SBC-LTER Long Term Experiment Methods

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Density of algae and invertebrates

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).

Experimental design: We initiated a long-term experiment (LTE) 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 for the experimental removal of kelp. 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 the kelp removal plots at each site within which giant kelp is continually removed throughout the year. Transects are oriented parallel to shore in an eastward direction and are marked with six bolts placed at distances of 0, 8, 16, 24, 32, and 40 meters. Before each survey, divers swim a fiberglass meter tape along the transect and clip it to each permanent bolt before pulling it taut. All transects were sampled every six weeks (twice per season) from 2008 through 2012 and have been sampled once per season since then. Seasonal sampling is conducted midmonth in February, May, August, and November. Giant kelp is removed from the experimental plots immediately after the first survey of each year is completed.

Methods: The abundance and size of a specified number of common species of invertebrates, algae are sampled by divers in 1 m^2 quadrats positioned at each of the six permanent bolts along each transect (Figure 1). The list of species and size categorizes sampled in the quadrats is shown in Table 1. Sampling entails thoroughly searching the area within each quadrat for the targeted species without disrupting the bottom substrate or displacing organisms.

The abundance and average size of a select group of larger common algae and mobile invertebrates that are not easily counted in a 1 m^2 quadrats are counted in four contiguous 20 m x 1m swaths that run parallel and adjacent to the 40 m transect (Figure 2). The average size of each targeted species encountered is estimated for each 20 m x 1 m swath. The list of species and size categorizes sampled in the swaths is shown in Table 2. Sampling entails thoroughly searching the area within each swath for the targeted species without disrupting the bottom substrate or displacing organisms.

Figure 1. Schematic diagram showing the positioning of the 1 m^2 quadrats along the 40 m transect. Quadrats at 0 m, 16 m, and 32 m are positioned on the offshore side of the transect and quadrats at 8 m, 24 m and 40 m are positioned on the onshore side of the transect

