

## Understory Kelp Allometrics

*Overview:* One potential manifestation of climate change is an increase in the frequency of severe storms. Such changes are likely to have profound effects on giant kelp forest ecosystems because storms are a major source of disturbance that removes kelp and other biota. An increase in the frequency of severe storms would likely result in large losses of giant kelp every winter. Giant kelp is the foundation species of the ecosystem and our long-term monitoring shows that the dynamics of the benthic community of understory algae and sessile invertebrates are directly linked to the dynamics of giant kelp (Arkema et al. 2009. *Ecology* 90: 3126–3137).

*Study Sites.* Time series data of reef biota (i.e., algae, invertebrates and fish) and irradiance were collected at five reefs as part of a long-term experiment designed to evaluate the effects of disturbance to giant kelp (*Macrocystis pyrifera*) on the structure and productivity of the benthic community. The five reefs (Arroyo Quemado 34° 28.048'N, 120° 07.031'W; Carpinteria 34° 23.474'N, 119° 32.510'W; Isla Vista 34° 23.275'N, 119° 32.792'W; Mohawk 34° 23.649'N, 119° 43.762'W; and Naples 34° 25.342'N, 119° 57.102'W) ranged in depth from 5.8 m to 8.9 m (MLLW) and were chosen to represent a range of physical and biological characteristics known to influence the structure and productivity of subtidal reef communities in the region. A ubiquitous (but not always persistent) feature on these reefs was the presence of giant kelp, which forms a dense canopy at the sea surface that alters the biomass, diversity and temporal stability of reef biota (Castorani et al. 2018, Miller et al. 2018, Lamy et al. 2020).

Beginning in 2008, giant kelp was removed from a 2000 m<sup>2</sup> plot once per year in winter at four reefs (Arroyo Quemado, Carpinteria, Mohawk and Naples) to simulate the effects of winter storm disturbance (referred to as “annual removal” treatment). An adjacent unmanipulated 2000 m<sup>2</sup> plot served as a control. Beginning in winter 2010, giant kelp was removed 1 to 2 times per season within a 600 m<sup>2</sup> area within (or in the case of Mohawk adjacent to) each of the annual removal plots to create a “continual removal” treatment. In fall 2011, a fifth site was established at Isla Vista with 2000 m<sup>2</sup> annual removal and control plots (a 600 m<sup>2</sup> continual removal treatment was not established at this site). The reef community of algae (including giant kelp), invertebrates and fish were surveyed in annual removal and continual removal plots prior to each experimental removal of giant kelp. Thus data collected on the date following the first kelp removal represents the first sampling period of the annual and continual removal treatments. The last experimental removals of giant kelp occurred in winter 2016 or winter 2017, depending on the site. The last sampling of reef communities under experimental conditions for annual and continual kelp removal treatments occurred ~12 months following the last kelp removal. Control, annual removal, and continuous removal plots continue to be sampled seasonally to document the recovery of the reef community in the absence of experimental kelp removal. Dates of the initiation and cessation of kelp removal in the experimental plots are provided in Table 1.

Table 1: Dates, in the format yyyy/mm/dd, of the first and last kelp removal for the annual and continual giant kelp removal treatments at the five reef sites.

Reef	Treatment	Date of First Removal	Date of Last Removal
Arroyo Quemado	Annual	2008/01/30	2017/03/02
	Continual	2010/02/04	2017/03/02
Carpinteria	Annual	2008/02/12	2017/02/15
	Continual	2010/01/29	2017/02/15
Isla Vista	Annual	2011/10/26	2016/02/18
Mohawk	Annual	2008/01/17	2017/02/13
	Continual	2010/05/05	2017/02/13
Naples	Annual	2008/01/10	2016/02/09
	Continual	2010/01/28	2016/02/09

*Methods:* Allometric measurements of adult individuals of the understory kelps *Laminaria farlowii* and *Pterygophora californica* were made for the purpose of obtaining estimates of the biomass of these species within each transect. Adults of these species are defined as follows:

*Pterygophora:* stipe length  $\geq$  20cm, stipe diameter > 0.7cm measured 20cm above the holdfast

*Laminaria:* blade width  $\geq$  15cm

The first 30 individuals of each species encountered along each transect were measured twice per season from 2008 - 2012. The number of *Pterygophora* blades  $\geq$  30cm and the total length of each *Laminaria* blade  $\geq$  30cm were recorded for each adult individual encountered. Biomass in units of g dry mass  $m^{-2}$  was estimated from linear regressions based on data of individuals collected in the field and measured and weighed in the laboratory (shown below). Allometric sampling was discontinued in 2013 at which time sufficient data had been collected to predict the biomass of these species from density data of different size classes.

Phylum	Taxon	Equation to estimate biomass (dry g $m^{-2}$ )	$r^2$	N
Phaeophyta	<i>Pterygophora californica</i>	6.29 ( # blades > 30 cm )	0.77	145
Phaeophyta	<i>Laminaria farlowii</i>	0.31 ( blade length in cm )	0.9	52