Data Collection

Light

To ensure that data collection sites were evenly distributed throughout the bay, a grid was laid over the bay and one location was randomly selected from each of the resulting 50 grid squares (Figure 1). Data collection began in September 2011 and seventeen sampling events occurred every three weeks over a one year period. A sampling event required two days (10 am to approximately 2 pm each day) to visit all 50 sites. Not all sites could be accessed during every sampling event due to environmental and/or vessel limitations. A majority of sites (33) were sampled 13 times, while two sites were sampled only 10 times and one site was sampled 15 times.

During each site visit, three paired underwater and surface light readings were taken at 30 second intervals using two LI-193 Spherical PAR sensors for Quantum Scalar Irradiance coupled to a LI-1400 datalogger. One of the paired light sensors was placed 25 cm above the bay floor (to reduce sensor shading by existing seagrass and the influence of turbidity caused by sediment disturbance) and the other sensor was held just above the water surface. The time (min) of each reading was recorded. In total 1,926 paired readings were taken during the one year period. Simultaneous with light measurements, water depth (cm) was recorded using a metric tape attached to the LI-COR sensor mounting pole. Between July and September, two separate snorkel visits were made to each site to note the presence or absence of seagrass. An YSI Pro2030 Dual Dissolved Oxygen/Conductivity Instrument was used to record water temperature (°C), salinity (ppt), and dissolved oxygen (mg/L) directly below the surface at each site during each data collection event.

Bathymetry

Bathymetry data for Estero Bay were obtained from the South Florida Water Management District (SFWMD). Bottom depths were quantified in 2003 using two methods: the Experimental Advanced Airborne Research LIDAR (EAARL) system developed by the National Aeronautical and Space Administration (NASA) and the acoustic-based System for Accurate Nearshore Depth Surveys (SANDS) developed by the U.S. Geological Survey (USGS) (Hansen and Patino 2006). EAARL was used to map shallow, nearshore and non-turbid bay areas, and SANDS was used for the remaining areas (Hansen and Patino 2006). The SFWMD provided an ArcGIS compatible raster file of merged, corrected data with depth measurements, in NAVD88, spaced 75 feet (22.86 m) apart. The stated horizontal accuracy of depths is +/- 4 cm and the vertical accuracy is +/- 8 cm. Elevations of tidal datums published by NOAA for three historical tide stations in Estero Bay were used to convert depths from NAVD88 to Mean Sea Level (MSL). The average relative height difference between NAVD88 and MSL for the three stations[1] (0.196 m) was subtracted from all depths.

Data Analyses

Light Attenuation

Using the paired light readings and the simultaneously measured depths, light attenuation coefficients (K_d) were calculated using the Lambert-Beer Law:

$$I_z = I_O e^{-K_d Z}$$

Where I_Z is light measured at depth z, I_O is light measured just above the water surface, and K_d is the light attenuation coefficient (m^{-1}). A K_d was calculated for each of the three

[1] The station names and IDs are: Matanzas Pass, Estero Island (8725366); Coconut Point, Estero Bay (8725319); and Estero Island, Estero Bay (8725351).

paired light readings taken at each site visited during a sampling event and the three K_d values were then averaged to get a single K_d for each site for each sampling event. In 3% of the paired readings one reading differed by more than 20% from the other two readings and this reading was removed and the remaining 2 readings were averaged to get the K_d for the site for that sampling event. Next, the median annual K_d was calculated for each of the 50 sites based on the averaged values for each sampling event. Median was used instead of average to normalize the data.

The median K_d values were kriged in ArcGIS 10.1 Geostatistical Analyst (Esri 2013b). Ordinary, simple, and universal kriging models were tested, using transformations and trend removal as necessary to improve fit. The model was checked for anisotropy, and iterative cross validation was used to optimize model parameters. The model with the smallest root mean square error was selected and the resulting K_d predictions were converted to a raster with a cell size equivalent to that of the bathymetry data (75 ft^2). The predicted K_d and bathymetry raster were input to ArcGIS 10.1 Raster Calculator and an output raster of predicted I_Z, the percent light at known depth z (MSL), was created based on the Lambert-Beer Law.

Spatial and Temporal Variability in Light Measures

Each 75 ft^2 cell was placed into one of three categories based on the predicted I_Z values from the kriging model. Each cell of the predicted I_Z raster was placed in a category according to the percentage of surface light reaching the bottom. A value of 3 was assigned to those areas that were predicted to have the 25% or more of surface light available at the bottom that is deemed necessary by the CHNEP study (Janicki Environmental 2010). To reflect literature that indicates that seagrass can survive at lower light levels, a value of 2 was assigned to areas with 15% or more (but less than

25%) of surface light at the bottom. Finally, a value of 1 was assigned to areas that had less than 15% of surface light available at the bottom as those areas were not thought likely to support seagrass.

Additionally, the averaged bay bottom and surface light data at each site and for each event were used to estimate the proportion of the year during which 25% or more of surface light reached seagrass. The resulting proportions were kriged as described above. Each cell of the output raster was placed into one of three categories that indicate the estimated proportion of the year during which 25% or more of surface light was available to seagrass. Cells that had 62% or more of the year with 25% or more surface light received a 3. This category was based on the minimum amount of the year (62%) that 25% or more surface light was available at a site where seagrass was present during study year. Cells that had 50% to <62% of the year with 25% or more surface light received a 2 based on the assumption that seagrass might temporarily persist in an area where 25% or more surface light is available for 50 to <62% of the year. Cells that had <50% of the year with 25% or more surface light received a 1 and were not considered favorable for seagrasses.

Each cell in the output was added to its corresponding cell in the raster of categorized I_Z values, thus allowing for categorization of sites according to median annual light availability and the relative amount of time that light equals or exceeds 25% at the bay bottom. Integration of the light data was used to identify areas where average light is masking long time periods of low light that are offset by a brief period of high light. Based on light data alone areas that were categorized 5 are the best sites for seagrass restoration and areas that were categorized 1 are the worst.