Quantifying seagrass light requirements using an algorithm to 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 meters and square kilometers, 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 **??** 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

[a]BB: Big Bend, OTB: Old Tampa Bay, UIRL: Upper Indian River Lagoon, WCB: Western Choctawhatchee Bay.

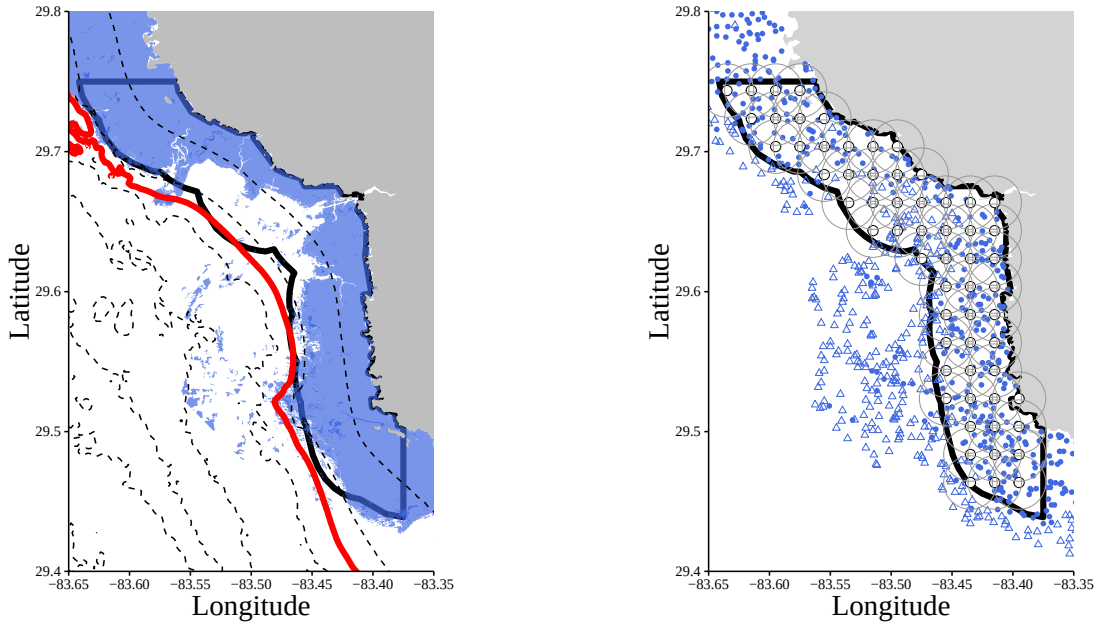
Table 3: Summary of median depth of colonization ($Z_{c,\,med}$, m) and light requirements (%) for all bay segments of Choctawhatchee Bay, Indian River Lagoon, and Tampa Bay. See Figs. 7 to 9 for spatial distribution of the results.

Segment[a]		$Z_{c,\,med}$				**% light**			
	n	Mean	St. Dev.	Min	Max	Mean	St. Dev.	Min	Max
Choctawhatchee Bay									
CCB	111	2.1	0.6	0.6	4.2	51.2	13.2	19.5	87.1
ECB	4	0.8	0.1	0.7	0.9	67.9	8.9	55.1	74.7
WCB	140	2.4	0.3	1.7	2.8	49.9	6.4	22.0	70.0
Indian River Lagoon									
BR	2	1.0	0.1	1.0	1.1	20.7	0.8	20.2	21.3
LCIRL	14	1.2	0.3	0.9	1.6	13.6	6.3	5.8	24.7
LIRL	3	1.6	0.0	1.5	1.6	9.2	2.8	6.0	11.2
LML	4	1.0	0.0	1.0	1.0	22.1	2.2	19.3	24.3
UCIRL	17	0.9	0.1	0.8	1.1	20.0	7.0	7.5	30.7
UIRL	1	1.0		1.0	1.0	24.1		24.1	24.1
UML	4	0.9	0.1	0.8	1.0	23.6	6.4	15.2	30.9
Tampa Bay									
HB	53	1.1	0.2	0.8	1.3	36.8	8.9	12.8	55.7
LTB	140	1.3	0.1	1.0	1.5	42.3	7.6	23.8	56.6
MTB	226	1.3	0.1	1.1	1.6	38.5	6.2	17.0	57.5
OTB	117	0.9	0.2	0.6	1.1	48.8	7.8	29.9	66.0

[a]CCB: 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.

