

1 **Quantifying seagrass light requirements using an algorithm to**
2 **spatially resolve depth of colonization**

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Table 1: Characteristics of coastal segments used to evaluate seagrass depth of colonization estimates (see Fig. 2 for spatial distribution). Year is the date of the seagrass coverage and bathymetric data. Latitude and longitude are the geographic centers of each segment. Area and depth values are square kilometers and meters, respectively. Secchi measurements (m) were obtained from the Florida Department of Environmental Protection’s Impaired Waters Rule (IWR) database, update number 40. Secchi mean and standard errors are based on all observations within the ten years preceding each seagrass survey.

	BB ^a	OTB	UIRL	WCB
Year ^b	2006	2010	2009	2007
Latitude	29.61	27.94	28.61	30.43
Longitude	-83.48	-82.62	-80.77	-86.54
Surface area	271.37	205.50	228.52	59.41
Seagrass area	203.02	24.48	74.89	3.51
Depth (mean)	1.41	2.56	1.40	5.31
Depth (max)	3.60	10.40	3.70	11.90
Secchi (mean)	1.34	1.41	1.30	2.14
Secchi (se)	0.19	0.02	0.02	0.08

^a BB: Big Bend, OTB: Old Tampa Bay, UIRL: Upper Indian R. Lagoon, WCB: Western Choctawhatchee Bay

^b Seagrass coverage data sources, see methods for bathymetry data sources:

BB: http://atoll.floridamarine.org/Data/metadata/SDE_Current/seagrass_bigbend_2006_poly.htm

OTB: http://www.swfwmd.state.fl.us/data/gis/layer_library/category/swim

UIRL: <http://www.sjrwmd.com/gisdevelopment/docs/themes.html>

WCB: http://atoll.floridamarine.org/data/metadata/SDE_Current/seagrass_chotawhatchee_2007_poly.htm

Table 2: Summary of seagrass depth estimates (m) for each segment in Fig. 4. Whole segment estimates and prediction intervals were obtained from a single point estimate that included all seagrass depth data for the segment. Mean, standard error, standard deviation, minimum, and maximum values are for multiple grid points within each segment in Fig. 4. Mean and standard error estimates were from intercept-only models that included Gaussian correlation structures to account for spatial dependencies between points.

Segment^a	Whole Segment	Pred. Int. (+/-)	Mean	St. Err.	St. Dev.	Min	Max
BB							
$Z_{c, min}$	0.75	0.25	1.56	0.18	0.79	0.00	2.72
$Z_{c, med}$	2.29	0.19	1.94	0.17	0.76	0.55	2.97
$Z_{c, max}$	3.84	0.43	2.29	0.19	0.81	0.74	3.48
OTB							
$Z_{c, min}$	0.83	0.16	0.58	0.07	0.28	0.05	1.48
$Z_{c, med}$	0.95	0.07	0.86	0.08	0.30	0.33	1.74
$Z_{c, max}$	1.07	0.21	1.17	0.12	0.40	0.34	2.04
UIRL							
$Z_{c, min}$	1.19	0.04	1.36	0.06	0.27	0.75	2.01
$Z_{c, med}$	1.48	0.02	1.51	0.08	0.23	0.98	2.08
$Z_{c, max}$	1.77	0.05	1.63	0.08	0.23	1.11	2.16
WCB							
$Z_{c, min}$	1.84	0.42	1.58	0.11	0.34	0.78	2.29
$Z_{c, med}$	2.17	0.22	1.96	0.10	0.31	1.51	2.51
$Z_{c, max}$	2.50	0.47	2.36	0.14	0.39	1.75	3.10

^aBB: Big Bend, OTB: Old Tampa Bay, UIRL: Upper Indian River Lagoon, WCB: Western Choctawhatchee Bay.

Table 3: Summary of median depth of colonization ($Z_{c,med}$, m) and light requirements (%) for all bay segments of Choctawhatchee Bay, Indian River Lagoon, and Tampa Bay. Superscripts for mean $Z_{c,med}$ denote significant differences within each bay. See Figs. 7 to 9 for spatial distribution of the results.

Segment ^a	n	$Z_{c,med}$				% light			
		Mean	St. Err.	Min	Max	Mean	St. Err.	Min	Max
Choctawhatchee Bay									
CCB	171	1.9 ^{ab}	0.2	0.5	4.2	56.4	5.2	19.5	91.7
ECB	16	0.8 ^a	0.4	0.4	0.9	74.7	10.0	58.0	88.6
WCB	151	2.3 ^b	0.3	1.6	2.8	46.4	6.4	22.3	77.9
Indian River Lagoon									
BR	2	1.0 ^a	0.4	1.0	1.1	20.7	7.5	20.2	21.3
LCIRL	14	1.2 ^a	0.3	0.9	1.6	13.6	6.4	5.8	24.7
LIRL	3	1.6 ^a	0.4	1.5	1.6	9.2	7.1	6.0	11.2
LML	4	1.0 ^a	0.4	1.0	1.0	22.1	6.9	19.3	24.3
UCIRL	17	1.0 ^a	0.3	0.8	1.1	20.0	6.4	7.5	30.7
UIRL	1	1.0 ^a	0.4	1.0	1.0	24.1	8.6	24.1	24.1
UML	6	1.0 ^a	0.3	0.8	1.0	24.0	6.7	15.2	30.9
Tampa Bay									
HB	22	1.0 ^{ab}	0.2	0.6	1.3	41.1	6.0	17.7	50.8
LTB	70	1.3 ^{ab}	0.1	0.8	1.5	39.1	4.8	21.0	58.7
MTB	73	1.4 ^b	0.1	1.1	1.6	36.4	4.7	11.8	50.2
OTB	87	0.8 ^a	0.1	0.5	1.1	48.7	4.9	31.5	77.4

^aCCB: Central Choctawhatchee Bay, ECB: Eastern Choctawhatchee Bay, WCB: Western Choctawhatchee Bay, BR: Banana R., LCIRL: Lower Central Indian R. Lagoon, LIRL: Lower Indian R. Lagoon, LML: Lower Mosquito Lagoon, UCIRL: Upper Central Indian R. Lagoon, UIRL: Upper Indian R. Lagoon, UML: Upper Mosquito Lagoon, HB: Hillsborough Bay, LTB: Lower Tampa Bay, MTB: Middle Tampa Bay, OTB: Old Tampa Bay.

