Exploring the use of HOBO pendant light loggers to measure light attenuation on a shallow seagrass bed in the Loxahatchee River Estuary

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Introduction

Seagrasses are marine flowering plants found globally in shallow coastal waters and are a vital ecosystem component that provide important ecological services (Beck *et al*., 2001). Seagrasses, like their terrestrial counterparts, require light to carry out photosynthesis. Thus, water quality parameters that limit light attenuation, or reduction of light through the water column, can negatively impact seagrass growth.

In estuarine systems like the Loxahatchee River Estuary, water clarity can change substantially in response to tidal fluctuation ranging from clear marine water to stormwater flows composed of dissolved organic matter (tannins) and suspended sediment within a single tidal cycle (≈12 hours). Ideally, measuring light attenuation across all tidal conditions and during optimal solar elevations would render a more accurate depiction of light reaching the seagrass bed.

Previous research has utilized inexpensive and readily available HOBO pendant light loggers to quantify light penetration. Long *et al*. (2012) demonstrated the effectiveness of using HOBO pendant light loggers for measuring both above surface and subsurface light when calibrated to the more conventional and highly accurate Licor light measuring instruments which provide conventional Photosynthetically Active Radiation (PAR) readings to quantify depth of light penetration. In this study we expand upon Long *et al*. (2012) deploying multiple calibrated HOBO pendant loggers vertically in the water column on a shallow seagrass bed and measured light attenuation at 15-minute intervals for a period of 77 days between June – August.

Phase I was a calibration study relating data collected simultaneously from HOBO and Licor instruments. **Phase II** a separate configuration was used to consider light penetration by depth (Fig. 2).

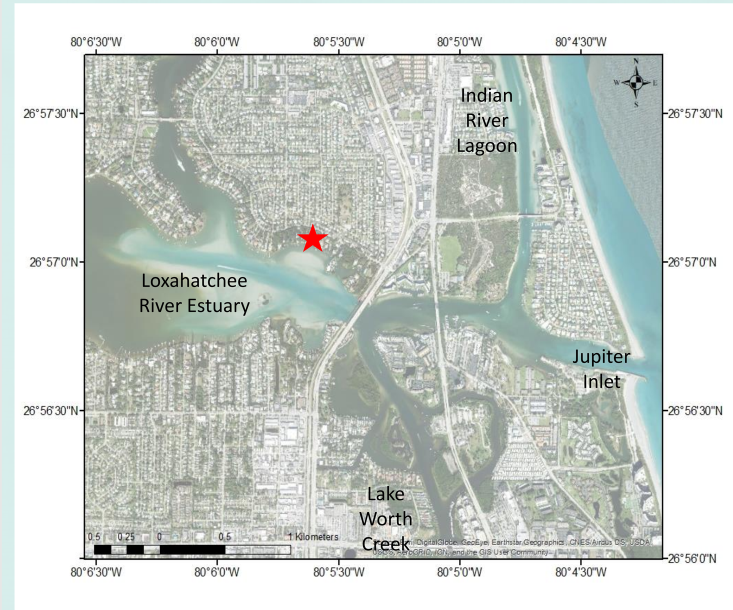
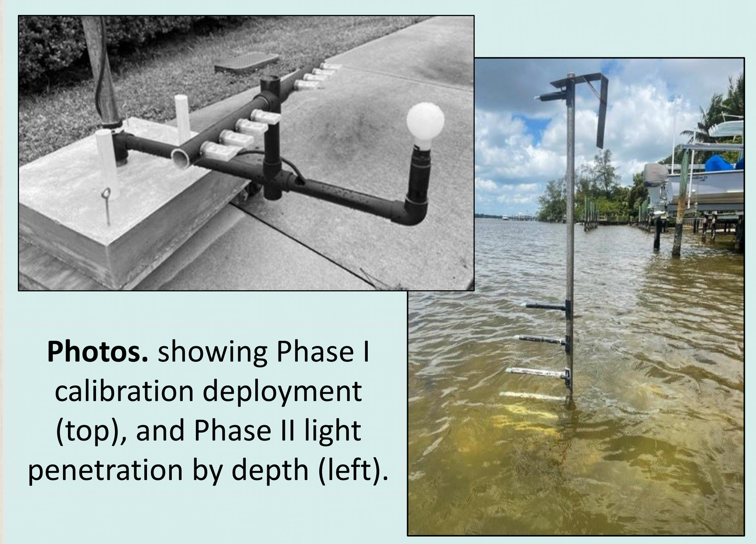


Figure 1. Map of Loxahatchee River Estuary and associated water bodies. Red star indicates location of study site (W80° 5'39.65", N26°57'3.27").



