PAR AND LIGHT EXTINCTION BENEATH VARIOUS DOCK DECK TYPES, PLEASANT HARBOR MARINA, WA

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Introduction

The Washington Department of Natural Resources (DNR) is challenged with finding a sustainable balance between water dependent uses and environmental protection of state-owned aquatic lands.. Studies indicate that shading by overwater structures in the marine nearshore is deleterious to nearshore species and their habitat (Ono et al. 2010). Therefore, DNR has an interest in ensuring that overwater structures are designed to maximize light available to the nearshore aquatic resources; to allow enough photosynthetically active radiation (PAR) to reach submerged vegetation and fish swimming in the shallow nearshore.

A previous controlled, mesocosm experiment was conducted by DNR to quantify and compare light attenuated by five decking types that differed in the percentage and shape of open space, as well as the vertical thickness of the decking material. There were significant differences found in light at the surface directly beneath the various decking types, at different deck elevations above water and orientation to shoreline. In most cases light passing through the decking was below ecological thresholds required for eelgrass survival and normal fish behavior.

Objectives

This project built upon the findings of the mesocosm study to assess light under decking of various types and down through the water column in a field setting, at Pleasant Harbor Marina in Brinnon, WA (Fig. 1). The shading effects of various deck types were determined by reductions in available PAR as a proportion of available light at neighboring (control) open water locations, including analysis of significant differences due to seasonal and diurnal sun angle variations.

Methods

Between August 2015 - June 2016, ten Odyssey light (PAR) sensors were deployed beneath four deck types with various transmission properties (Fig. 1). Deck types included solid and wood decking, as well as two with light transmission capabilities, including slot and grid types, with 42 and 70% open space respectively (Fig. 2).