(a) Seagrass coverage and bathymetry for the segment

(b) Grid of locations and sample areas for estimates



(c) Sampled seagrass data for a test point

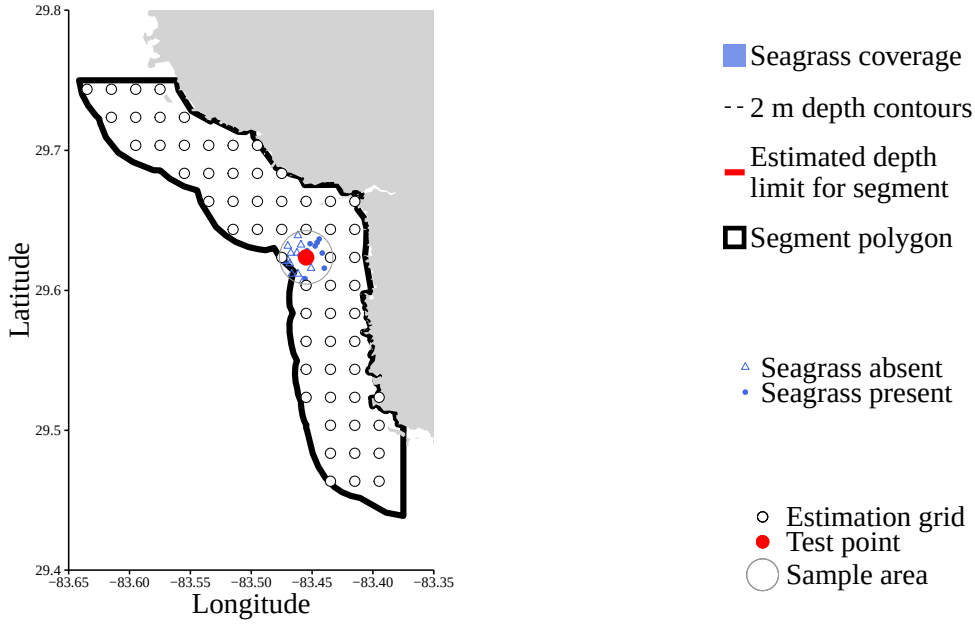


Fig. 1: Examples of data and grid locations for estimating seagrass depth of colonization for a region of the Big Bend, Florida. Fig. 1a shows the seagrass coverage and depth contours at 2 meter intervals, including the whole segment estimate for depth of colonization. Fig. 1b shows a grid of sampling locations with sampling radii for estimating Z_c and seagrass depth points derived from bathymetry and seagrass coverage layers. Fig. 1c shows an example of sampled seagrass depth points for a test location. Estimates in Fig. 3 were obtained from the test location in Fig. 1c.