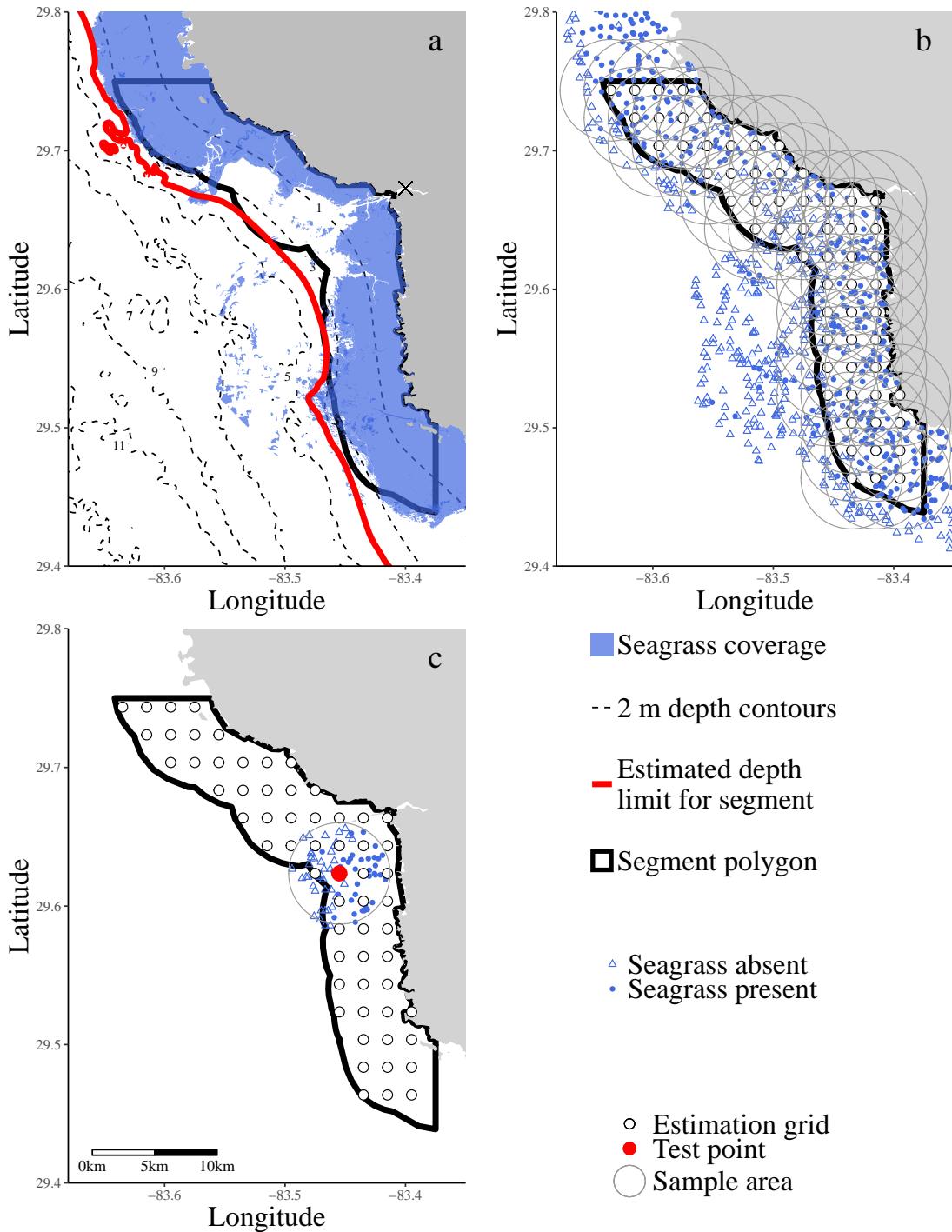


Fig. 1: Examples of data and grid locations for estimating seagrass depth of colonization for a region of the Big Bend, Florida. Subfigure a shows the seagrass coverage and depth contours at 2 meter intervals, including the whole segment estimate for depth of colonization and location of the outflow of the Steinhatchee River (x). Subfigure b shows a grid of sampling locations with sampling radii for estimating Z_c and seagrass depth points derived from bathymetry and seagrass coverage layers. Subfigure c shows an example of sampled seagrass depth points for a test location.

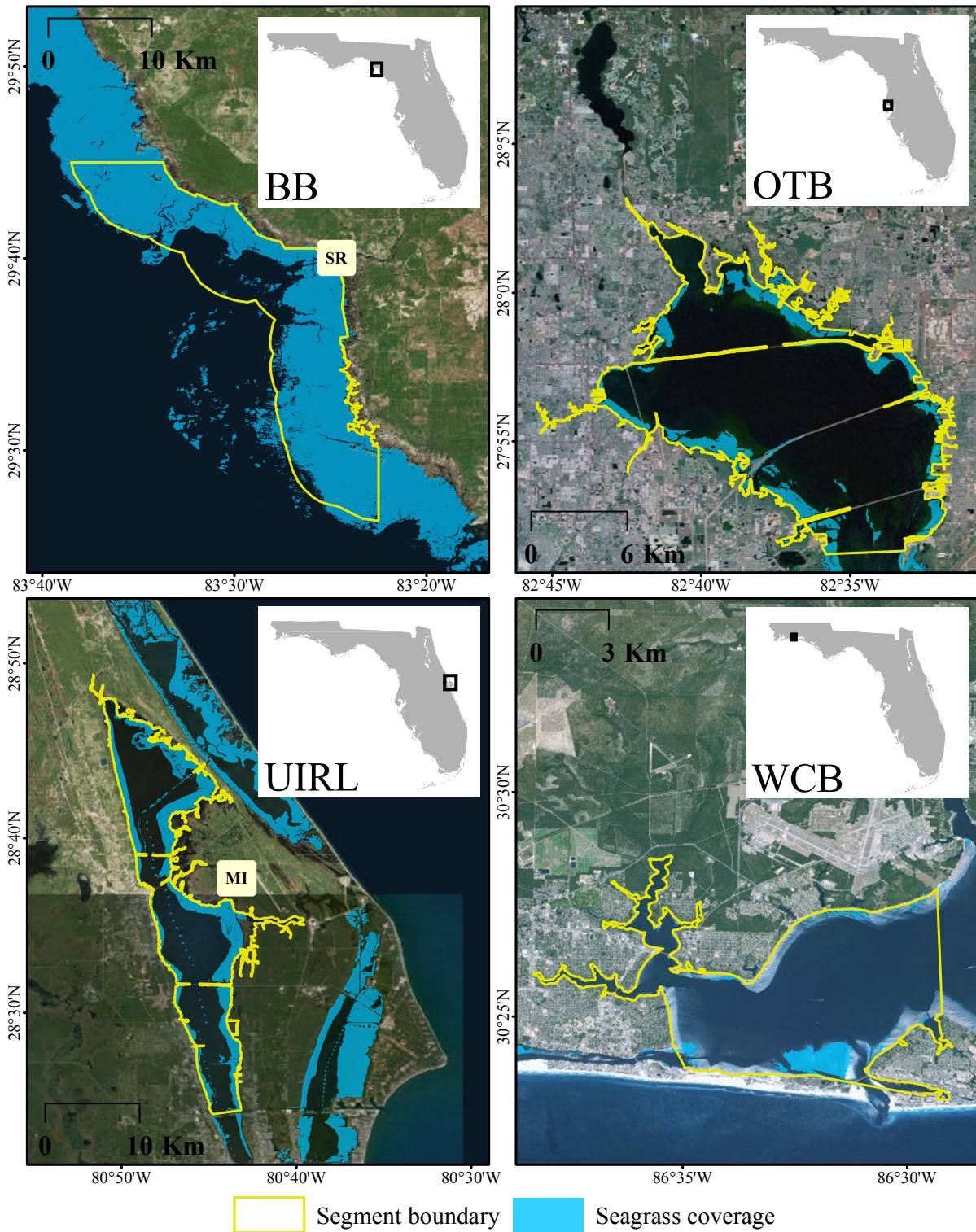


Fig. 2: Locations and seagrass coverage of estuary segments used to evaluate depth of colonization estimates. Seagrass coverage layers are from 2006 (BB: Big Bend), 2010 (OTB: Old Tampa Bay), 2009 (UIRL: Upper Indian R. Lagoon), and 2007 (WCB: Western Choctawhatchee Bay). SR: Steinhatchee River outflow, MI: Merritt Island National Wildlife Refuge.