Fig. 1 Field Site Pleasant Harbor Marina, Brinnon, WA

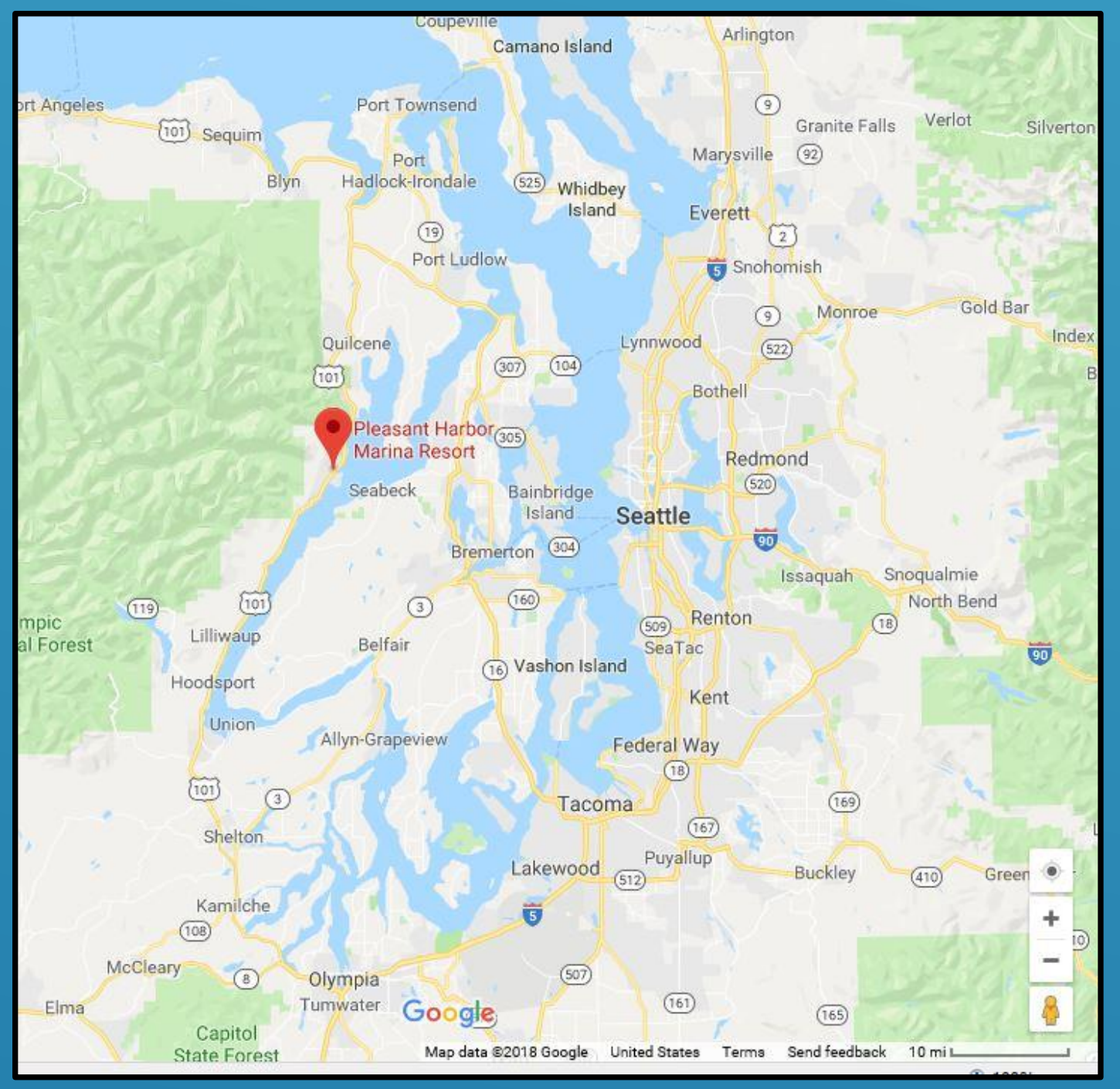
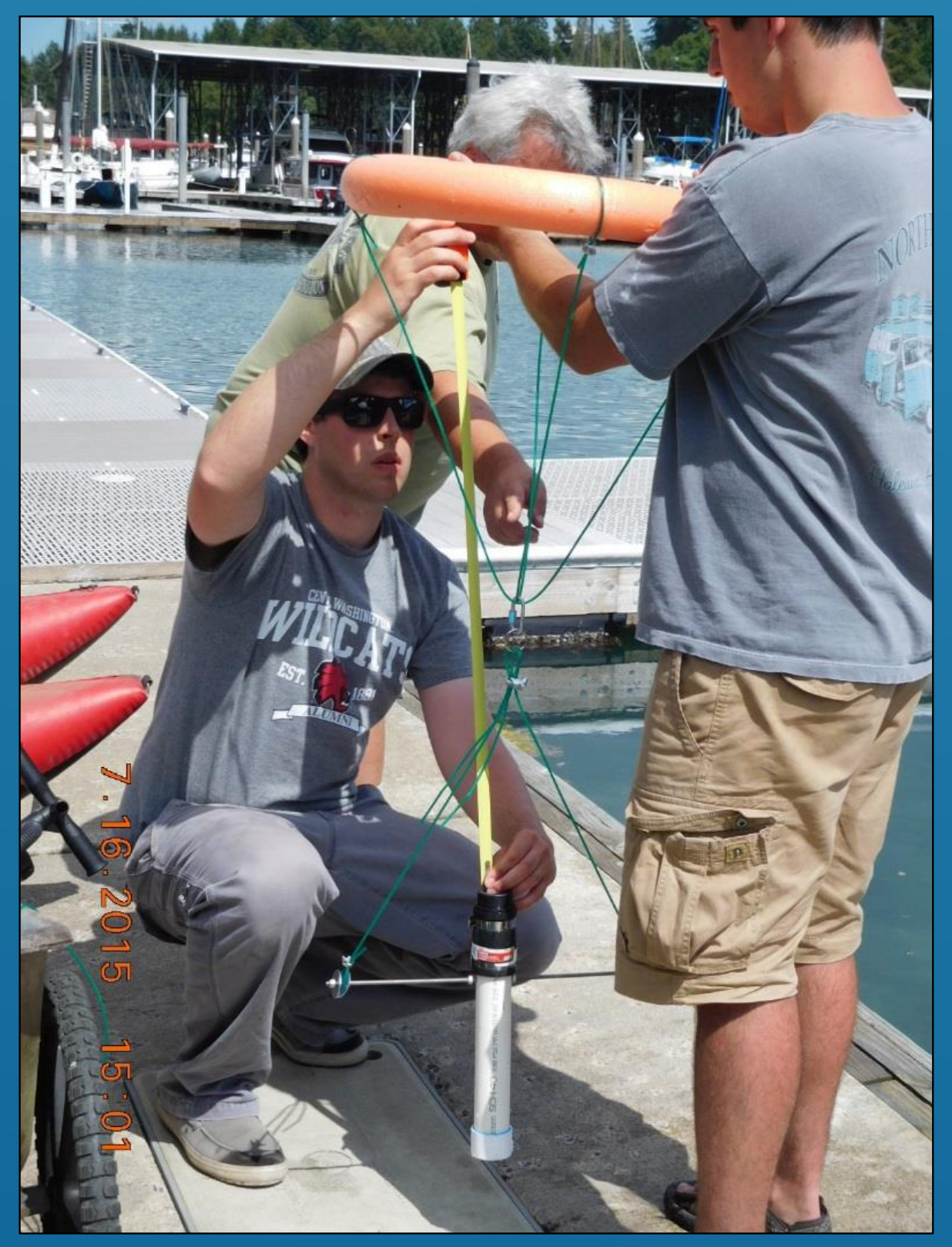