Photos. showing Phase I calibration deployment (top), and Phase II light penetration by depth (left).

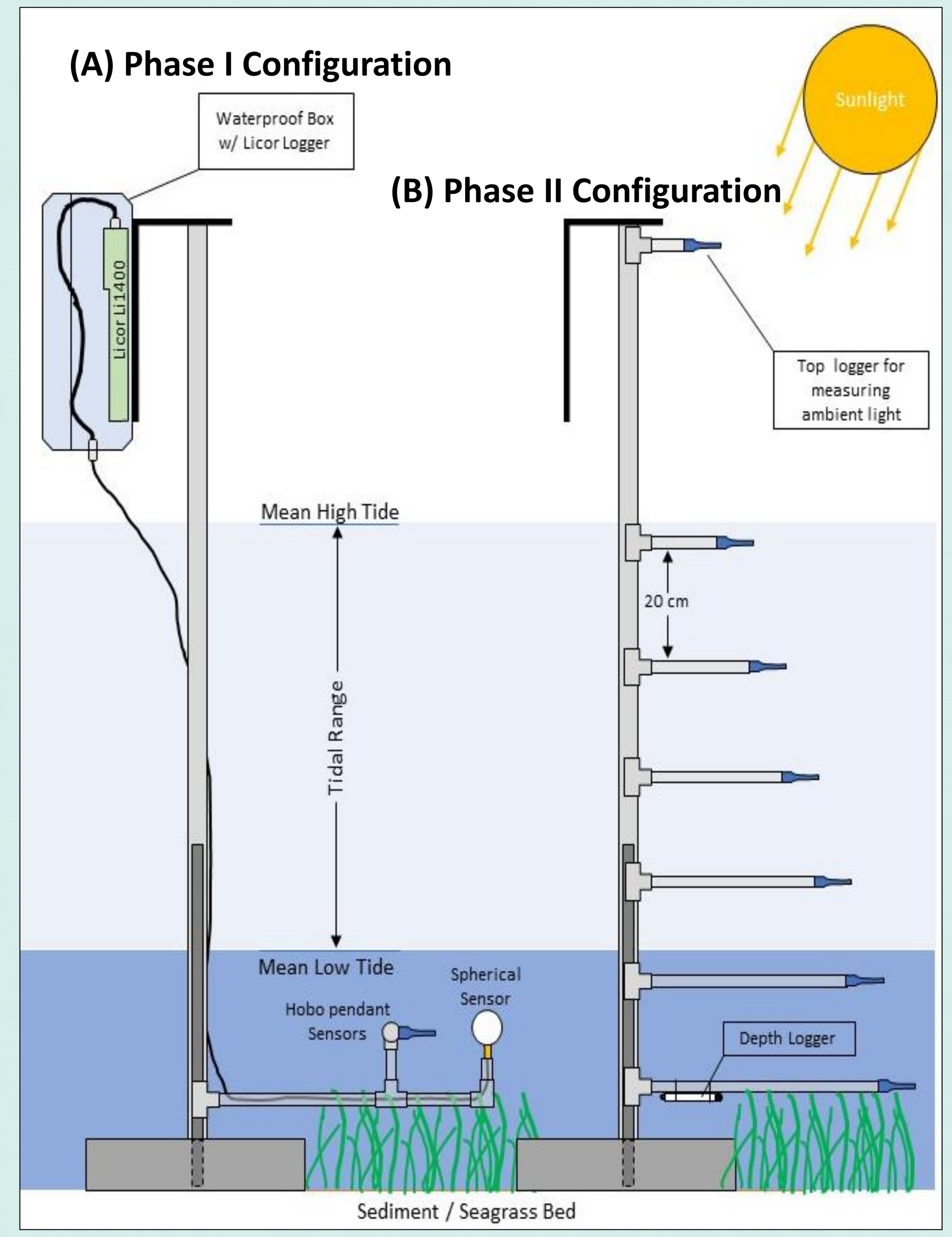


Figure 2. (A) Light measuring station (not drawn to scale) illustrating **Phase I** calibration configuration where the Hobo light loggers are placed on the same horizontal plane as the Licor spherical light sensor. Also shown is the waterproof box modified with bulkhead connectors for the sensor cable. **(B)** Depicts the **Phase II** light attenuation measurement configuration where HOBO light loggers were placed vertically within the intertidal & subtidal zone at 20 cm intervals. A depth logger was attached to the bottom sensor and the bottom sensor was compared to whichever sensor was just below the surface depending on tide. The top HOBO measured ambient sunlight.

Materials & Methods

Set-up

A stand-alone concrete base was built measuring 67cm x 67cm x 13cm (26" x 26" x 5") with a 70cm x 3cm OD (1 ¼") stainless steel pole set vertically in the center. A 2.1m x 4.5cm pole with a flat bracket at top was placed over pole on the base (done for ease of transport and fine-tuning horizontal angle).

Phase I: Calibration

Sensor calibration in air was conducted over five days during August and November of 2021 to include varying sky conditions. Sensor calibration in water was conducted over a period of eleven days during May and June 2022 to capture varying sky and tidal conditions. A Licor Li1400 data logger modified with waterproof connectors was placed inside a clear weatherproof box equipped with waterproof bulkhead connectors to allow water-tight connection between logger and sensors. A 3 meter cable connected logger to a single Licor Li-193 4π spherical quantum sensor that had been serviced and calibrated by manufacturer in July 2021. Eight HOBO UA-002-64 loggers were aligned on the same