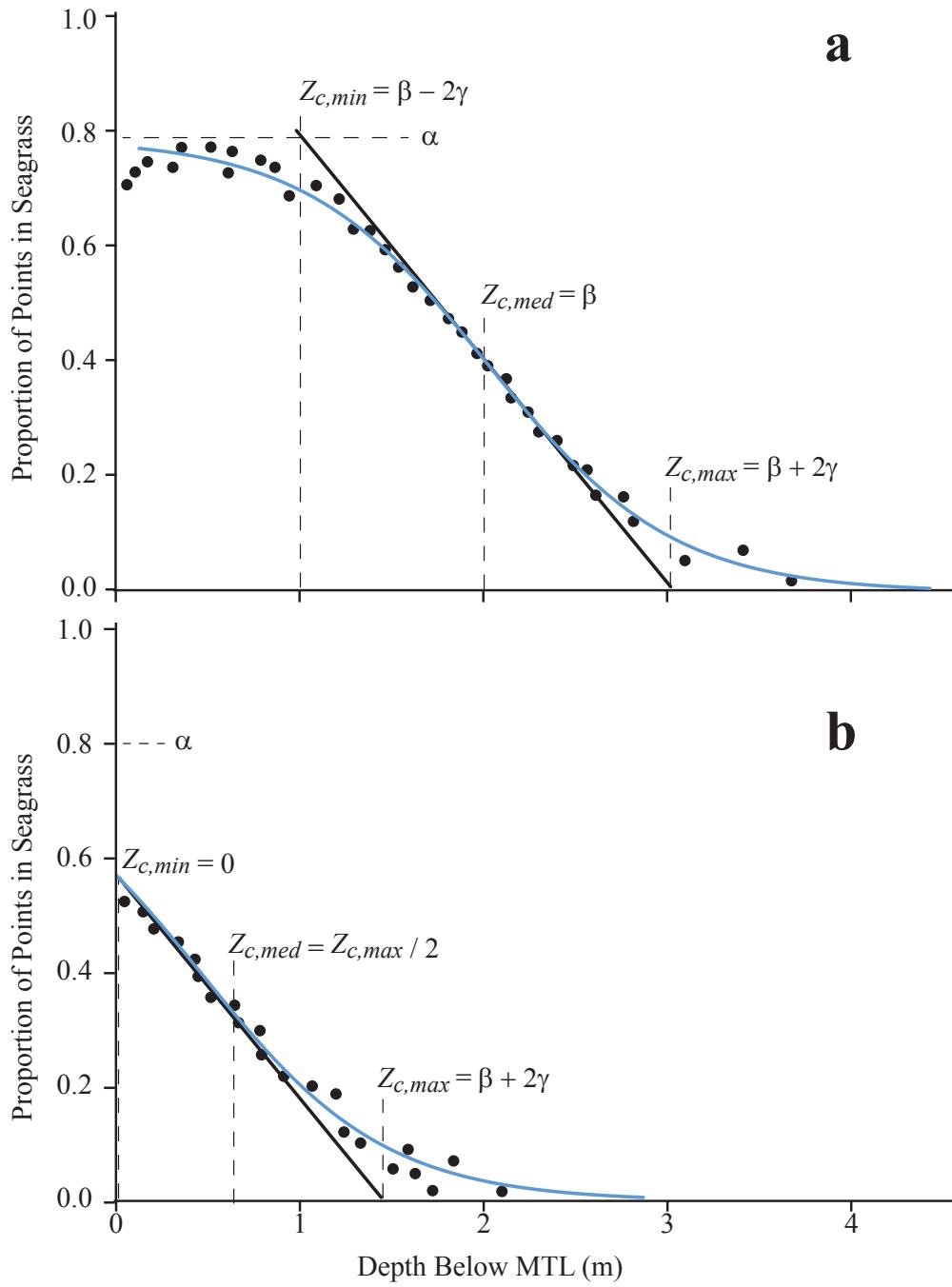


Fig. 3: Methods for estimating seagrass depth of colonization using sampled seagrass depth points around a single location. Three depth estimates ($Z_{c,min}$, $Z_{c,med}$, $Z_{c,max}$) are based on a linear curve through the inflection point of a logistic growth curve. The logistic curve is defined by the parameters α , β , and γ and describes the decrease in the proportion of sample points with seagrass as a function of depth below mean tide leavel (MTL). The top figure shows the estimation method when the linear curve intercepts α at depth greater than zero and the bottom figure shows the estimation method when the linear curve intercepts α at depth less than zero.

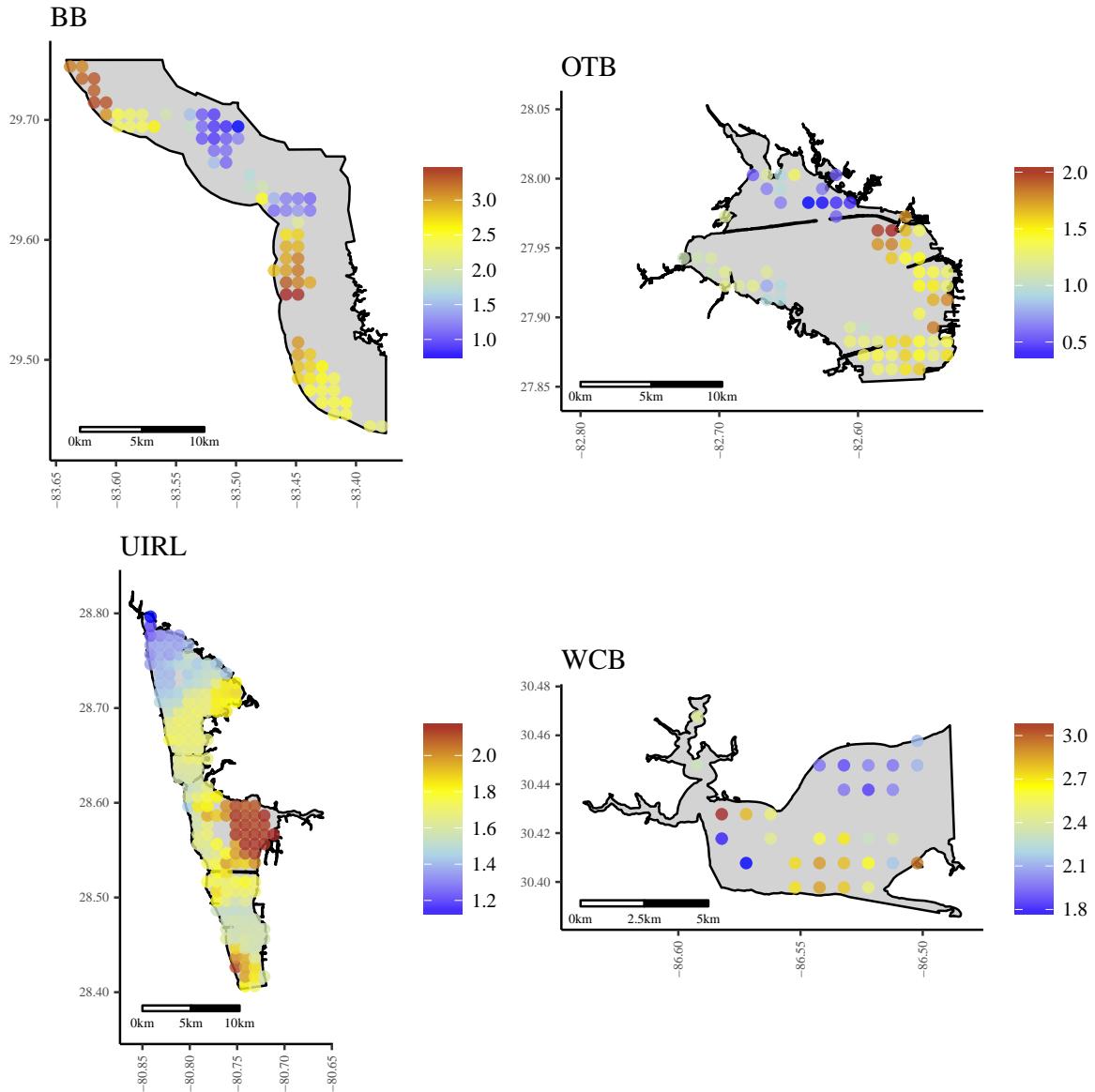


Fig. 4: Spatially-resolved estimates of maximum seagrass depth of colonization (m) for four coastal segments of Florida. Estimates are assigned to grid locations for each segment, where grid spacing was fixed at 0.01 decimal degrees. Radii for sampling seagrass bathymetric data around each grid location were fixed at 0.02 decimal degrees. BB: Big Bend, OTB: Old Tampa Bay, UIRL: Upper Indian R. Lagoon, WCB: Western Choctawhatchee Bay.

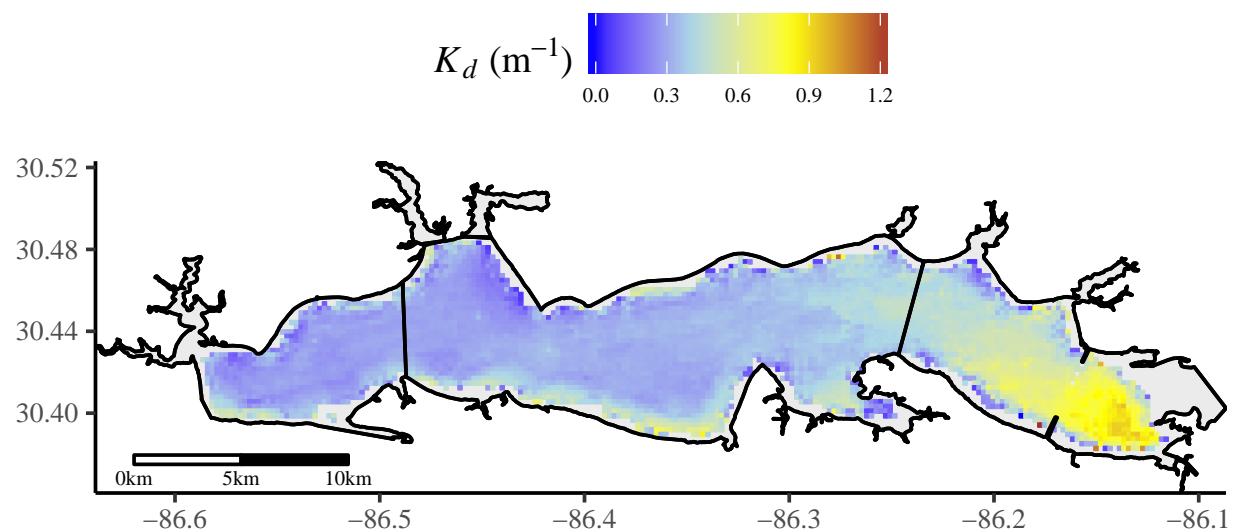


Fig. 5: Satellite estimated light attenuation for Choctawhatchee Bay as an average of all years from 2003 to 2007. See Fig. 7 for segment identification.