Fig. 2 Deck Types and Dimensions

	Grid 70% open space	**Slotted** 42% open spachce	**Wood** No open space	**Cement** No open space
Width (m)	2.44	2.44	2.44	1.83
Elevation above water (cm)	38	35.5	35	35.5
Depth below water (cm)	25	25	25	46

Fig. 3 Light Sensor Calibration & Deployment



Sensors were suspended from harnesses at 88 cm water depth below the middle of each deck type (two replicates) (Fig. 3) Two control sensors were installed at the same depth on uncovered floats anchored to the bed.

The Odyssey ™ light sensors were calibrated over a 24 hour period to a manufacturer calibrated LI-COR® light meter. The light sensors are coupled to an electronic amplifier that gives a pulse output. The repetition rate of the output is proportional to the intensity of light reaching the sensor. The total accumulated pulses received over a ten minute periods are recorded. The watts per square meter logged are converted to quantum flux units (μmol m^{-2} s^{-1}). PAR measured at each sensor was summed over the entire day to give total daily PAR (in units of mol m^{-2} day^{-1}). Data was collected over several three week periods during the spring, summer and fall.

Analysis

Light measurements were compared between various decking type, and an open water control. Analyses were conducted for each season and time of day to capture differences due to higher or lower sun angles

Season	Noon Sun Angle	Number of data collection days
Spring (April-May)	50.8-64.2°	46
Summer (June-August)	50.7-65.5°	50
Fall (Sept. – Oct.)	31.8-50.3°	49

Results

The mean percent of PAR available below various deck types (as a proportion of available light at neighboring open water location), varied between 3.4-19.7% over the study period (Fig. 4). Decking with light transmission properties (grid and slotted types) received 5-13% more PAR than solid decking during seasons with higher sun angles (spring and summer) (two sample t-test, p<0.05). Of the two, slotted decking received 42-46% less PAR than grid decking. The proportion of PAR received directly below solid decking (either wood or cement) did not vary significantly by season, ranging between 3.9-5.1% of the PAR received at the open water location (two sample t-test, p>0.05). Differences in the proportions of PAR received between higher sun and lower sun seasons (i.e. spring/summer vs. fall) was more evident in decking types with light transmission capabilities, which received 68-70% less of the available PAR in the fall.