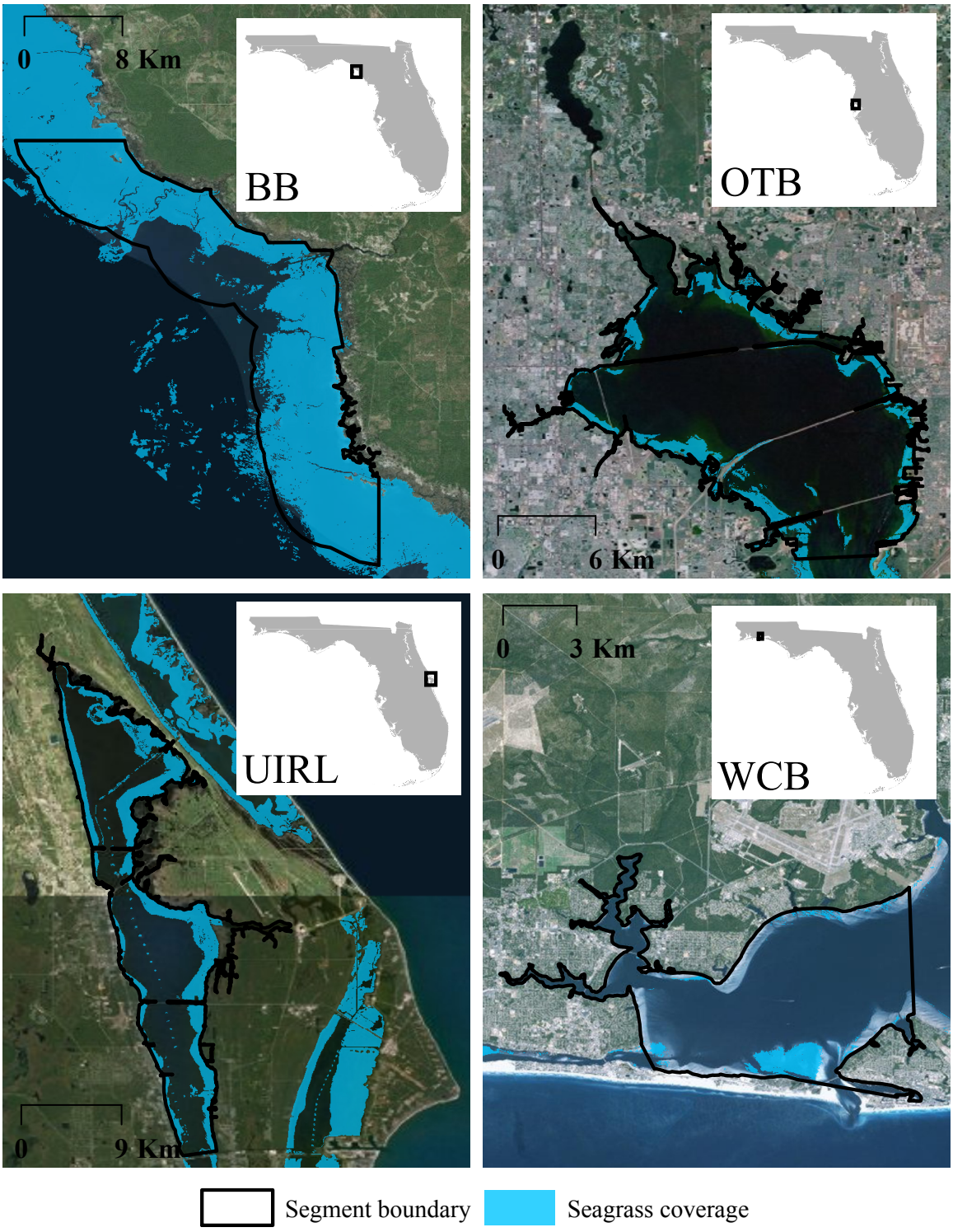


Fig. 2: Locations and seagrass coverage of estuary segments used to evaluate depth of colonization estimates. Seagrass coverage layers are from 2006 (BB: Big Bend), 2010 (OTB: Old Tampa Bay), 2009 (UIRL: Upper Indian R. Lagoon), and 2007 (WCB: Western Choctawhatchee Bay).

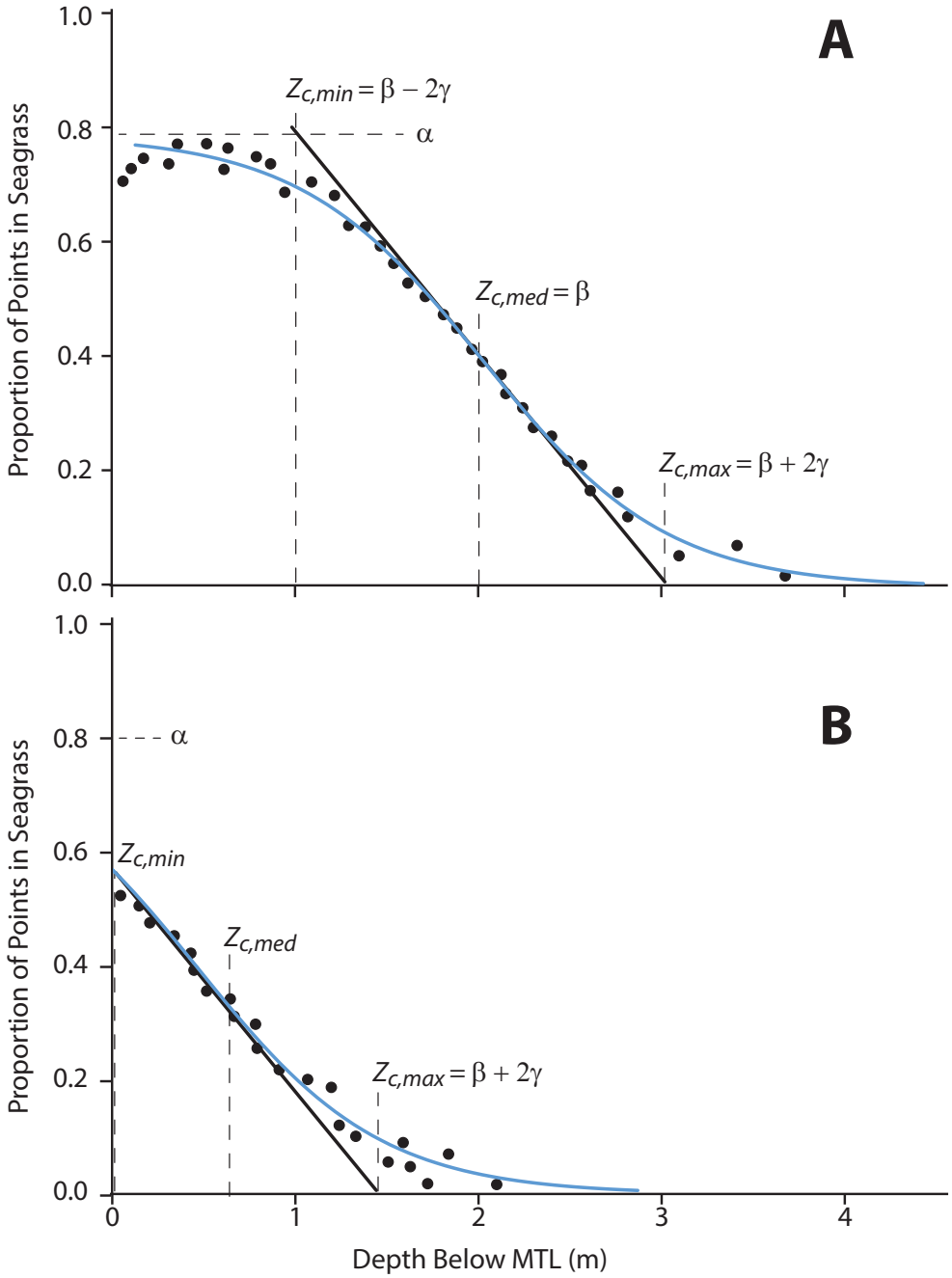


Fig. 3: Methods for estimating seagrass depth of colonization using sampled seagrass depth points around a single location. Three depth estimates ($Z_{c,min}$, $Z_{c,med}$, $Z_{c,max}$) are based on a linear curve through the inflection point of a logistic growth curve . The logistic curve is defined 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.