horizontal plane to calibrate HOBOs to the Licor (Fig 2A). Lambert's Cosine Law accounts for the effect of incident light at various angles from vertical; the greater the angle from vertical, the lower the amount of light striking a surface. The cosine law is described by the equation:

$$I_\theta = I_0 \cos(\theta) * \frac{\pi}{180}$$

Where I_Θ is the light intensity adjusted from the initial light intensity, I_0, and incoming light angle Θ in radians. The π/180 term converts radians to degrees. This study used 45° from vertical to identify the appropriate time of day to begin and end light measurements (light incidence vs reflectance at the water surface; typically, between 10:00 and 16:30; ± 15 minutes, https://gml.noaa.gov/grad/solcalc/), falling within the cosine capability of both sensor types. Plugging 45° into Lambert's cosine equation, not less than 70% of incoming light would be measured by the sensor.

Licor and HOBO loggers were programmed to record a single instantaneous light measurement every 15 and 10 seconds respectively and measurements were averaged for each 15 minutes for both sensors. Calibrations were performed "in air" (5 days) and "in water" (11 days). For calibrations performed in water, the sensors were set at one-half mean low tide depth. The number of days of each calibration setup was to capture a variety of meteorological and tidal conditions. Using Microsoft Excel's Solver function, the Licor and HOBO data were fitted to the nonlinear exponential decay equation (Long *et al*., 2012):

$$PAR_{Licor} = A_1 e^{-\text{Hobo}/t_1} + y_0$$

Where PAR_{Licor} is μmols photons $m^{-2}s^{-1}$; Hobo (lumens m^2) data from HOBO logger; A_1, t_1, and Y_o are fitting constants (Long *et al*, 2012). This equation was used to develop a predictive relationship between the two light measuring devices (Licor and HOBO; Fig. 3).