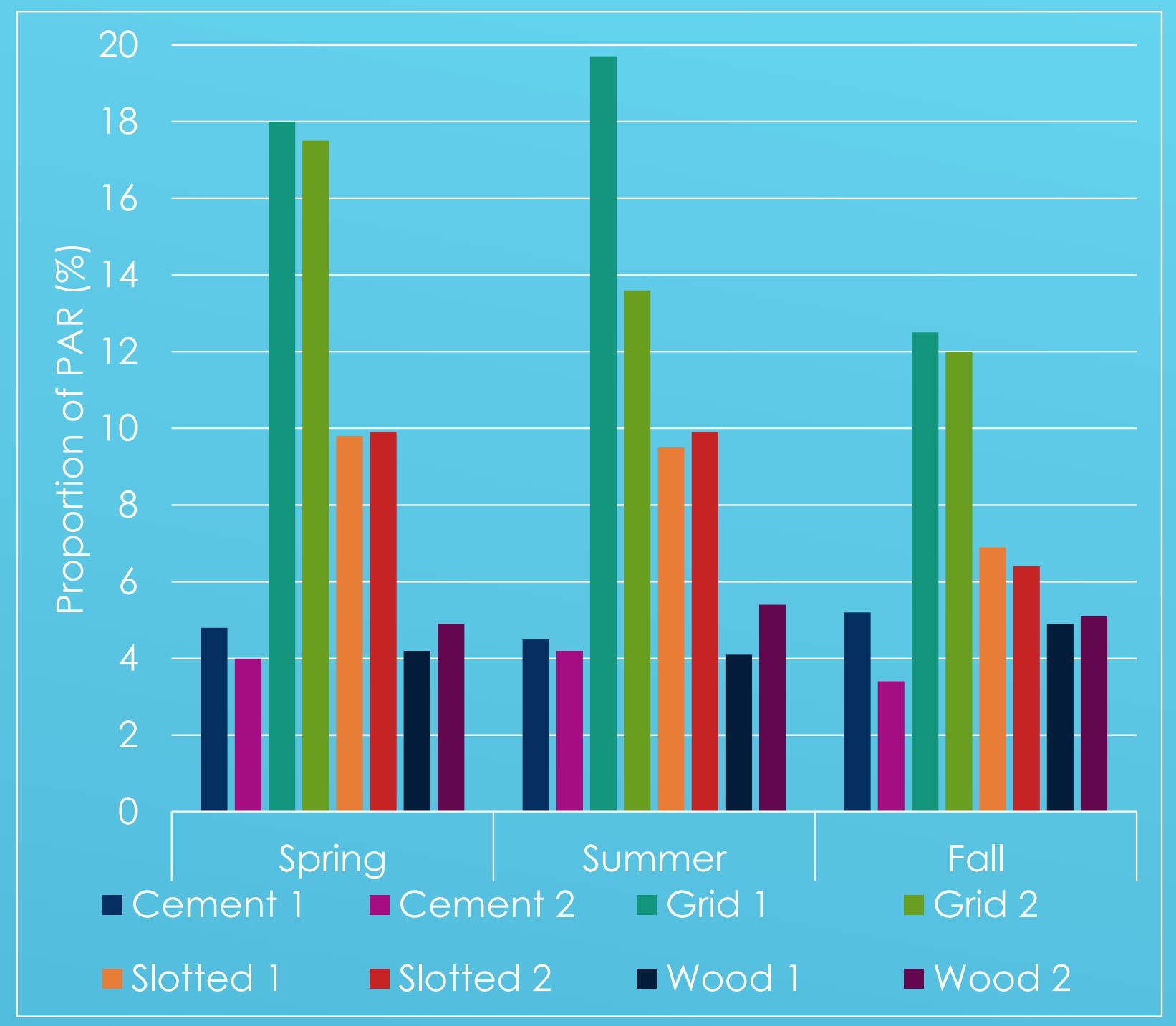


Fig. 4. Mean percentage of integrated PAR measured, beneath various deck types (@ 89 cm depths below water surface) proportional to open water control.