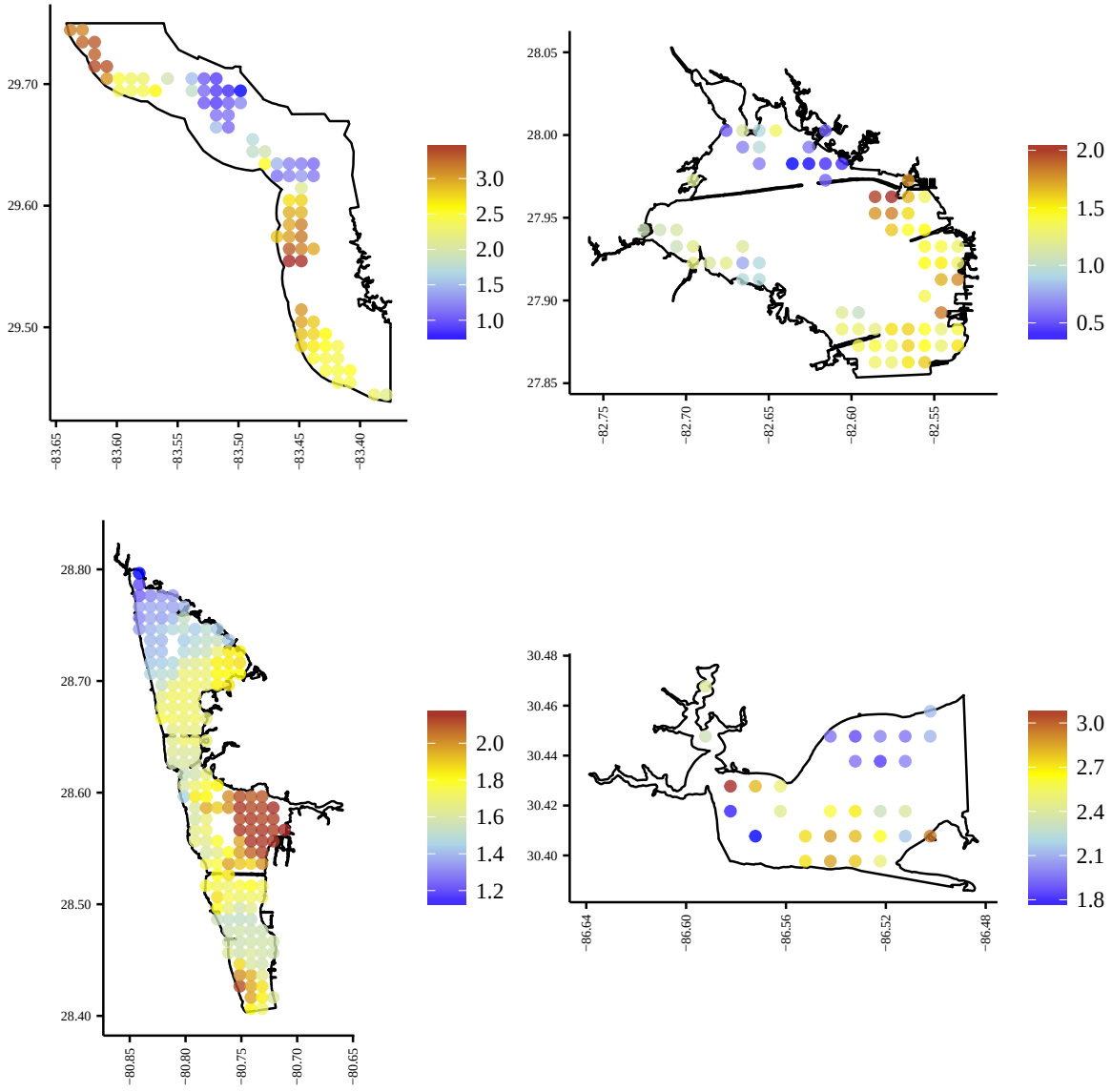


Fig. 4: Spatially-resolved estimates of maximum seagrass depth of colonization (m) for four coastal segments of Florida. Estimates are assigned to grid locations for each segment, where grid spacing was fixed at 0.02 decimal degrees. Radii for sampling seagrass bathymetric data around each grid location were fixed at 0.06 decimal degrees. From left to right, top to bottom: Big Bend, Old Tampa Bay, Upper Indian R. Lagoon, Western Choctawhatchee Bay.

