Daily irradiance at the surface and seafloor

Overview: Irradiance in giant kelp forests can be affected by biotic and abiotic processes including giant kelp surface canopy, plankton abundance and sedimentation associated with waves and tides. The following describes methods used to characterize the spatial and temporal patterns of irradiance at the surface and on the seafloor at four SBC LTER kelp forest sites. These data compliment a long-term experiment in which giant kelp is removed annually from permanent plots to investigate the ecological consequences of kelp loss during winter storms.

Experimental design: We initiated a long-term experiment at four kelp forest sites (Arroyo Quemado, Naples, Mohawk, and Carpinteria) in 2008 to investigate the ecological consequences of regular kelp loss during winter to the structure and function of kelp forest communities in the Santa Barbara Channel (a fifth site, Isla Vista, was added in 2011). Paired 40 m x 40 m plots were established at each site and giant kelp is removed once per year in winter from one of the plots in each pair to simulate the effects of increased frequency of storm disturbance on giant kelp. The other plot in each pair is subjected to only natural disturbance and serves as a control. Changes in the structure (e.g. species abundance, diversity) and function (e.g. primary production of understory algae, detrital accumulation) of the benthic community are being followed over time with seasonal monitoring in permanent 40 m x 2 m transects centered within each plot. To evaluate the effects of the constant removal of giant kelp on the benthic community we established a second 40 m x 2 m transect in 2001 in the four original kelp removal plots within which giant kelp is continually removed throughout the year.

Methods: Submersible PAR sensors (MKV-L, Alec Electronics, Japan) are used to measure instantaneous irradiance at the surface and on the seafloor. The measuring range of these sensors is 0-2000 μmol m^{-2} s^{-1} with resolution to 0.5 μmol m^{-2} s^{-1}.

Surface irradiance is measured using submersible PAR sensors calibrated for use in air. Sensors were deployed at Mohawk and Arroyo Quemado from 2008-present. A shorter time series (2008-2010) of surface irradiance is available for Carpinteria. Sensors are mounted ~30 to 100 cm above the sea surface on a moored vertical spar buoy at each site. Instantaneous irradiance is recorded in units of μmol m^{-2} sec^{-1}. From 2008-2012, irradiance was recorded once per minute. Beginning in May 2013, samples were recorded once every two minutes. Instantaneous records are averaged to obtain hourly estimates over the course of each day and these hourly estimates are summed to yield estimates of daily quanta in units of moles m^{-2} day^{-1}.

Irradiance on the seafloor is measured using submersible PAR sensors calibrated for use in water. Instantaneous irradiance is recorded in units of μmol m^{-2} sec^{-1}. From 2008-2012, irradiance was recorded once per minute. Beginning in May 2013, samples were recorded once every two minutes. Sensors are mounted on a stake 30 cm above the seafloor in the kelp removal and control plots at Arroyo Quemado, Naples, Mohawk and Carpinteria reefs. Beginning in 2010, par sensors in the kelp removal plots at Arroyo Quemado, and Carpinteria reefs were moved from the transect subjected to annual kelp removal to the transect subjected to continuous kelp removal. Additionally at this time, a third sensor was deployed at Mohawk at the continuous removal transect enabling bottom irradiance data at this site to be collected at

transects subjected to continuous kelp removal, annual kelp removal and no experimental kelp removal.

Sensors are retrieved every six to twelve weeks and replaced with a clean newly calibrated sensor. Biofouling can be problematic when examining abiotic processes in marine systems. We quantified attenuation by fouling communities using irradiance records of fouled sensors. To calculate attenuation, we evaluated irradiance records of fouled sensors on the last day of their deployment. Irradiance of a fouled sensor was evaluated for 20 minutes, the sensor was cleaned, and irradiance records were evaluated for an additional 20 minutes post cleaning. Measurements of irradiance were then corrected for fouling as an exponentially increasing function of attenuation and time after deployment. Corrected records of instantaneous irradiance on the seafloor are averaged to obtain hourly estimates over the course of each day and these hourly estimates are summed to yield estimates of daily quanta on the seafloor in units of moles m^{-2} $day.^{-1}$