Similar to the DNR mesocosm study, mean proportions of PAR received by different decking types varied by sun angle during the day (Fig. 5). Again, differences in the proportions of PAR received between higher and lower sun angles by season (i.e. spring/summer vs. fall) was more evident in decking types with light transmission capabilities. Slotted and solid decking types received significantly higher proportions of available PAR during lower sun angle periods (dawn/dusk) than noon for all seasons (two sample t-test, p<0.05). Grid decking was the only type that received the greatest amount of the available PAR during the highest sun angle conditions (i.e. noon period) (two sample t-test, p<0.05).

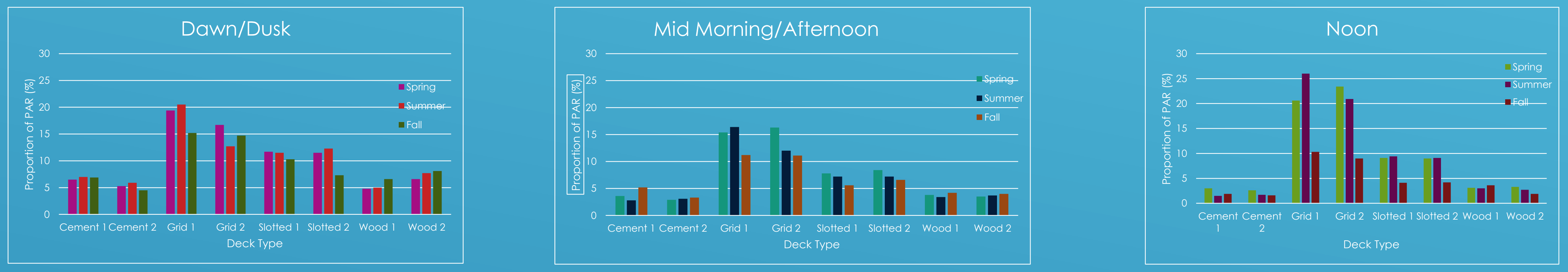


Fig. 5. Percent of PAR available below various deck types by season and time of day