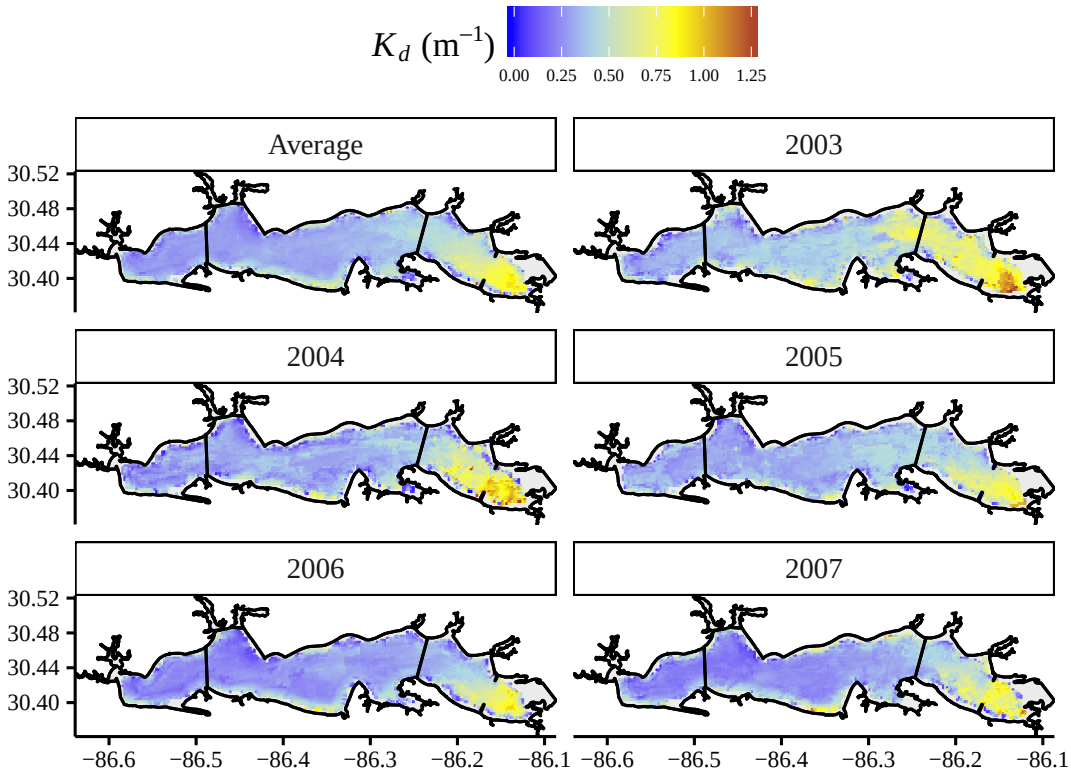


Fig. 5: Satellite estimated light attenuation for Choctawhatchee Bay. Each facet is an annual average of light attenuation for available years of satellite data up to the year of seagrass coverage used to estimate depth of colonization. The first facet is an average of all years. See Fig. 7 for segment identification.