Phase II: Light at Depth

Water column light attenuation measurements were collected during 77 days between June 10 - August 31 2022. For Phase II the Licor equipment and weatherproof box were removed, and HOBO sensors staggered vertically on pole at 20 cm intervals (Fig. 2B). A HOBO water level logger is attached to lowest sensor to record depth every 5 minutes. Once again loggers recorded data every 10 seconds and averaged every 15 minutes. Light attenuation coefficient (K_d) was determined during each 15 minutes using the following equation (Weiskerger *et al*., 2018):

$$K_d\, m^{-1} = \frac{\ln Iz_1 - \ln Iz_0}{z_1 - z_0}$$

Where K_d is the light attenuation coefficient (m^{-1}), Iz_1 and Iz_0 are irradiances at depth z_0 and z_1 ($z_1 > z_0$), and z_0 and z_1 are subsurface (0.1 to 0.25m) and depth to bottom (0.1m from sediment) respectively. The K_d value and corresponding depth (z) can be inserted into the equation e^{-Kd*z} x 100 to determine the average percent of sub-surface light reaching the seagrass bed (Gallegos and Moore, 2000).

Phase I: Calibrations

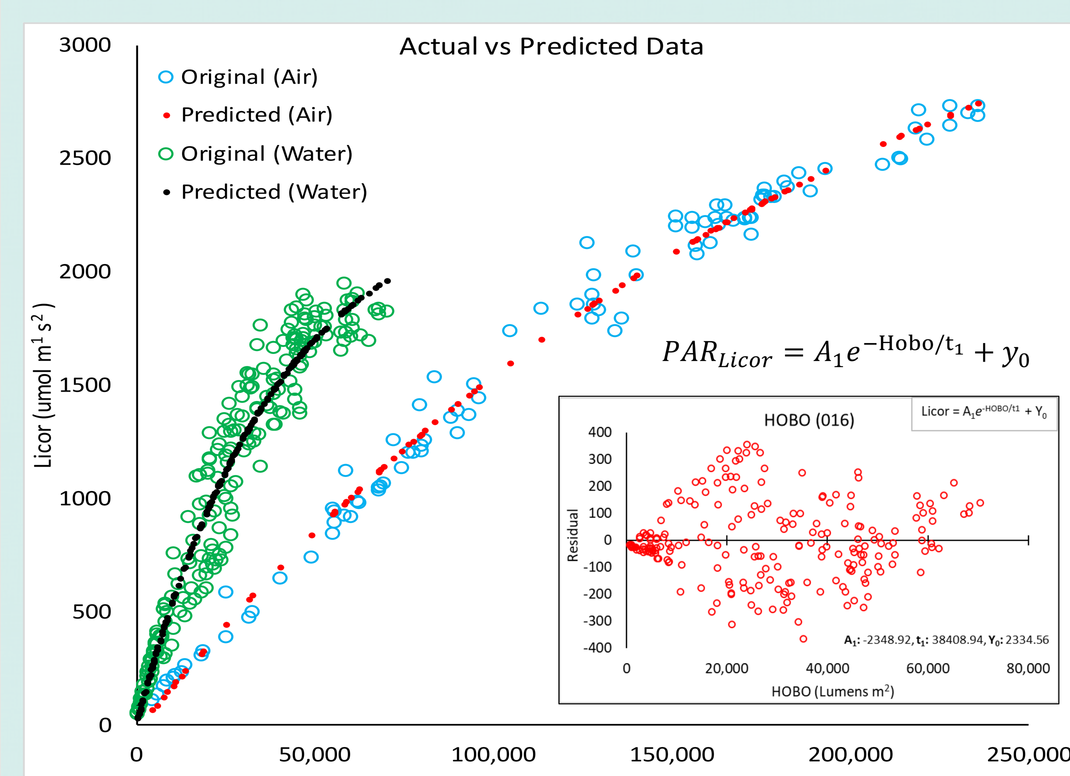


Figure 3. Plots showing the relationships between light measurements from Licor spherical sensor (y-axis) and HOBO pendant sensor (x-axis). Plots for both air (blue) and water (green) are shown to demonstrate differences in light readings between the two mediums. Plots also illustrate the subtle variations from predicted values due to water and weather conditions. Nonlinear exponential decay equation applied to derive trends is shown. Inset showing data derivations from the predicted equation (in water).

