Megonigal 2013). Of particular interest in this study are those characteristics that affect both wave parameters (e.g., wave height and period; Sorenson 2005) and plant responses (e.g., inundation and position within the marsh platform; Morris et al. 2002), as determined by previous research examining similar relationships (Feagin et al. 2013, Silinski et al. 2015, Silinski et al. 2018). Therefore, in addition to wave and plant response data, soil bulk density, marsh platform elevation and slope data were collected from each of the study sites. Data collection and analyses are described in the sections below.

Soil Bulk Density

A mini-Russian corer (1.65 cm radius x 18 cm length) was used to extract cores from each site plot. The length of cores extracted in the field was recorded and then placed in storage bags for cooler transport to the Dauphin Island Sea Lab (DISL; Dauphin Island, Alabama, USA) for processing. At DISL, cores were gently blotted, placed in pre-weighed aluminum dishes and weighed before drying at 50^{o}C to constant mass in a commercial drying oven. Bulk Density was calculated as the dried core mass (g) divided by the core volume (cm^3).

Marsh Platform Elevation and Slope

A six meter transect running perpendicular from the center of each site shoreline was established. Using a Trimble© Real Time Kinematic (RTK) Global Positioning System (TSC-2 controller and Trimble-R8 Model-3 rover), a total of six elevation measurements and coordinate points were recorded relative to the NAVD88 datum along the perpendicular transect at one-meter increments so that three elevation points were taken above (inland) and below (toward the water) the center of plot. Marsh platform elevation was calculated as the average of the two points closest (i.e., one inland and one toward the water) to the plot center point. All elevation data was adjusted in reference to local mean sea level (MSL) at the Dauphin Island tide station (https://tidesandcurrents.noaa.gov/stationhome.html?id=8735180; e.g., Constantin et al. 2019). Slope was assessed at each site by fitting elevation data to linear models.

Statistical Analyses and Results

Environmental data were analyzed in two ways, 1) as covariates in wave models and 2) as main predictor variables for plant responses in simple linear regression. Ultimately, adding environmental data as covariates in models did not further explain the variance in plant response data so only simpler models were used. Therefore, Pearson's correlation coefficients were used in addition to linear models to summarize relationships between wave, environmental and plant response data. These correlation matrices are provided below (Table S3.2). All statistical analyses were performed in R (R core team 2020)

Site environmental characteristics, including soil bulk density, elevation, and slope varied across and within waterbodies (i.e., regions along the bay or individual rivers) but were, on average, within range of those reported within the study area (Constantin et al. 2019, Gailani et al. 2001) and characteristic of coastal marshes in the Northern GoM region (Feagin et al. 2009, McKee & Cherry 2009). Soil bulk density was greatest at WMB sites where sandy sediments are common along the shoreline (Gailani et al. 2001). Bulk density at WMB averaged 1.15 g cm^3 and ranged from 0.66 to 1.50 g cm^{-3} (Table S3.1), and was nearly an order of magnitude greater than bulk density observed at any of the other study waterbodies ($p \leq 0.05$; Table 3). Bulk density at BSB sites averaged 0.21 g cm^{-3} and was more similar to bulk density at FiR, MaR and FoR river sites ($p > 0.05$; Table S3.1), which averaged 0.16, 0.14, and 0.14 g cm^{-3}, respectively, than bulk density found at BSR river sites, which averaged 0.31 g cm^{-3} and was significantly greater than all other river sites ($p \leq 0.02$; Table S3.1). In addition, changes in bulk density were not related to increasing distance up-river at any of the rivers examined, as has been observed elsewhere (e.g., Darke & Megonigal 2003). Shoreline slope was steepest at two up-river sites within FiR and MaR at 1.04 and 0.74, respectively. Elsewhere, slope averaged a gentle 0.13, ranging from near 0 to 0.32, and was not significantly different within or between river or bay sites ($p = 0.10$; Table S3.1). Marsh platform elevation data ranged from 1.33 m below to 0.37 m above MSL (NAVD88) and was, on average, greatest at BSB sites (mean elevation = 0.08 m above MSL; Table S3.1). Platform elevation at BSR, FiR, FoR, MaR and WMB averaged 0.47, 0.24, 0.24, 0.37, and 0.46 m below MSL but were, on average, not significantly different from one another ($p \geq 0.3$; Table S3.1). Within site variation was greatest in WMB (where elevation data ranged from 1.33 m below to 0.24 m above MSL) but was fairly consistent within sites elsewhere ($p > 0.05$; Table S3.1). Elevation tended to increase with increasing distance up-river (i.e., distance from river mouth; p of linear model = 0.02) in MaR but this trend was likely driven by elevated turf-forming clusters of *C. jamaicense* that were especially prevalent in this reach of MaR. Consequently, this trend was not observed in any of the other rivers examined ($p > 0.05$).