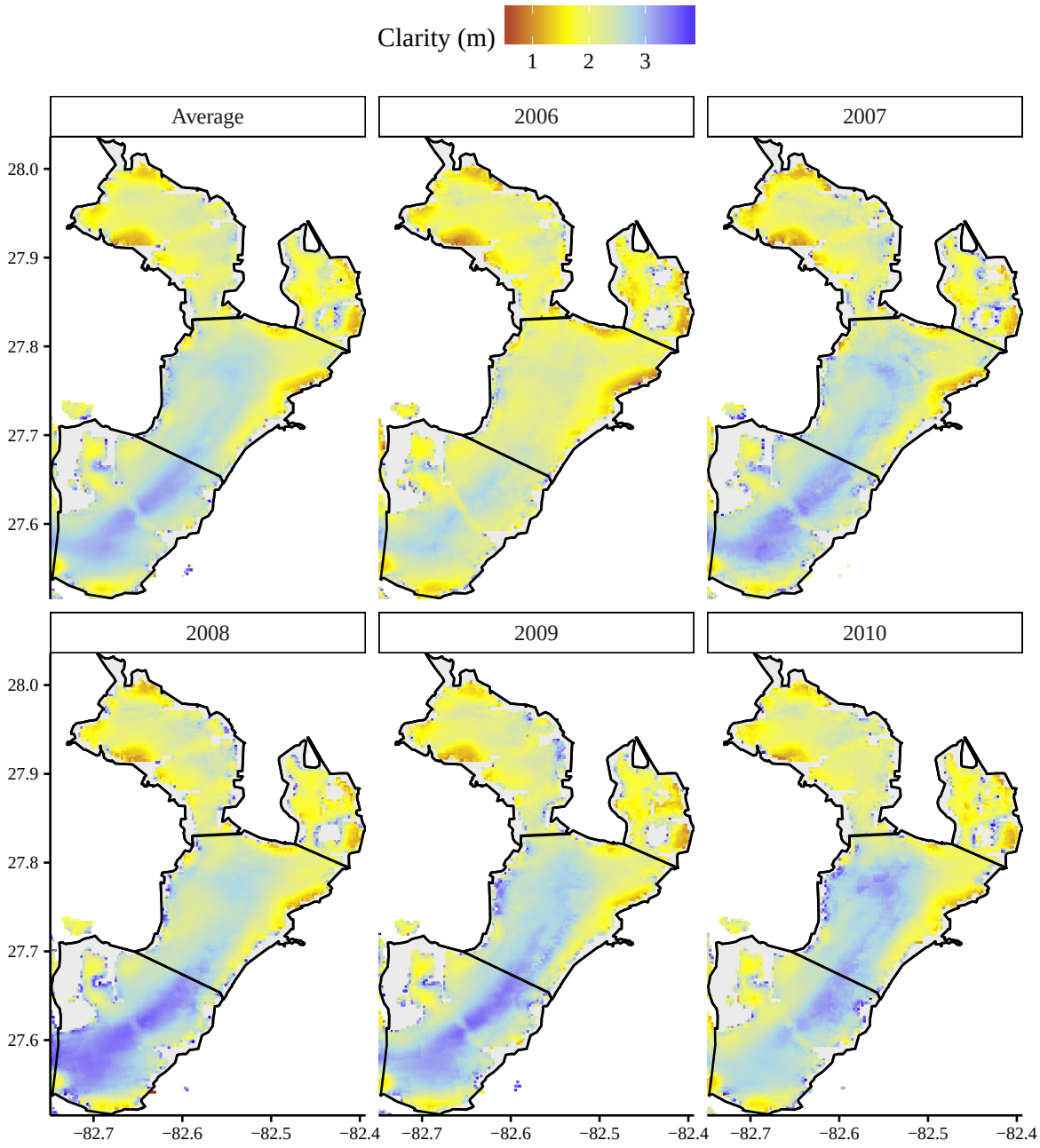


Fig. 6: Satellite estimated water clarity for Tampa Bay. Each facet is an annual average of water clarity for available years of satellite data. The first facet is an average of all years. See Fig. 8 for segment identification.