Phase I: Results

In water calibration was performed over 11 days, during daylight hours (10:00-16:30) (n=219). Applying the nonlinear exponential decay equation to the HOBO and Licor data, individual fitting constants were determined for each HOBO logger; averaging A_1= -2343.2 (sd ± 29.5); t_1= 39138.7 (sd ± 2072); and Y_0= 2313.5 (sd ± 26.0), with all residuals <400 Limens m^{-2}. Fitting constants were derived for each HOBO logger which were then used to determine light attenuation coefficient (Kd) values in Phase II.

Phase II: Light at Depth

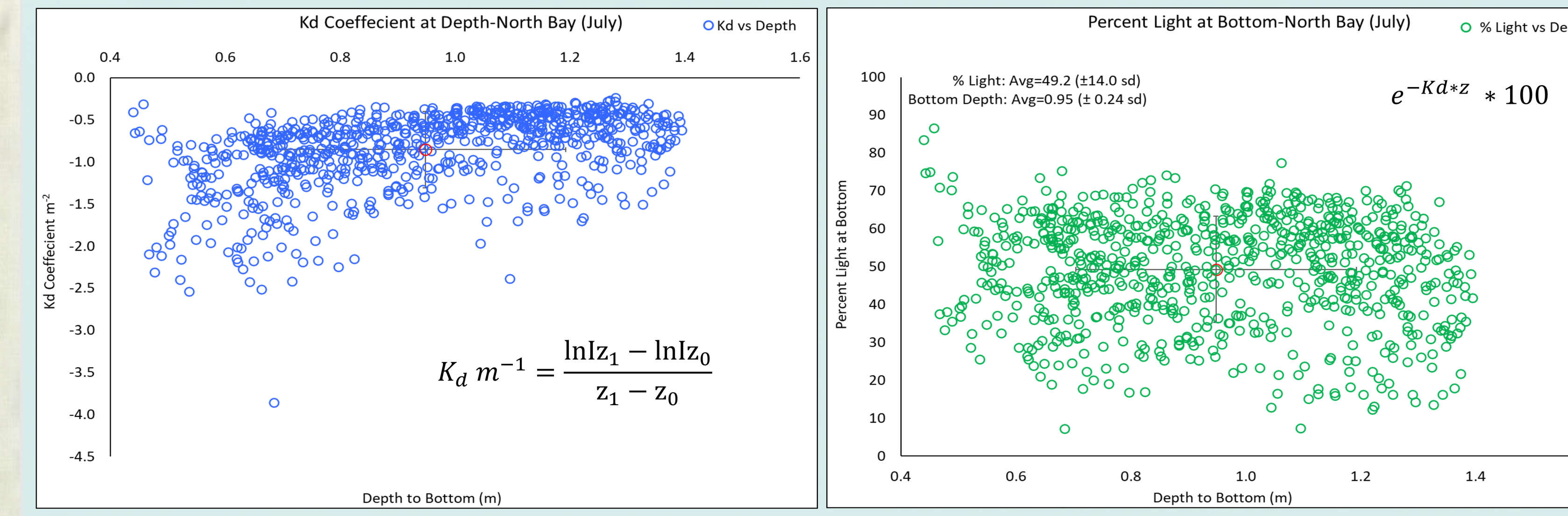


Figure 4. Relationship between **A** Light attenuation coefficient (Kd) and **B** percent of light at bottom and depth collected from HOBO loggers from June 10 - August 31 2022.

Phase II: Results

A total of 1,948 measurements were collected over 77 days with depth ranging from 0.4 to 1.5m with an overall average of 1.0m. The light attenuation coefficient (K_d) varied widely, ranging from -0.2 m^{-1} (high transmittance) to -3.9 m^{-1} (low transmittance) and an average of -0.9 m^{-1} (Fig. 4A). Showing a slight reduction in Kd coefficient at lower depth, with some outliers due mostly to meteorological conditions.

Among the most useful expressions for quantifying the light available to seagrasses is described by the equation e^{-Kd*z} x 100 (Gallegos and Moore, 2000). By inserting the Kd value at corresponding depth (z) the percent light reaching the bottom can be determined. In Fig 4B, an average of 49% light reached the bottom at an average depth of 1 meter through the duration of the study.