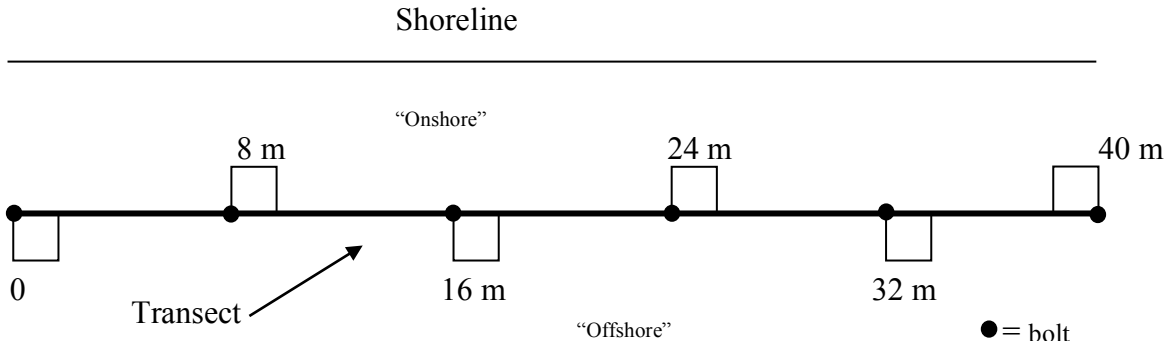

Table 1. List of species sampled in 1 m^2 quadrats

SP_CODE	GENUS	SPECIES	SIZE MEASUREMENT	COMMON_NAME
AMS	*Asterina*	*miniata*		Bat Star (<25mm)
ANSP	*Anthopleura*	*spp.*	.	.
BAEL	*Balanophyllia*	*elegans*	.	Orange Cup Coral
BLD		.	.	Blade stage of unidentified juvenile kelp
CHOV	*Chaceia*	*ovoidea*	.	Wart Necked Piddock
*COCA	*Conus*	*californicus*	length	Califonia Cone Snail
CUSA	*Cucumaria*	*salma*	.	.
CYJ	*Cystoseira*	*osmundaceae*		Bladder chain juvenile (< 5 cm diameter)
*CYSP	*Cypraea*	*spadicea*	length	Chestnut cowry
DIOR	*Diopatra*	*ornata*	.	Ornate tube worm
DIS	*Dermasterias*	*imbricata*		Leather star juvenile(<25mm)
EAJ	*Eisenia*	*arborea*		Southern sea palm juvenile (<5 cm stipe length).
EGJ	*Egregia*	*menziesii*		Feather boa kelp juvenile (<1m height)
*EUPO	*Eudistylia*	*polymorpha*	tube diameter	Feather duster worm
*EUQU	*Eupentacta*	*quinquesemita*	length	White sea cucumber
*LA	*Lytechinus*	*anamesus*	test diameter	White urchin
LFJ	*Laminaria*	*farlowii*		Oar weed juvenile (<15cm blade width).
LIGS	*Lithopoma*	*spp.*		Wavey turbin snail juvenile (<9cm diameter)
*MIID	*Mitra*	*idae*	length	Ida's mitre
MPJ	*Macrocystis*	*pyrifera*	0-33 cm, 34-66 cm, or 67-99 cm size categories	Giant kelp juvenile (<1m height)
*NONO	*Norrisia*	*norrisi*	length	Norris's top snail
OKS	*Orthasterias*	*koehleri*		Rainbow star juvenile (<25mm)
*OPES	*Ophioplocus*	*esmarki*	disc diameter	Smooth brittle star
*OPSP	*Ophiothrix*	*spiculata*	arm length (>2.5cm)	Spiny brittle star
PACA	*Parapholas*	*californica*	.	Scaleside piddock
*PAFI	*Pachycerianthus*	*fimbratus*	diameter	Tube dwelling anemone
PAST	*Paracyathus*	*stearnsi*	.	Brown cup coral
PBS	*Pisaster*	*brevispinus*		Short spined sea star juvenile

				(<25mm)
PGS	*Pisaster*	*giganteus*		Giant spined sea star juvenile (<25mm)
PHS	*Pycnopodia*	*helianthoides*		Sunflower sea star juvenile (<25mm)
*POPL	*Polyclinum*	*planum*	length	Elephant ear tunicate
POS	*Pisaster*	*ochraceus*		Ochre's sea star juvenile (<25mm)
PRUB	*Pachythyone*	*rubra*	.	.
PTJ	*Pterygophora*	*californica*		Stalked kelp juvenile (<20 cm stipe length)
*PTTR	*Pteropurpura*	*trialata*	length	Three-winged murex
*SFL	*Strongylocentrotus*	*franciscanus*		Red urchin adult (>25mm)
SFS	*Strongylocentrotus*	*franciscanus*		Red urchin juvenile (<25mm)
SKE	*Small Kelletia*	.	.	Kellet's welk
*SPL	*Strongylocentrotus*	*purpuratus*		Purple urchin adult (>25mm)
SPS	*Strongylocentrotus*	*purpuratus*		Purple urchin juvenile (<25mm)
STMO	*Stylela*	*montereyensis*	siphon diameter	Stalked tunicate
*TEAU	*Tethya*	*aurantia*	diameter	Orange puffball sponge
*TESP	*Tegula*	*spp.*	length	Turbin snail
URLO	*Urticina*	*lofotensis*	.	White-spotted rose anemone
URPI	*Urticina*	*piscivora*	.	Fish eating anemone

*denotes an estimate of mean size is recorded

Figure 2. Schematic diagram showing the position of the four 20 m x 1 m swaths relative to the 40 m transect.