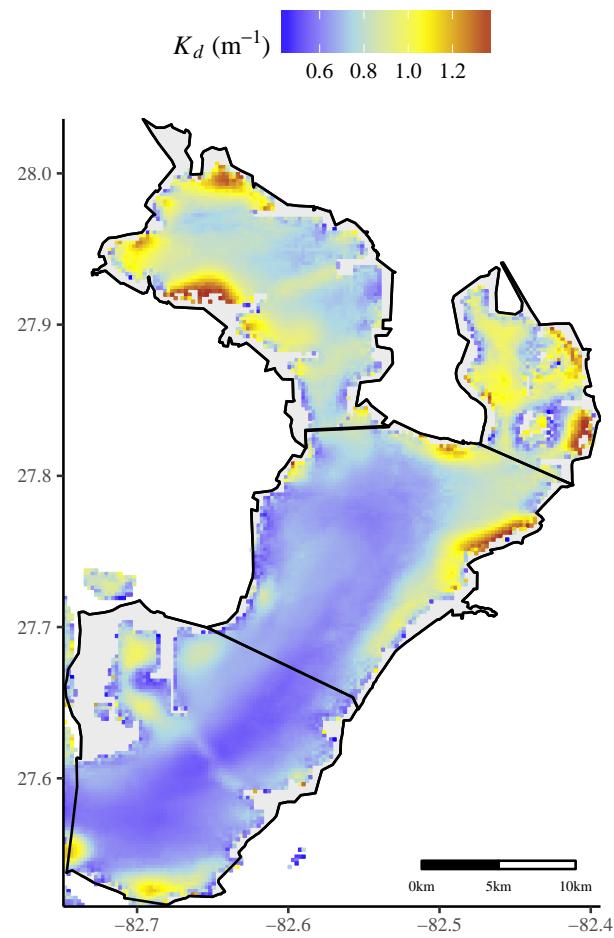


Fig. 6: Satellite estimated water clarity for Tampa Bay as an average of all years from 2006 to 2010. See Fig. 8 for segment identification.

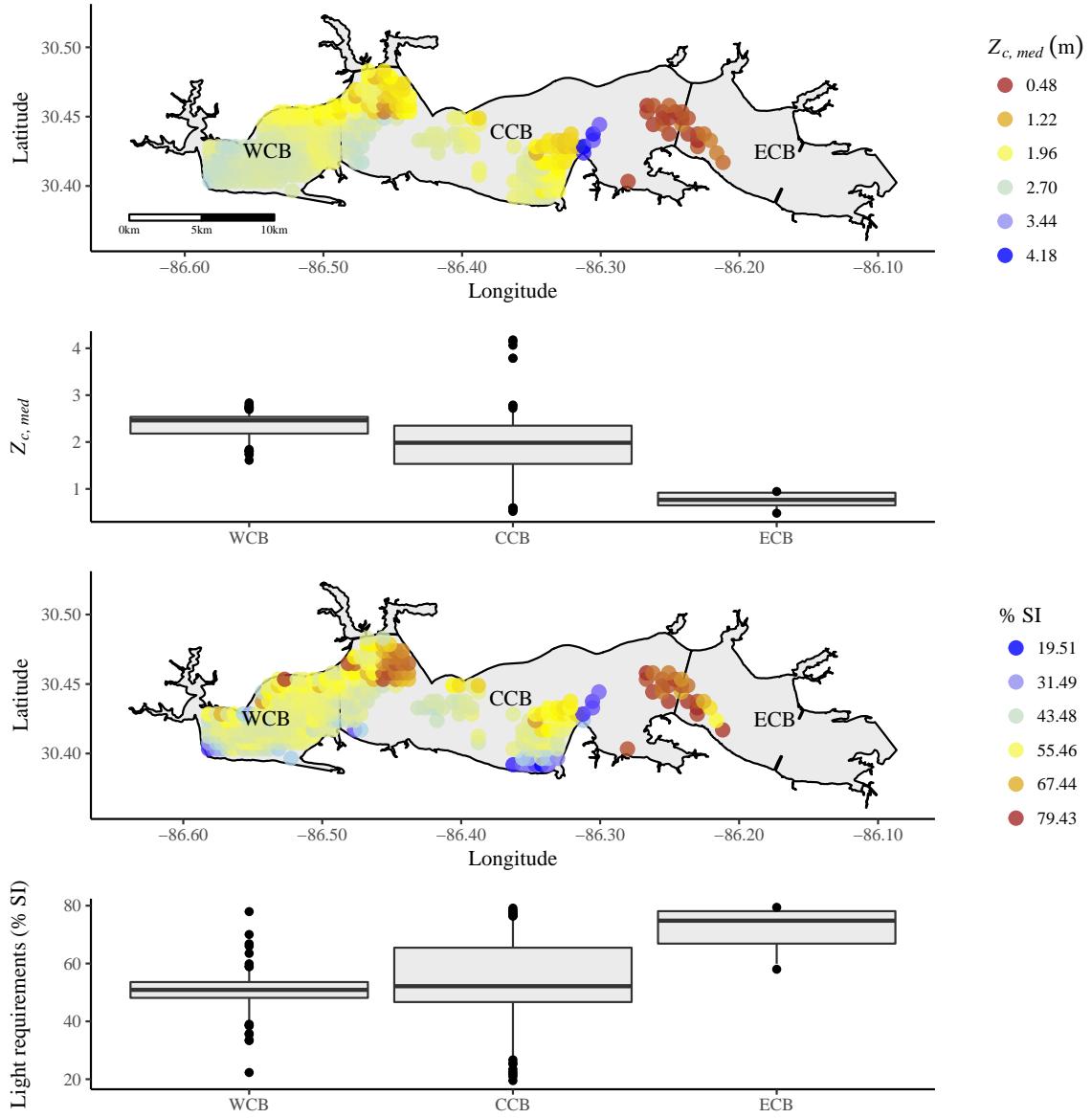


Fig. 7: Estimated median depths of seagrass colonization and light requirements for multiple locations in Choctawhatchee Bay, Florida. Locations are those where water clarity estimates were available from satellite observations and seagrass depth of colonization was estimable using a radius of 0.04 decimal degrees. Estimates are also summarized by bay segment as boxplots where the dimensions are the 25th percentile, median, and 75th percentile. Whiskers extend to the 5th and 95th percentiles with outliers beyond. CCB: Central Choctawhatchee Bay, ECB: East Choctawhatchee Bay, WCB: West Choctawhatchee Bay.