Soil bulk density and elevation had significant effects on some plant responses including shoot density, shoot height, and biomass but trends were species-specific (Table S3.2). *Juncus* shoot density was negatively correlated with soil bulk density ($r = -0.69$; Table 5) and declined linearly along a gradient of soil bulk density which increased from less than 0.1 to over 0.4 g cm^{-3} ($R^2 = 0.48$, $p = 0.006$), while *Spartina* shoot density was positively correlated with elevation (Table S3.2) and increased along a similar gradient in elevation from less than 0.6 m below to 0.2 m above MSL ($R^2 = 0.47$, $p < 0.001$). Similar, yet contrasting, trends were observed in shoot height, which were also not related to wave climate ($p > 0.05$; Table 4) but by other environmental factors (Table S3.2). On the one hand, *Juncus* shoot length, which averaged 0.72 m and ranged 0.50 to 1.04 m in total length, were positively correlated with bulk density (Table S3.2) and increased linearly with increasing bulk density ($R^2 = 0.30$, $p = 0.04$). On the other hand, *Spartina* shoot length, which averaged 0.66 m and ranged 0.23 to 1.09 m in total length, were negatively correlated with elevation (Table S3.2) and declined linearly with increasing elevation ($R^2 = 0.64$, $p < 0.001$).

These species-specific trends continued with aboveground biomass and biomass per shoot which were not related to wave climate but rather often related to bulk density and elevation, in the case of *Juncus* and *Spartina*, respectively (Table S3.2). *Juncus* aboveground biomass averaged 760 g m^{-2} and was negatively correlated with bulk density (-0.35). Conversely, biomass per shoot tended to increase with increasing bulk density ($r = 0.42$) which is likely due to the simultaneous decline in the number of shoots along the same gradient ($r = -0.69$; Table S3.2). *Spartina* aboveground biomass, which averaged 301.8 g m^{-2}, was not related to elevation change (Table S3.2), as some have found (e.g., DeLaune et al. 1979). However, *Spartina* biomass per shoot, which averaged 2.01 g m^{-2}, tended to decline with increasing elevation ($r = -0.61$, $p < 0.05$) as the number of shoots increased along the same gradient ($r = 0.68$, $p < 0.05$; Table S3.2).

Table S3.1. Mean (± SE) environmental characteristics of data collected at each of the study waterbodies: West Mobile Bay (WMB), Bon Secour Bay (BSB), Fowl River (FoR), Fish River (FiR), Magnolia River (MaR), and Bon Secour River (BSR). Data include soil bulk density, marsh platform elevation and slope.