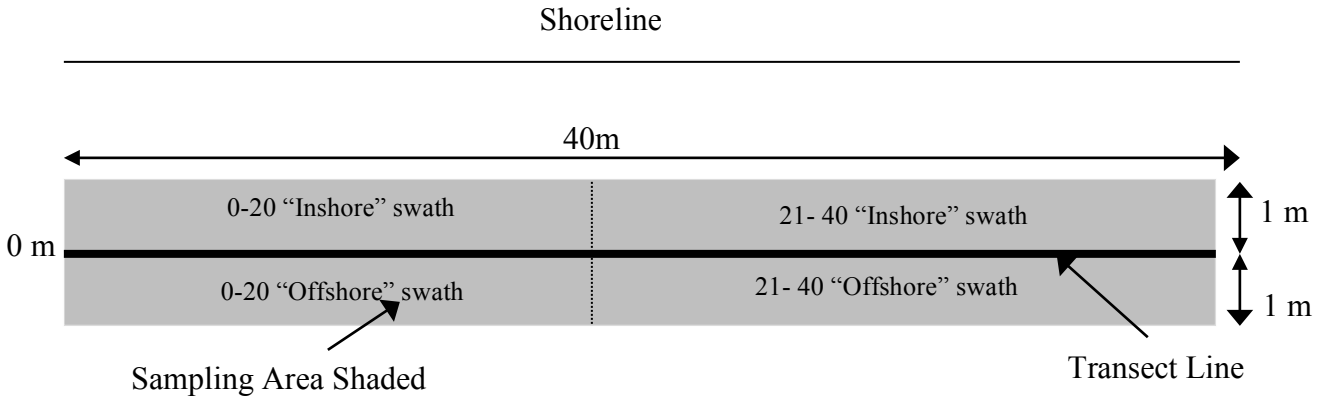

Table 2. List of species sampled in 20m x 1m swaths

SP_CODE	GENUS	SPECIES	SIZE	COMMON_NAME
*AML	*Asterina*	*miniata*	diameter	Bat star adult(> 25 mm)
*APCA	*Aplysia*	*californica*	agitated length	Sea hare
*APVA	*Aplysia*	*vaccaria*	agitated length	Spotted sea hare
*CASP	*Cancer*	spp.	carapace width	Cancer crab
*CRGI	*Crassadoma*	*gigantea*	diameter	Giant scallop
*CUKE	*Parastichopus*	*californicus*	agitated length	California cucumber
CYOS	*Cystoseira*	*osmundaceae*		Bladder chain adult (> 5 cm height)
*DIL	*Dermasterias*	*imbricata*	diameter	Leather star adult (> 25 mm)
*EA	*Eisenia*	*arborea*	number of blades >30cm	Southern sea palm adult (>5 cm stipe length)
*EGME	*Egregia*	*menziesii*	fronds > 1m tall	Feather boa kelp adult (>1m height)
*HACO	*Haliotis*	*corrugata*	length	Pink abalone
*HACR	*Haliotis*	*cracherodii*	length	Black abalone
*HAKA	*Haliotis*	*kamtschatkana*	length	Pinto abalone
*HARU	*Haliotis*	*rufescens*	length	Red abalone
*KEKE	*Kelletia*	*kelletii*	length	Kellet's welk
*LAFA	*Laminaria*	*farlowii*	length	Oar weed adult (>15cm blade width)
*LIGL	*Lithopoma*	spp.	diameter	Wavey turbin snail adult (> 25 mm)
*LOCH	*Lophogorgia*	*chilensis*	width	Red gorgonian
*LOGR	*Loxorhynchus*	*grandis*	carapace width	Sheep crab
*MECR	*Megathura*	*crenulata*	length	Giant key hole limpet
*MUCA	*Muricea*	*californica*	width	California golden gorgonian
*MUFR	*Muricea*	*fruticosa*	width	Brown gorgonian
*OCTO	*Octopus*	spp.	greatest arm length	Octopus
*OKL	*Orthasterias*	*koehleri*	diameter	Rainbow star adult (> 25 mm)
*PAIN	*Panulirus*	*interruptus*	carapace length	California spiny lobster
*PAPA	*Parastichopus*	*parvimensis*	agitated length	Warty sea cucumber
*PBL	*Pisaster*	*brevispinus*	diameter	Short spined sea star adult (> 25 mm)
*PGL	*Pisaster*	*giganteus*	diameter	Giant sea adult (> 25 mm)
*PHL	*Pycnopodia*	*helianthoides*	diameter	Sun star adult (> 25 mm)
*POL	*Pisaster*	*ochraceus*	diameter	Ochre sea star adult (> 25 mm)
*PTCA	*Pterygophora*	*californica*	number of blades >30cm	Stalked kelp adult (>20 cm stipe length)
*PUPR	*Pugettia*	*producta*	carapace width	Kelp crab

* denotes an estimate of the mean size is recorded