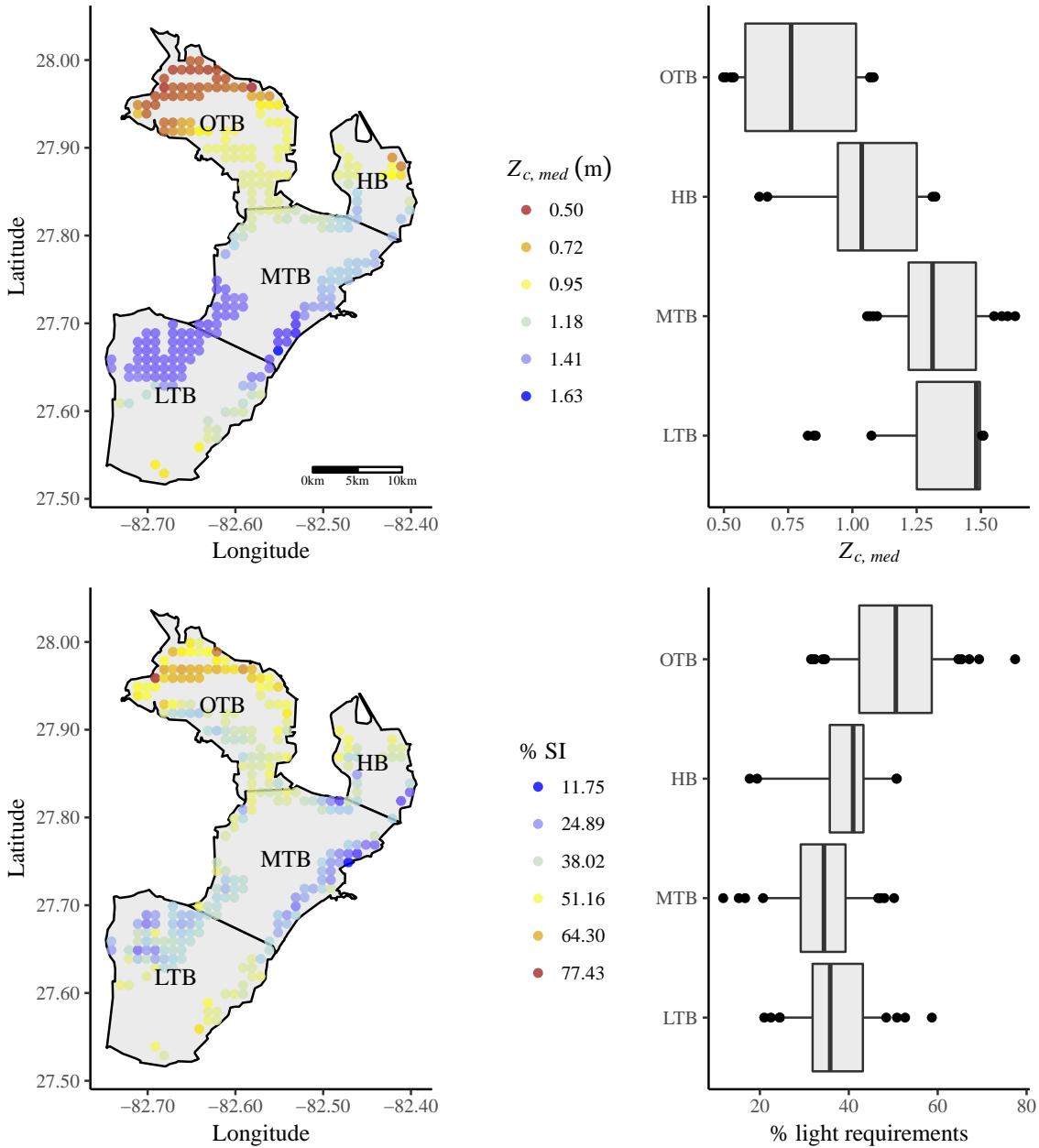


Fig. 8: Estimated median depths of seagrass colonization and light requirements for multiple locations in Tampa Bay, Florida. Locations are those where water clarity estimates were available from satellite observations and seagrass depth of colonization was estimable using a radius of 0.1 decimal degrees. Estimates are also summarized by bay segment as boxplots as in Fig. 7. HB: Hillsborough Bay, LTB: Lower Tampa Bay, MTB: Middle Tampa Bay, OTB: Old Tampa Bay.

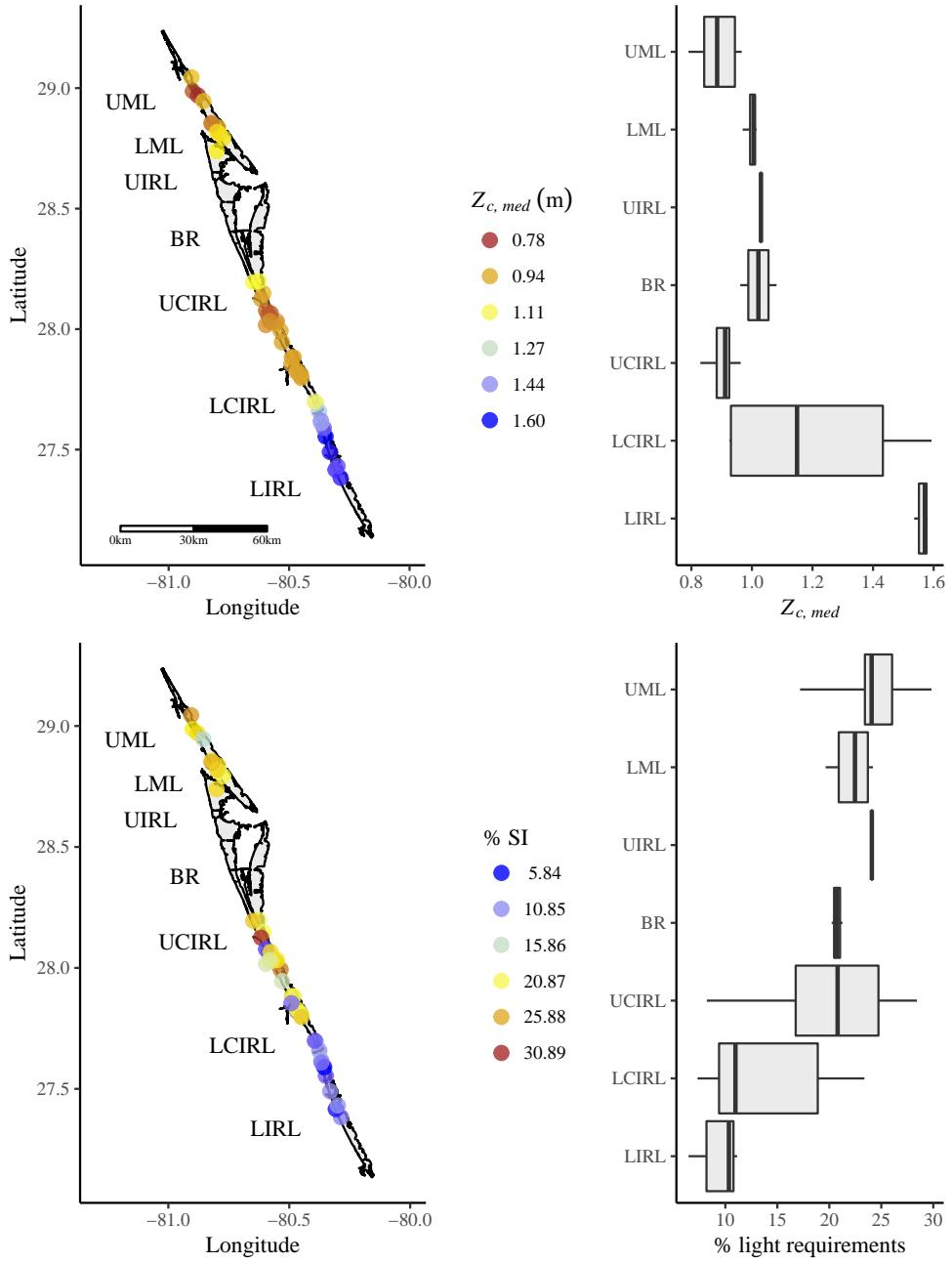


Fig. 9: Estimated median depths of seagrass colonization and light requirements for multiple locations in Indian River Lagoon, Florida. Map locations are georeferenced observations of water clarity in the Florida Impaired Waters Rule database, update 40. Estimates are also summarized by bay segment as boxplots as in Fig. 7. Light requirements are based on averaged secchi values within ten years of the seagrass coverage data and estimated maximum depth of colonization using a radius of 0.15 decimal degrees for each secchi location to sample seagrass depth points. BR: Banana R., LCIRL: Lower Central Indian R. Lagoon, LIRL: Lower Indian R. Lagoon, LML: Lower Mosquito Lagoon, LSL: Lower St. Lucie, UCIRL: Upper Central Indian R. Lagoon, UIRL: Upper Indian R. Lagoon, UML: Upper Mosquito Lagoon.