		Site					
Sample	**Unit**	WMB	BSB	FoR	FiR	MaR	BSR
Soil Bulk Density	g m^{-3}	1.03 ± 0.15	0.21 ± 0.05	0.14 ± 0.04	0.16 ± 0.04	0.14 ± 0.03	0.31 ± 0.03
Marsh Platform Elevation	m	-0.46 ± 0.18	0.08 ± 0.05	-0.24 ± 0.05	-0.24 ± 0.04	-0.37 ± 0.07	-0.44 ± 0.03
Slope	–	-0.14 ± 0.04	-0.17 ± 0.01	-0.10 ± 0.02	-0.12 ± 0.02	-0.10 ± 0.01	-0.13 ± 0.01

Table S3.2. Correlation matrices for plant response variables, log-transformed fiftieth percentile (H_{50}) wave height (waves), and environmental characteristics for both *J. roemerianus* and *S. alterniflora*. Plant responses include basal shoot diameter (diam), shoot height/length (length), the number of shoots m^{-2} (density), aboveground biomass g m^{-2} (aB), biomass per shoot g (sB), total live root biomass g m-2 (bB), root to shoot ratio (r:s), and percent live shoots (PL). Environmental characteristics such as marsh platform elevation (elevation) and soil bulk density (BD) are also included. Slope was similar across all sites and is excluded here. Variables include above- and below-ground data collected from each of the study sites in which each of the study species were found. Significance at the α = 0.05 level is denoted by *.

		waves	BD	elevation	diam	length	density	aB	sB	bB	r:s
Juncus roemerianus	**BD**	-0.08	—	—	—	—	—	—	—	—	—
	elevation	0.36	-0.38	—	—	—	—	—	—	—	—
	diam	-0.72*	0.21	-0.5	—	—	—	—	—	—	—
	length	0.22	0.55*	-0.53*	0.18	—	—	—	—	—	—
	density	0.15	-0.69*	0.35	-0.12	-0.18	—	—	—	—	—
	aB	0.19	-0.35	0.004	0.08	0.47	0.71*	—	—	—	—
	sB	0.26	0.42	-0.34	0.11	0.84*	-0.38	0.35	—	—	—
	bB	0.51	-0.44	0.27	-0.09	0.02	0.12	0.15	0.1	—	—
	r:s	-0.07	0.09	-0.05	-0.05	-0.2	-0.28	-0.47	-0.3	0.53*	—
	PL	-0.58*	0.3	-0.56	0.42	0.15	-0.35	-0.22	-0.05	-0.08	0.27

		waves	BD	elevation	diam	length	density	aB	sB	bB	r:s
Spartina alterniflora	**BD**	-0.08	—	—	—	—	—	—	—	—	—
	elevation	0.31	-0.2	—	—	—	—	—	—	—	—
	diam	-0.58*	0.01	-0.39	—	—	—	—	—	—	—
	length	-0.41*	0.27	-0.8*	0.56*	—	—	—	—	—	—
	density	0.3	-0.11	0.68*	-0.39	-0.75*	—	—	—	—	—
	aB	0.19	0.16	-0.1	0.23	0.04	0.36	—	—	—	—
	sB	-0.21	0.43*	-0.6*	0.57*	0.8*	-0.57*	0.4	—	—	—
	bB	-0.04	0.26	0.38	0.08	-0.36	0.31	0.05	-0.29	—	—
	r:s	-0.07	-0.16	0.17	0.15	-0.22	-0.06	-0.32	-0.32	0.51*	—
	PL	0.16	0.14	0.003	0.11	0.1	-0.02	0.18	0.36	-0.15	-0.21

Text S4. Gauge Record Data Comparisons to 10-year Wind-wave Models

Shallow water wave forecasting models were used to hindcast the long-term (i.e., 10-year) wave climate at study sites so that they could be compared to the wave climate estimated from gauge data. These comparisons were not meant to be exhaustive but rather a limited survey of six sites along northern- and southern-facing sites since these sites experience differing wind patterns during the study period (Figure S1.1).

