

### Reef Fish Density

*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.

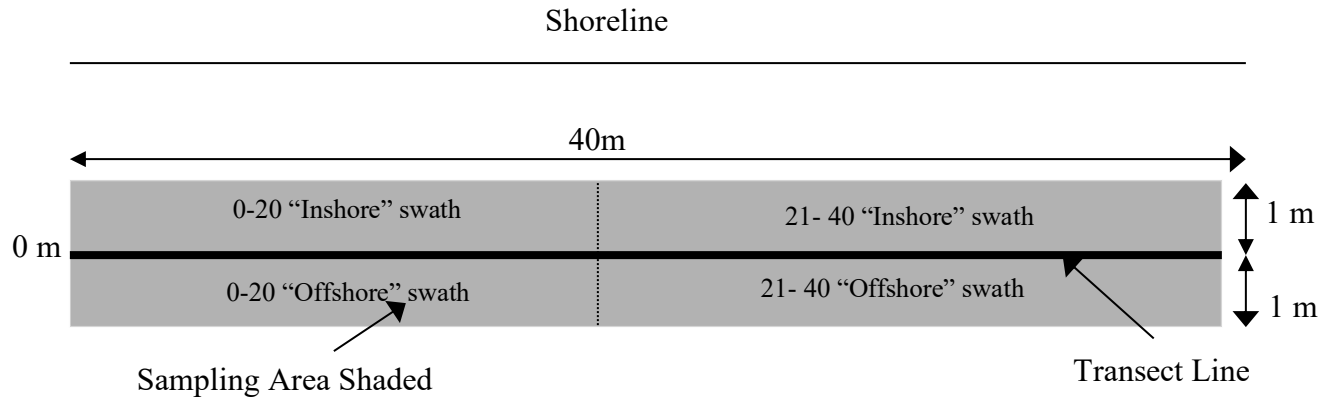
Reef	Treatment	Date of First Removal	Date of Last Removal
Arroyo Quemado	Annual	2008/01/30	2017/03/02
	Continual	2010/02/04	2017/03/02
Carpinteria	Annual	2008/02/12	2017/02/15
	Continual	2010/01/29	2017/02/15
Isla Vista	Annual	2011/10/26	2016/02/18
Mohawk	Annual	2008/01/17	2017/02/13
	Continual	2010/05/05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

*Methods:* The number, size and species identity of reef fish are recorded within a 2 m wide swath centered along each transect extending 2 m off the bottom. A diver swims the length of the 40 m transect approximately 1m above the bottom at a constant deliberate speed and records all fish passing through the sampling area. Fish size is measured as total length (TL) estimated to the nearest cm. Care is taken by the diver to not count the same individual more than once if it leaves and re-enters the sampling area. Surveys are carried out by only a select number of highly trained divers whose sampling techniques have been standardized in order to minimize observer bias. The horizontal visibility along the transect is measured and recorded for each sampling event. The number of fish taxa sampled is not fixed as all species of reef fish encountered in the sampling area are recorded. Species that are difficult to identify underwater are lumped into broader taxonomic categories (e.g., flatfish in the family Bothidae) to facilitate sampling.

Several species of small bottom-dwelling fish are difficult to accurately count and size during the reef fish survey due to their cryptic appearance and behavior. Individuals in a select group of these species are counted and sized in a separate survey done in the four contiguous 20 m x 1 m swaths that centered on the 40 m transect (Figure 1). A diver carefully searches the area within each swath taking time to look on the undersides of ledges and in crevices, and within understory vegetation for select species of small cryptic fish that are purposely not counted in the reef fish survey. Understory algae are brushed aside during the search, but no organisms or

boulders are physically moved. Size is recorded as total length (TL) to the nearest cm. The species of small cryptic fish counted in this survey are listed in Table 1.

**Figure 1.** Schematic diagram showing the position of the four 20 m x 1 m swaths relative to the 40 m transect.



**Table 1.** Species list of small cryptic fish surveyed.

SP_CODE	GENUS	SPECIES	COMMON_NAME
AHOL	<i>Alloclinus</i>	<i>holder</i>	Island kelpfish
CLIN	<i>Gibbonsia</i>	spp.	Crevice kelpfish
CNIC	<i>Rhinogobius</i>	<i>nicolsii</i>	Blackeye goby
COTT	Cottid	spp.	Sculpins
CSTI	<i>Citharichthys</i>	<i>stigmaeus</i>	Pacific sanddab
LDAL	<i>Lythrypnus</i>	<i>dalli</i>	Bluebanded goby
LHIR	<i>Leiocottus</i>	<i>hirudo</i>	Lavender sculpin
NBLA	<i>Neoclinus</i>	<i>blanchardi</i>	Sarcastic fringehead
OPIC	<i>Oxylebius</i>	<i>pictus</i>	Painted greenling