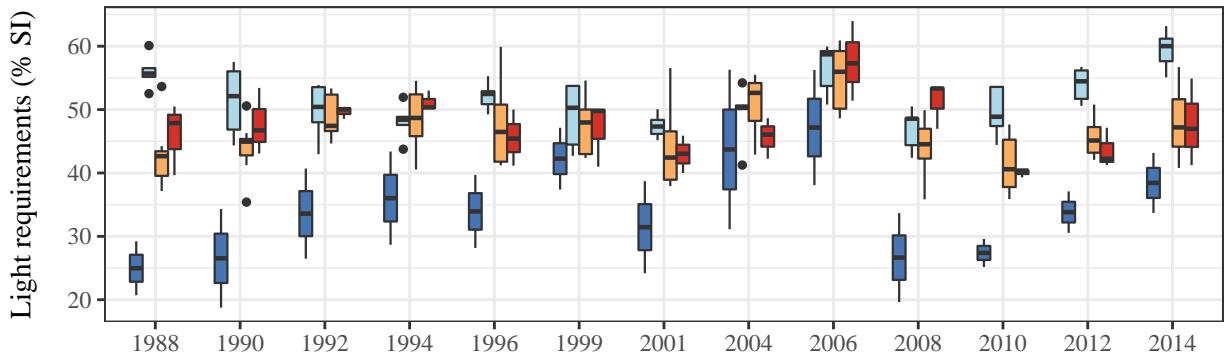
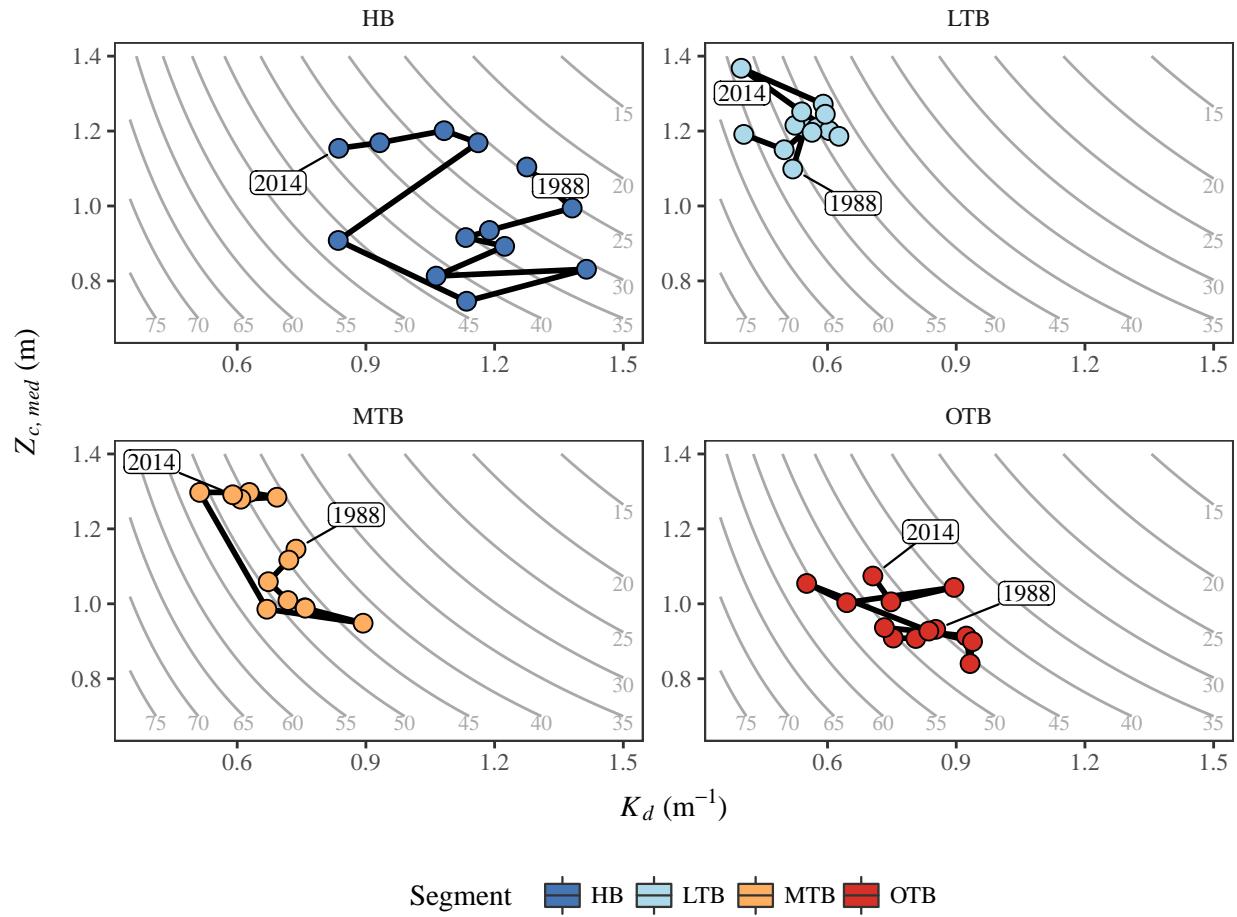
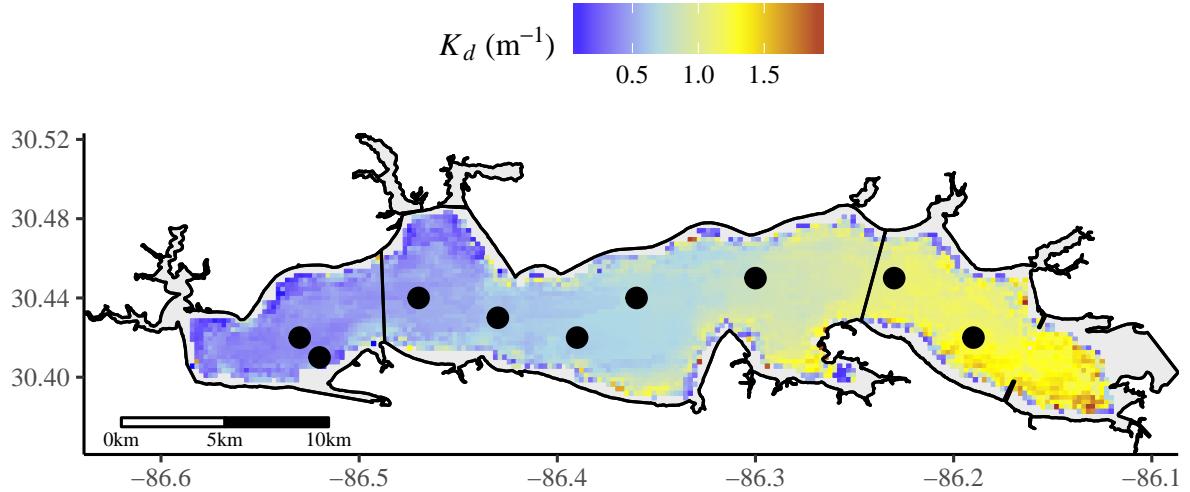


Fig. 10: Summary of light requirements of seagrasses in segments of Tampa Bay. Estimates are based on Secchi observations at routine monitoring stations and median depth of colonization estimates from coverage maps at approximate biennial intervals from 1988 to 2014. Median changes of $Z_{c,med}$ (m) and light attenuation in each year are shown as continuous paths in the top plot and boxplot distributions of light requirements are shown in the bottom plot. Contoured light requirements (% SI) are shown in grey in the top plot. See Fig. S2 for locations of stations in each segment. HB: Hillsborough Bay, LTB: Lower Tampa Bay, MTB: Middle Tampa Bay, OTB: Old Tampa Bay.

(a) Uncorrected satellite estimates and stations for *in situ* data



(b) Example of satellite correction

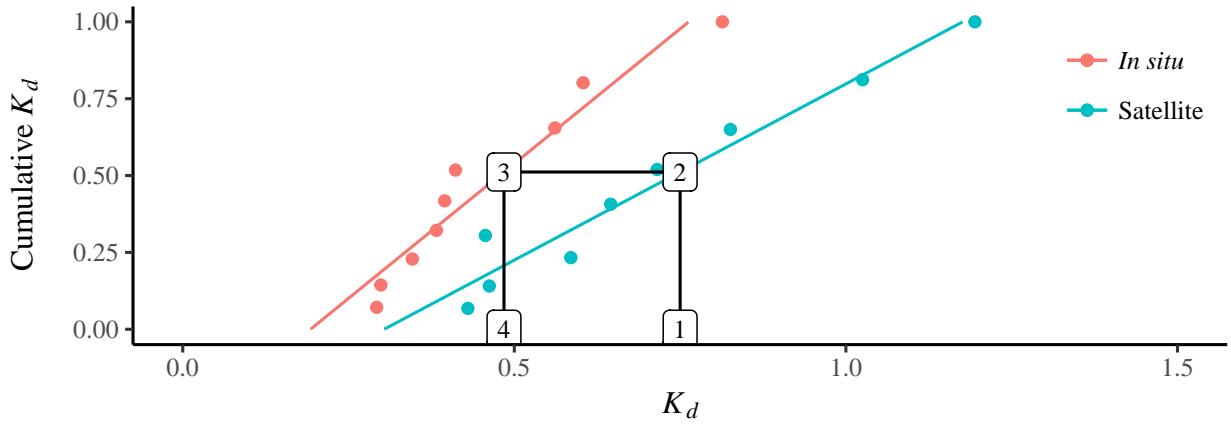


Fig. S1: Uncorrected satellite estimates of light attenuation in Choctawhatchee Bay (a) and example of correction with *in situ* data (b). *In situ* data of light attenuation were estimated as an annual average (2010) for monthly data at the sampling sites labelled as points in (a) (mean depth 7.2 m, minimum 3.5 m). The corresponding satellite data in the same grid cells were compared to the *in situ* data based on regressions of each dataset with cumulative estimates for both. An example correction is shown in (b) where for any uncorrected satellite estimate (point 1), the corresponding cumulative estimate on the regression curve was identified (point 2), matched with the same cumulative estimate from the *in situ* data (point 3), and then matched to the corresponding value on the x-axis (point 4) to yield the corrected satellite estimate.