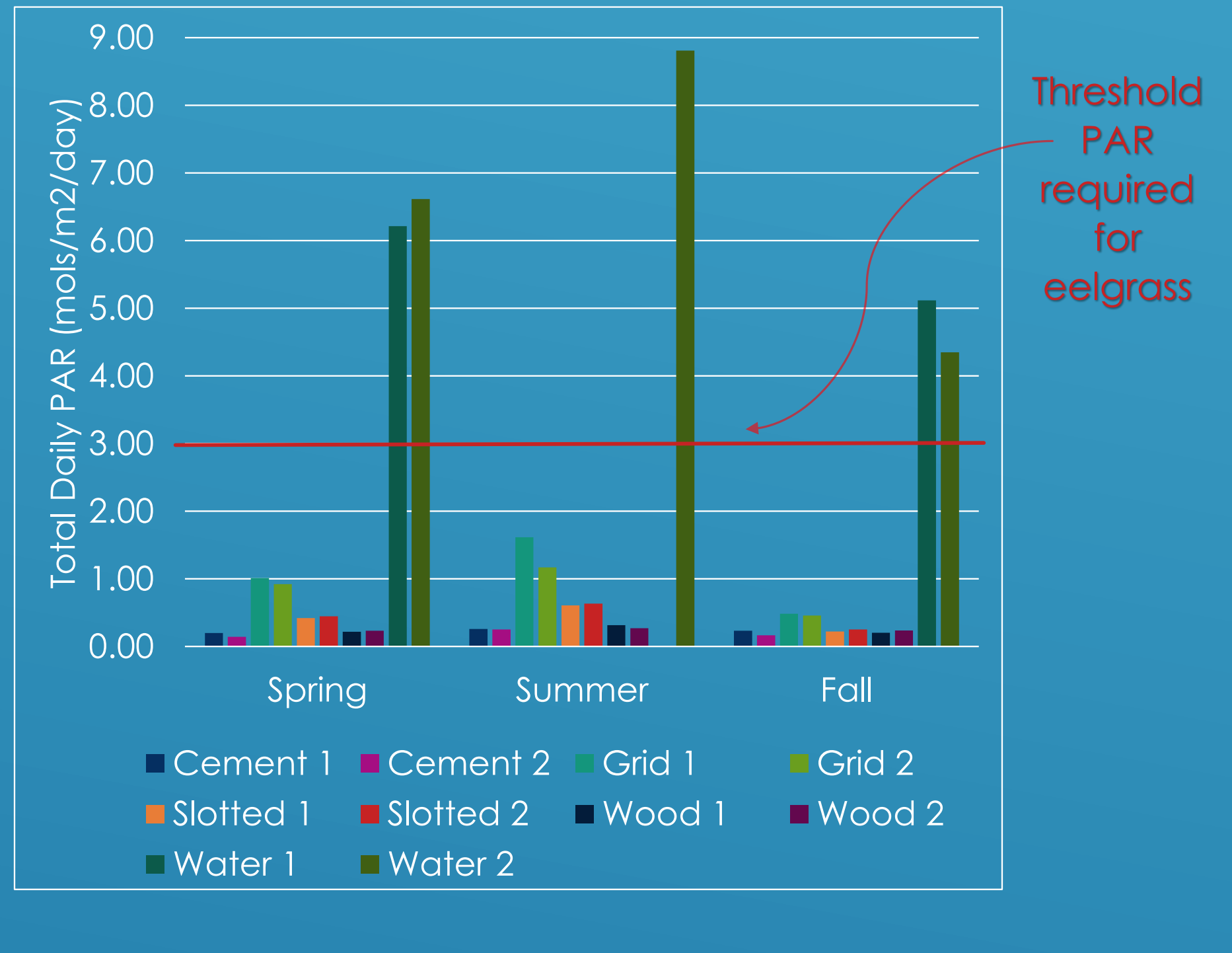


Fig 6. Total daily PAR available at 89 cm water depths below various deck types and open water surface (mols/m^2/day).