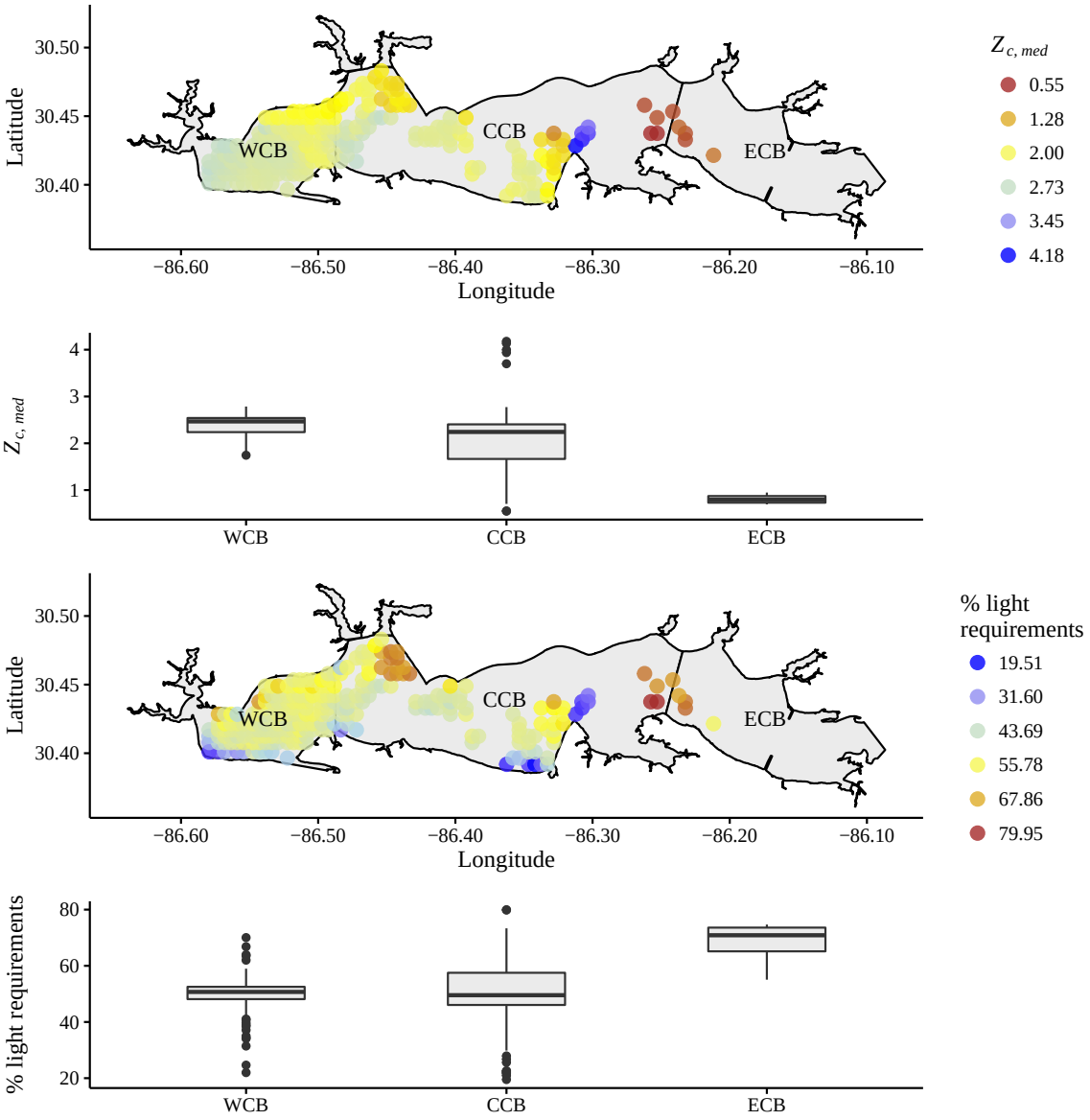


Fig. 7: Estimated median depths of seagrass colonization and light requirements for multiple locations in Choctawhatchee Bay, Florida. Locations are those where water clarity estimates were available from satellite observations and seagrass depth of colonization was estimable using a radius of 0.04 decimal degrees. Estimates are also summarized by bay segment as boxplots where the dimensions are the 25th percentile, median, and 75th percentile. Whiskers extend beyond the boxes as 1.5 multiplied by the interquartile range. CCB: Central Choctawhatchee Bay, ECB: East Choctawhatchee Bay, WCB: West Choctawhatchee Bay.