Conclusions

- This study identified a sound relationship in light data collected from two different instruments (HOBOs and Licor) as a first phase of characterizing light penetration at depth (phase II).
- In Phase I the Hobo data loggers were deployed alongside a Licor over a period of 11 days, capturing a variety of weather and water quality conditions. Following the methods outlined by Long *et al*. (2012) we were able to develop a sound relationship between instrument readings in both air and water (Fig. 3).
- In Phased II the equation developed in Phase I was applied to derive light attenuation coefficients (Kd) values using the HOBO light loggers alone. Reconfiguring the HOBO logger deployment to create a depth profile (Fig. 2B), we were able to measure subtle changes in Kd (Fig. 4A) and light penetration (Fig. 4B) at varying depth due to tide.
- Using these values (Fig. 4), a light regime can then be described for a given area and time period. For example, at North Bay in the Loxahatchee River Estuary, for approximately 3 months in the summer during the peak seagrass growing season (Metz *et al*. 2020), less than 30% of the light measurements (blue bars) fell outside seagrass growth requirements (green box; based on the 24-37% minimum light requirement for *Halodule wrightii*; Kenworthy and Fonseca 1996), indicating that North bay experiences ideal light conditions for *Halodule wrightii* seagrass growth (Fig. 5).
- Unlike general habitat characterizations which include data from multiple locations, this work is site specific. Where a specific set of calibrations (Phase I), is used to determine light penetration depth (Phase II). This information can then be applied to determine site-specific light regime (Fig. 5), a useful tool in pre-restoration habitat site selection, for activities such as seagrass restorations.

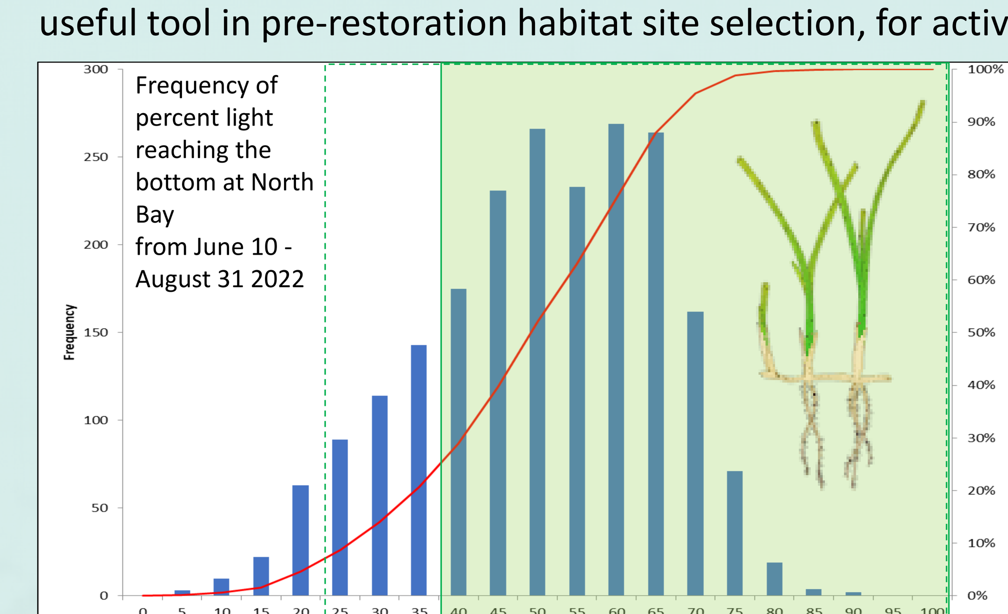


Figure 5. Frequency (y-axis, blue bars) of percent light reaching the bottom (x-axis) with secondary y-axis (red line) showing the cumulative % of each percent light represented in the dataset. Solid green box indicates 37% and dashed green box 24% min light requirements for *Halodule wrightii (*Kenworthy and Fonseca, 1996). The higher frequencies of over 40% light reaching the bottom shown in the green box suggest the minimum light requirements for *Halodule wrightii* were met and exceeded during peak growing season at the North Bay site.

Acknowledgements & References

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Halodule wrightii digital library image: Integration and Application Network https://ian.umces.edu/media-library/

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