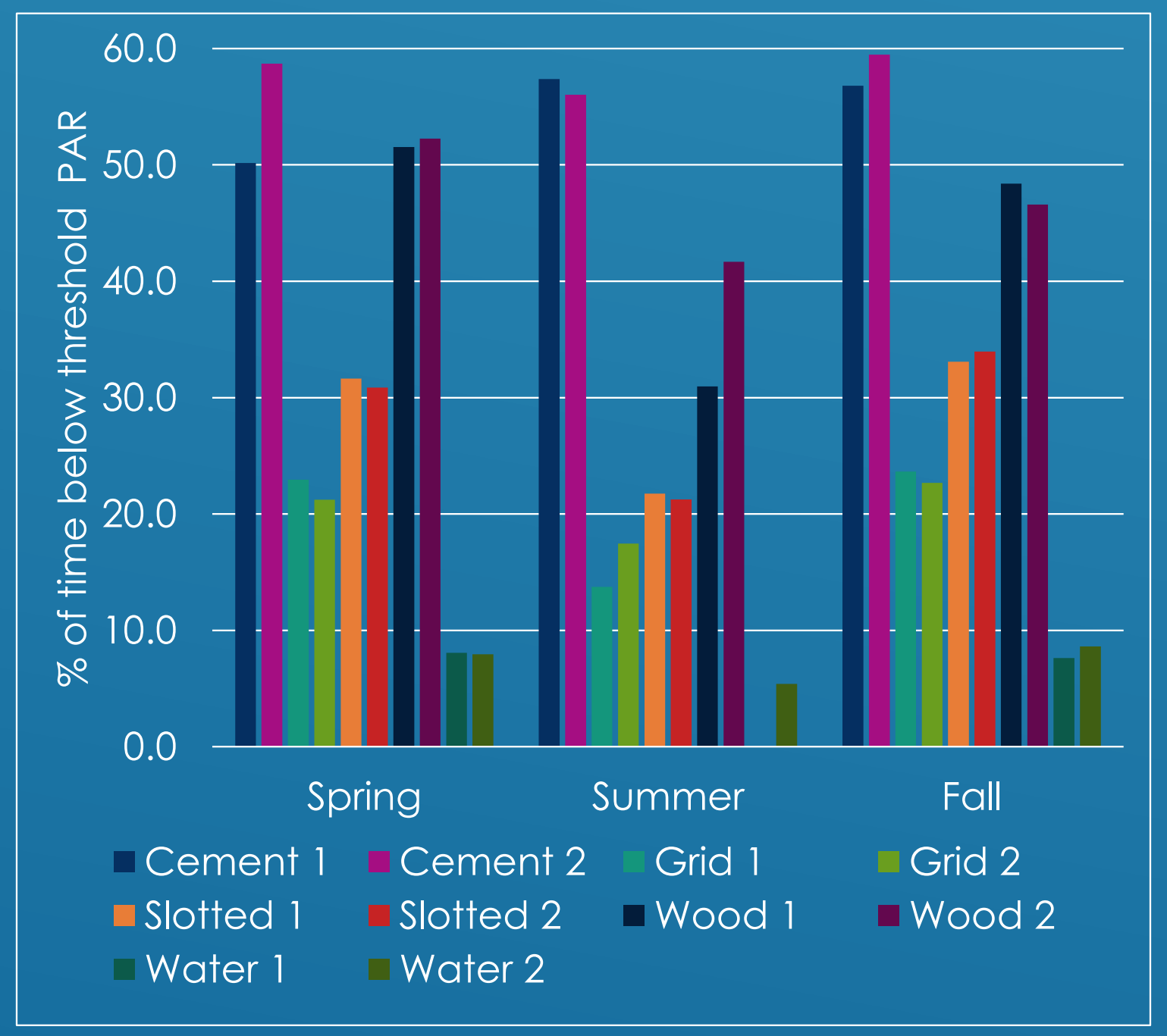


Fig 7. Proportion of time during daylight hours where instantaneous PAR was lower than ecological threshold of 2 μmols/m^2/second.

Previous research has demonstrated that reduction in light can limit the growth and reproduction of the native seagrass *Zostera marina* (Burdick and Short 1999, Shafer 1999, Smith and Mechid 1999). Eelgrass plants need daily PAR values of 3 mol/m^2/day during spring and summer to survive (Thom et al., 2008). When comparing this empirical ecological threshold value to the daily total PAR values measured below each deck type and the open water location, only the open water sites received PAR values above this minimum, ranging from 6.61-8.81 mols/m2/day) in the spring and summer (Fig. 6). The various deck types received <40% of these total values. The grid decking with the greatest amount of open space allowed < 55% of the threshold value of PAR required for eelgrass survival. All the other deck types received > 25% of this threshold PAR value.

An instantaneous PAR values of 2 μmol/ m^2/sec is a threshold value of light below which behavior changes have been observed in juvenile salmon and herring (Suzuki et al., 2007, Ali and Hoar 1959, Blaxter, 1966). Instances where sensors beneath each deck and the open water recorded a value lower than the threshold were identified, tallied and calculated as a percentage of daylight time (Fig. 7). All deck types had significantly more time periods below the threshold value (13.7-59.5%) than the open water location (5.4-8.6%)(Kruskal-Wallis, p<0.05). Of the various deck types, the grid decking had were below this threshold value the smallest proportion of time.

All deck types reduced the amount of light reaching just 89 cm below the water surface. The amount of light that travels through the water column to the depth of submerged vegetation or fish habitat is reduced even further, as light is extinguished exponentially with distance traveled through water according to the Beer-Lambert Law: $I_z / I_o = e^{-kz}$

Where: I_z = the intensity of light at depth z,
I_o = the intensity of light at the ocean surface
k = the light attenuation or extinction coefficient

Using this equation, light intensity at a given depth can be calculated if the extinction coefficient and light intensity at the water surface are known. For example, applying an extinction coefficient of 0.60/m (the median value from the range of extinction coefficients measured throughout the summer at sites in Puget Sound), and a water surface light intensity of 4 mole/m2/day (above the eelgrass minimum threshold) results in a light intensity of just 1.2 mole/m2/day at 2 meters below the water surface. This is far below the required minimum threshold.