

Estimates of kelp blade erosion rates

Contains excerpts from: Rodriguez, G. E. 2014. Turnover dynamics of the giant kelp, *Macrocystis pyrifera*. Ph.D Dissertation, University of California, Santa Barbara.

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Overview/Background- The giant kelp, *Macrocystis pyrifera*, supports one of the most productive ecosystems on Earth and this high productivity is driven by rapid growth and frequent turnover of standing biomass. Losses of entire individuals, entire fronds and of dissolved exudates have been studied at length by the Santa Barbara Coastal Long Term Ecological Research program. However, before an *M. pyrifera* frond or individual is detached, a portion of the blade biomass on the frond is lost and this material may constitute a significant proportion of giant kelp's productivity. This study uses a combination of field measurements and mathematical modeling to estimate daily loss rates of blade tissue found on intact kelp fronds that compose the standing biomass.

Methods: Macrocystis blade loss observations

Field Collection. Changes in the area of tagged blades located on intact giant kelp fronds were measured from July to November 2012 (Rodriguez et al. 2016). One bottom, one midwater and one canopy blade from each of twenty mature sporophytes (hereafter referred to as plants) were haphazardly chosen along two transects: one following the offshore edge of the Isla Vista Kelp Forest and another 10 m inshore running parallel through the interior of the forest. A single young frond ~75 cm in total length was chosen from each replicate plant, and changes in the area of three blades on each of these fronds were followed over time. Bottom, midwater and top blades were defined as the 2nd, 6th and 40th blade from the base of each frond, respectively. 120 blades were measured every seven days following an initial observation (or from the time of separation from the apical meristem in the case of "top" blades) until the blades had eroded to less than 10% of the maximum area, the frond had senesced to less than 50% of its maximum length or until the frond was lost from the holdfast.

On each sampling date, the length and width of each blade was measured by divers using SCUBA. Length was measured as the longest distance along the primary axis of the blade. Width was measured as the greatest distance perpendicular to the primary axis of the blade. Blade area was calculated from length and width using the equation for an ellipse.

Data Processing. Although blades were selected based on their position on the frond (Rodriguez et al. 2016), for the purpose of this analysis we assigned each blade as being subsurface (occurring in the water column of a young frond that does not reach the sea surface, water column (occurring in the water column section of a frond that reaches the sea surface), or canopy (occurring in the floating canopy section of a frond that reaches the sea surface) as per the definitions used in Rassweiler et al. (2008). Blades were sorted into these three categories on each sampling date based on their location on the frond (2nd, 6th and 40th from the base) and the length of the frond on that sampling date. Any blade sampled prior to 58 days from the initial observation was categorized as a subsurface blade. Blades sampled 59 or more days from the

initial observation were assumed to be located on a frond that reached the sea surface. Bottom and midwater blades (2nd and 6th from the base) observed on surface reaching fronds were categorized as water column blades while top blades (40th from the base) were categorized as canopy blades.

Daily change in blade area from one observation to the next was calculated for each blade on each sampling day using linear interpolation. Changes in blade area were used to calculate daily loss rates for each sampling period. Loss rates from growing blades (i.e. blades that had not reached their maximum size) were assumed to be zero. Hence non-zero loss rates represent the loss of tissue from senescing blades (i.e. blades that were no longer increasing in size). Observations of interior and edge blades were combined to yield daily loss rates for 104 subsurface blades, 70 water column blades and 34 canopy blades.

Modeled Loss Rates from Senescing Blades. To estimate mean loss rates for subsurface, water column and canopy blades we simulated populations of 500 blades of each type over the course of 10,000 days. Field-estimated rates of blade senescence were applied to simulated blades and material lost each day was estimated over the lifetime of each blade. Blades in our simulation also experienced complete loss when the frond or plant to which they were attached to was lost. The probability of plant or frond loss was 0.0176 per day based on the average observed at three sites in the Santa Barbara Channel from 2002- 2016 (Rassweiler et al. 2016). Blades lost as a result of frond or plant loss were immediately replaced by blade of the same type in the simulation with new age-zero blades to simulate a population at equilibrium. Daily loss rates were calculated as the sum of the area lost from all blades on a given day (cm² lost) divided by the sum of the areas of all blades at the beginning of that day (cm²). Daily loss rates were calculated separately for subsurface, water column and canopy blades, and were averaged over the entire simulation. The resulting loss rates of blade area were assumed to be representative of the fraction of mass lost by senescing blades (i.e., the amount of blade mass lost per unit blade mass).

Estimates of Uncertainty in Loss Rates from Senescing Blades. To quantify uncertainty in our modeled rates of loss from senescing blades, we iterated our simulation 10,000 times. For each iteration, we drew an alternative blade loss rate (the sum of whole plant and whole frond loss rates) from a lognormal distribution with mean = 0.01763 and standard deviation = 0.0091392. These values were derived from the distribution of loss rates in all seasons at three sites from 2002-2016 (Rassweiler et al. 2016).

We used a bootstrapping approach in our simulations to account for uncertainty due to sampling error in our field observations of blade senescence. For each iteration, we randomly re-sampled with replacement from our measured trajectories of senescence for subsurface, water column and canopy blades, constructing a new set of trajectories that were used for that iteration of the simulation.

Loss rates from senescing subsurface, water column and canopy blades from the 10,000 iterations were found to be normally distributed. The mean and standard deviation of the daily

loss rate (d^{-1}) from senescing subsurface, water column and canopy blades were calculated and are presented here.

References

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