Shallow water wind-wave models were executed as follows:

1. Ten-year wind records were collected from the Dauphin Island weather station, using data collected hourly (https://tidesandcurrents.noaa.gov/met.html?id=8735180). These data were then organized with 15^{o} directional bins (e.g., 0^{o}, 15^{o}, 30^{o} …345^{o}) for subsequent analyses.
2. Mobile Bay bathymetric data was acquired from the US National Oceanic and Atmospheric Administration's bathymetric data viewer website (https://maps.ngdc.noaa.gov/viewers/bathymetry/). This bathymetric data layer and site GPS coordinates were then imported into QGIS (QGIS Development Team 2019).
3. In QGIS, line vectors were created from the study sites across Mobile Bay to the closest reciprocal shoreline along each of the 15^{o} directions. Average depth along and total distance (i.e., fetch distance) along these vectors was then extracted using Zonal Statistics in the Raster Analysis toolbox.
4. Wind speed and direction, depth and fetch distance data were then used to generate wave height climate statistics in MATLAB (2017a) routines following spectral methods described in the US Army Corps of Engineer's Shoreline Protection Manual, Volume 1 (1984).

Wind-wave models generated spectrally significant wave height (i.e., H_{m0}) statistics, which while different, are similar to the significant wave height statistics generated for wave gauge record data (Temple et al. 2020). Modelled H_{m0} statistics were then ordered to calculate the frequency of occurrence following the methods described for gauge wave height statistics. Gauge and model-generated wave height statistics were then plotted together for qualitative comparisons of short- and long-term wave climate data. These comparisons illustrate that the similarity between gauge and modelled statistics was greatest at southern facing sites (Figure S4.1) as compared to northern facing sites (Figure S4.2), likely due to the predominance of winds out of the south during the study period (Figure S1.1).