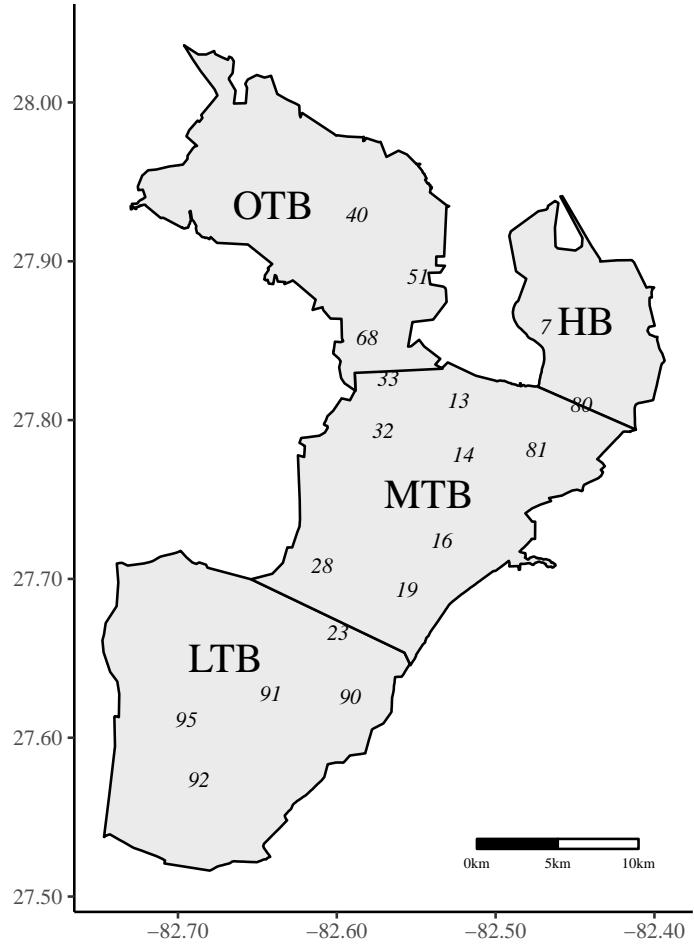


Fig. S2: Locations of selected water quality stations monitored by the Hillsborough County Environmental Protection Commission (TBEP 2011). Secchi observations at each station were used to evaluate changes in light requirements of seagrass at approximate biennial intervals from 1988 to 2014. Stations are labelled by their designation and were chosen based on continuity of data for the period of interest. HB: Hillsborough Bay, LTB: Lower Tampa Bay, MTB: Middle Tampa Bay, OTB: Old Tampa Bay.

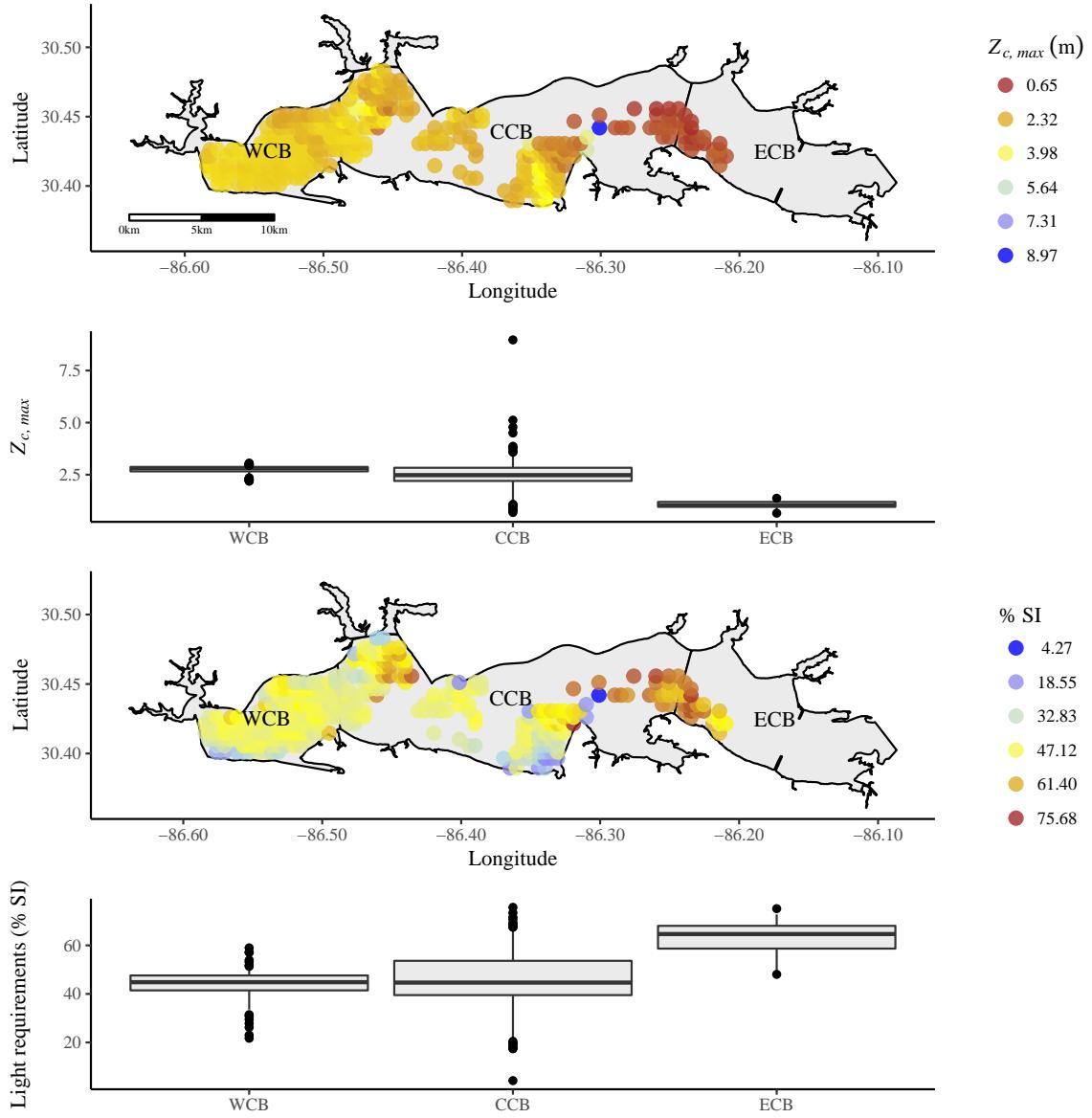


Fig. S3: Estimated maximum depths of seagrass colonization and light requirements for multiple locations in Choctawhatchee Bay, Florida. Locations are those where water clarity estimates were available from satellite observations and seagrass depth of colonization was estimable using a radius of 0.04 decimal degrees. Estimates are also summarized by bay segment as boxplots where the dimensions are the 25th percentile, median, and 75th percentile. Whiskers extend to the 5th and 95th percentiles with outliers beyond. CCB: Central Choctawhatchee Bay, ECB: East Choctawhatchee Bay, WCB: West Choctawhatchee Bay.