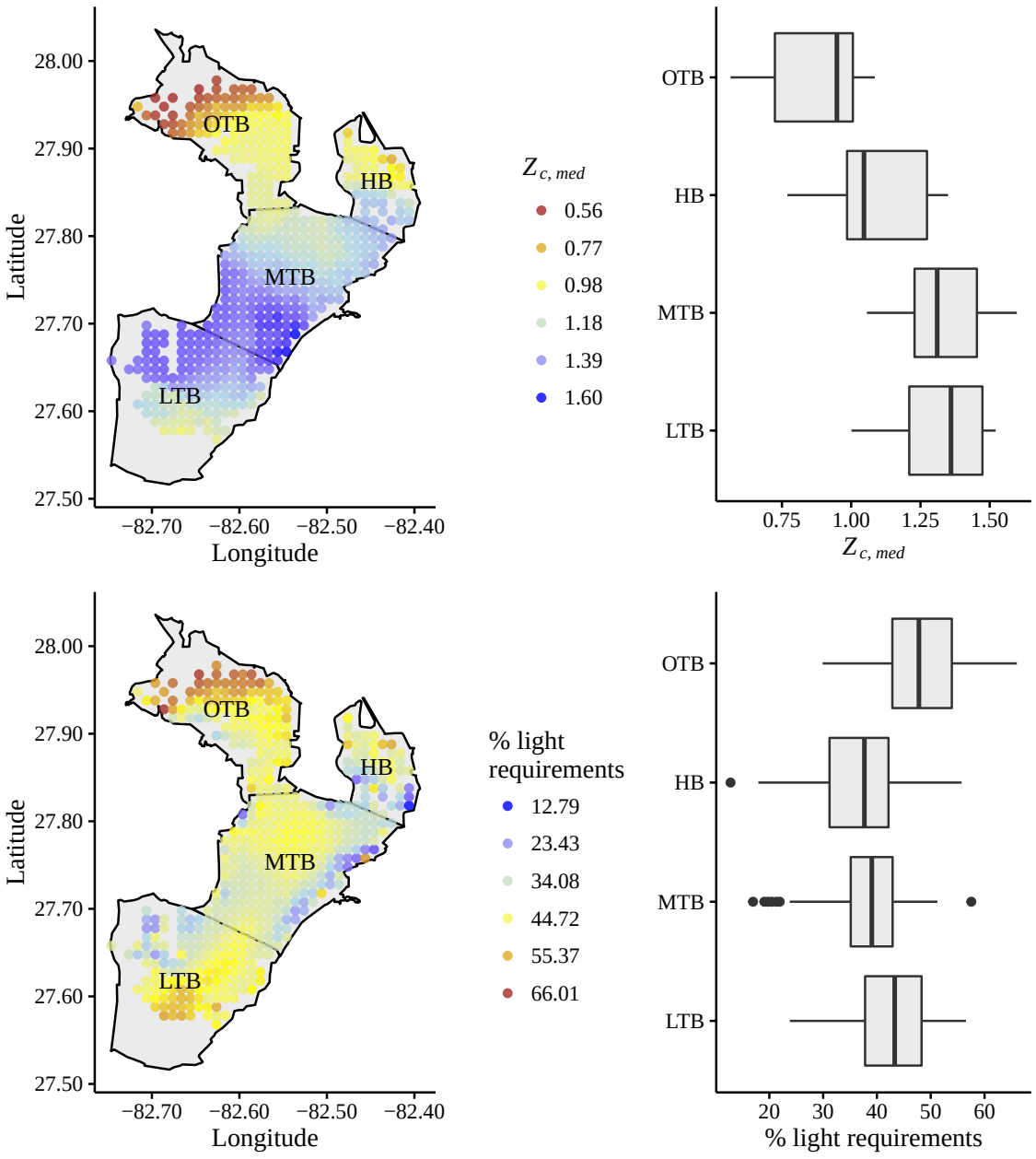


Fig. 8: Estimated median depths of seagrass colonization and light requirements for multiple locations in Tampa Bay, Florida. Locations are those where water clarity estimates were available from satellite observations and seagrass depth of colonization was estimable using a radius of 0.1 decimal degrees. 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.

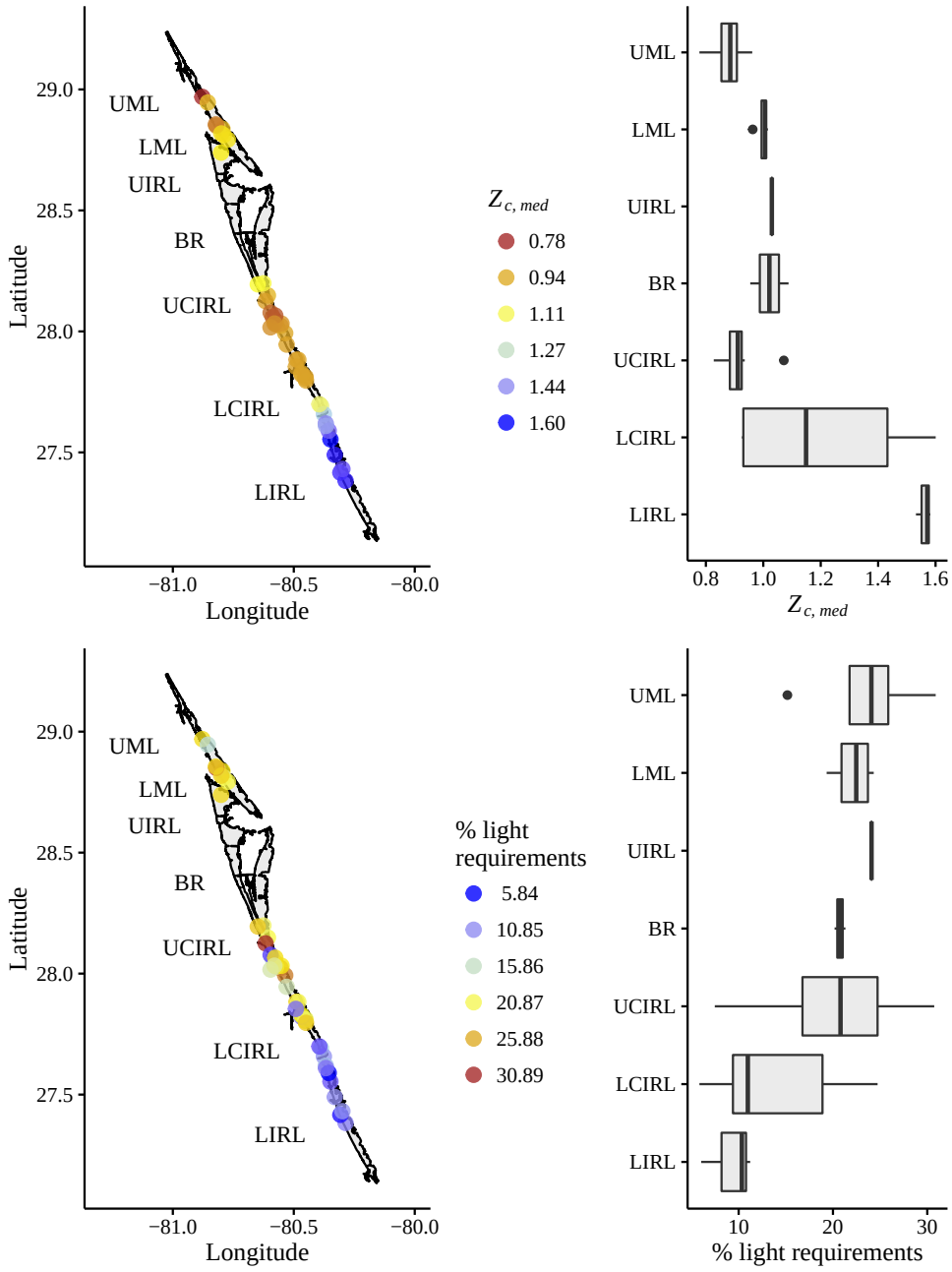


Fig. 9: Estimated median depths of seagrass colonization and light requirements for multiple locations in Indian River Lagoon, Florida. Map locations are georeferenced observations of water clarity in the Florida Impaired Waters Rule database, update 40. Estimates are also summarized by bay segment as 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.