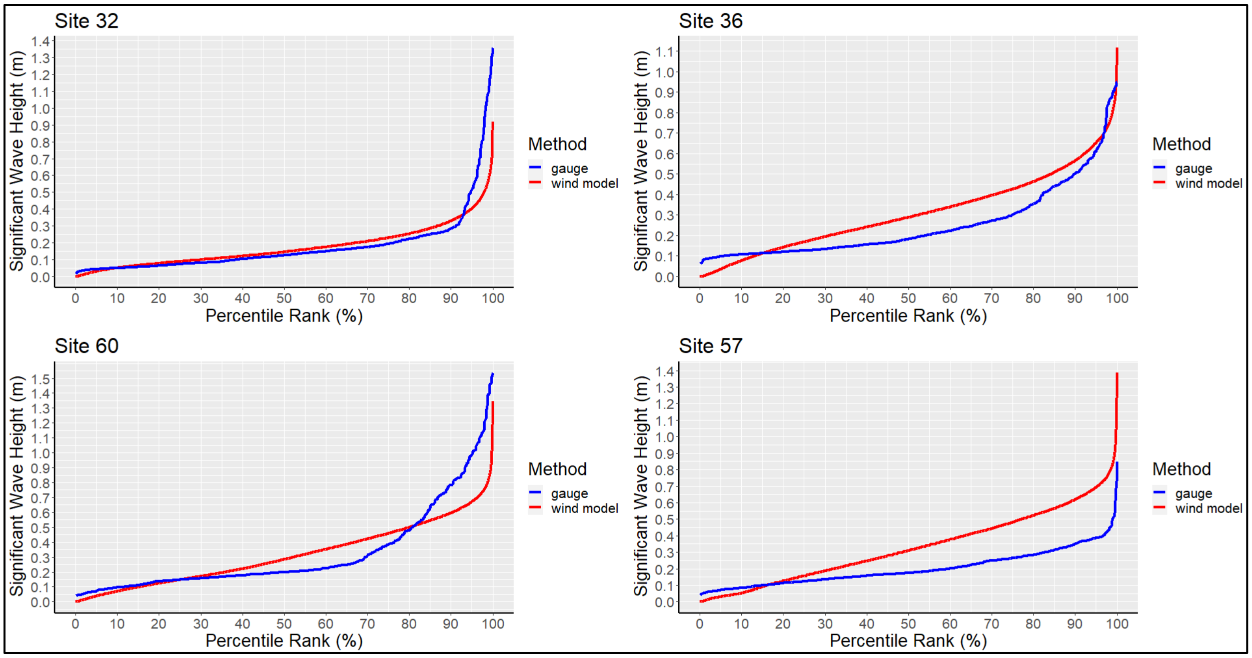

Figure S4.1. Wave statistic comparisons at southern facing sites in Mobile Bay. Significant wave height (y axis; H_s and H_{m0}, for gauge and modelled statistics respectively) is plotted against the percentile rank (x axis; i.e., cumulative frequency of occurrence). There is some deviation between gauge- (blue line) and model- (red line) generated wave statistics at site 57 but overall, gauge statistics were similar to those generated by models considering 10 year conditions.

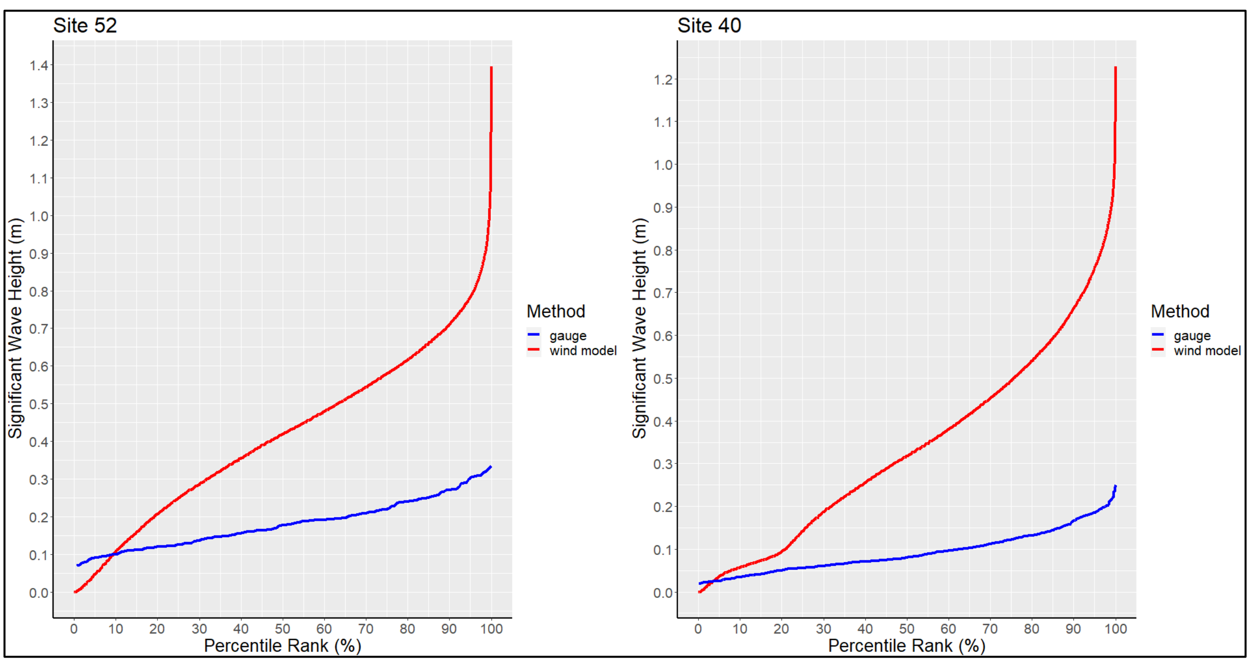

Figure S4.2. Wave statistic comparisons at northern facing sites in Mobile Bay. Significant wave height (y axis; H_s and H_{m0}, for gauge and modelled statistics respectively) is plotted against the percentile rank (x axis; i.e., cumulative frequency of occurrence). At these sites, gauge- (blue line) generated statistics tended to underestimate those generated from long-term models (red line).

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