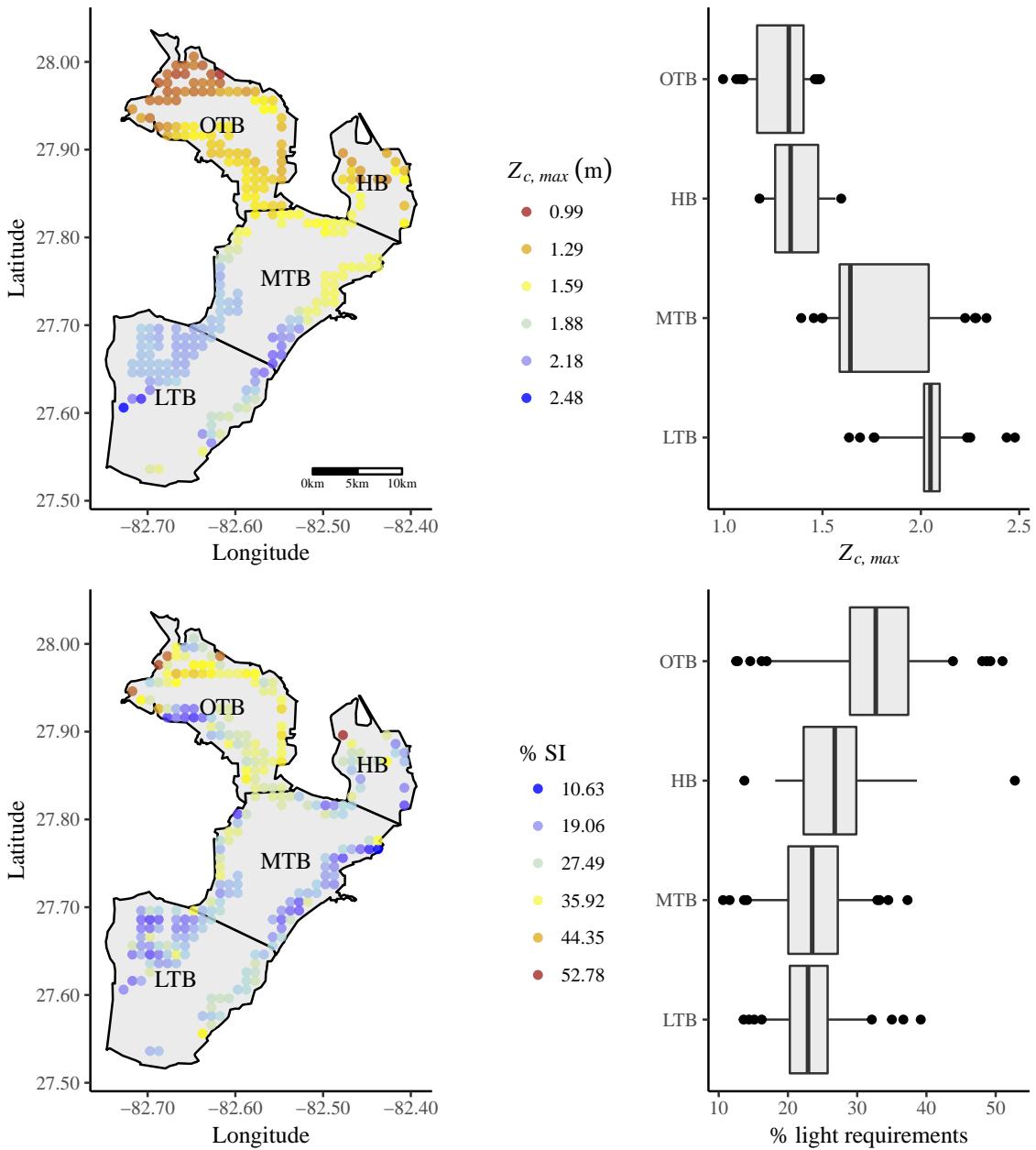


Fig. S4: Estimated maximum depths of seagrass colonization and light requirements for multiple locations in Tampa Bay, Florida. Locations are those where water clarity estimates were available from satellite observations and seagrass depth of colonization was estimable using a radius of 0.1 decimal degrees. Estimates are also summarized by bay segment as boxplots as in Fig. 7. HB: Hillsborough Bay, LTB: Lower Tampa Bay, MTB: Middle Tampa Bay, OTB: Old Tampa Bay.

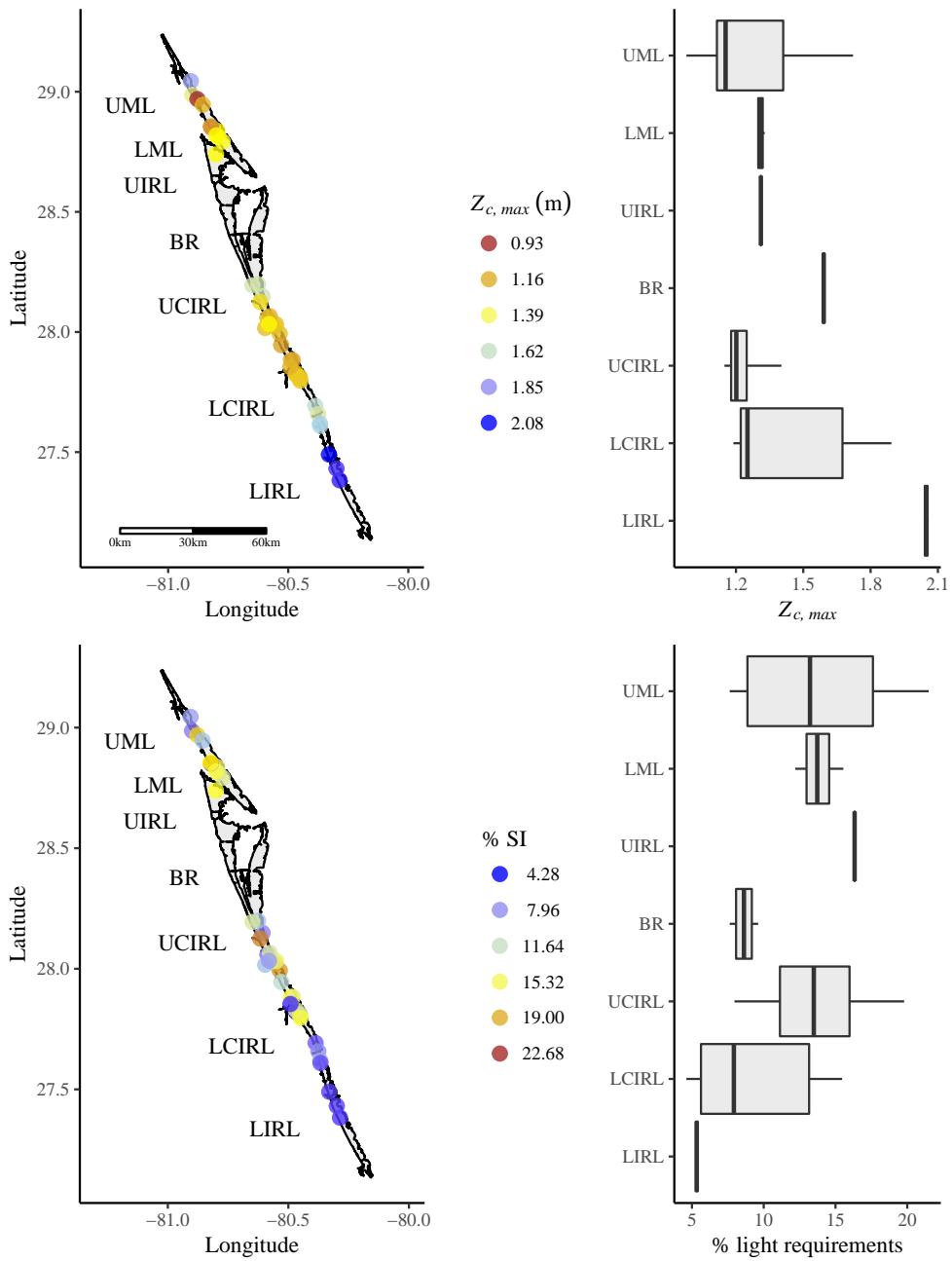


Fig. S5: Estimated maximum depths of seagrass colonization and light requirements for multiple locations in Indian River Lagoon, Florida. Map locations are georeferenced observations of water clarity in the Florida Impaired Waters Rule database, update 40. Estimates are also summarized by bay segment as boxplots as in Fig. 7. Light requirements are based on averaged secchi values within ten years of the seagrass coverage data and estimated maximum depth of colonization using a radius of 0.15 decimal degrees for each secchi location to sample seagrass depth points. BR: Banana R., LCIRL: Lower Central Indian R. Lagoon, LIRL: Lower Indian R. Lagoon, LML: Lower Mosquito Lagoon, LSL: Lower St. Lucie, UCIRL: Upper Central Indian R. Lagoon, UIRL: Upper Indian R. Lagoon, UML: Upper Mosquito Lagoon.