Kelp Forest Community Structure Methods

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Annual time series of biomass for kelp forest species

Overview: These data are part of a larger collection of ongoing data sets that describe the temporal and spatial dynamics of kelp forest communities in the Santa Barbara Channel. Data on the abundance (density or percent cover) and size of ~250 species of reef associated macroalgae, invertebrates and fishes, substrate type and bottom topography are collected annually by divers in the summer within fixed plots (i.e. 40 m x 2 m transects) at 11 sites (n = 2 to 8 transects per site) that have historically supported giant kelp (*Macrocystis pyrifera*). Species-specific relationships between size (or percent cover) and mass developed for the region are used to convert abundance data to common metrics of mass (e.g., wet, dry, de-calcified dry) to facilitate analyses of community dynamics involving all species. Data collection began in 2000 and is ongoing.

Study Sites: Nine of the 11 study sites occur along the mainland coast of the Channel (Arroyo Burro 34^0 24.007' N 119^0 44.663' W; Arroyo Hondo 34^0 28.312' N, 120^0 08.663' W; Arroyo Quemado 34^0 28.127' N, 120^0 07.285' W; Bulito 34^0 27.533' N, 120^0 20.006' W; Carpinteria 34^0 23.545' N, 119^0 32.628' W; Goleta Bay 34^0 24.827' N, 119^0 49.344' W; Isla Vista 34^0 24.170' N 119^0 51.472' W; Naples 34^0 25.340' N 119^0 57.176' W; Mohawk 34^0 23.660' N, 119^0 43.800' W) and two occur on the northern coast of Santa Cruz Island (Diablo 34^0 03.518' N, 119^0 45.458' W; Twin Harbors West 34^0 02.664' N, 119^0 42.908' W).

The time period of data collection varied among the 11 kelp forest sites. Sampling at Bulito, Carpinteria, and Naples began in summer 2000, sampling at the other six mainland sites (Arroyo Burro, Arroyo Hondo, Arroyo Quemado, Goleta Bay, Isla Vista, Mohawk) began in summer 2001 (transects 3, 5, 6, 7, 8 at Isla Vista were added in fall 2011). Data collection at the two Santa Cruz Island sites began in summer 2004.

Abundance

Species-specific estimates of biomass of benthic macroalgae, sessile and mobile macro invertebrates and fish were derived from abundance data on size-specific density or percent cover collected by divers within permanent 40 m x 2 m plots (hereafter referred to as transects) at each site. The abundance data and a description of the methods used to collect them can be found at:
1. percent cover of macroalgae and sessile invertebrates, https://portal.edirepository.org/nis/mapbrowse?scope=knb-lter-sbc&identifier=15;
2. size-specific density of macroalgae and invertebrates, https://portal.edirepository.org/nis/mapbrowse?scope=knb-lter-sbc&identifier=19;
3. size-specific density of giant kelp, https://portal.edirepository.org/nis/mapbrowse?scope=knb-lter-sbc&identifier=18;
4. size-specific density of fish, https://portal.edirepository.org/nis/mapbrowse?scope=knb-lter-sbc&identifier=17.

Occasionally data for a particular taxon were lost or not collected. In these cases, all metrics of abundance and biomass were assigned a value = -99999.

Abundance (count or percent cover) is recorded for specific size classes for some species in the four datasets listed above. In these cases, each size class of a species has a unique species code.

In this biomass dataset the biomass of all size classes is summed to obtain a single value for each species, and the species code for the large (adult) size class is used to represent the species. .

Biomass of Macroalgae:

Annual measurements of the abundance of all understory macroalgae including small *M. pyrifera* (< 1 m in height) were converted to de-calcified dry mass using taxon-specific relationships with percent cover or size-specific density developed for 23 taxa that accounted for more than 95% of the standing biomass of understory macroalgae averaged across locations sampled seasonally from 2008 to 2018 (algae biomass relationship data table in https://portal.edirepository.org/nis/mapbrowse?scope=knb-lter-sbc&identifier=127. The conversion of abundance to de-calcified dry mass for less common taxa was done by proxy using the relationship generated for a morphologically similar species (Table 1).

Biomass was converted from de-calcified dry mass to units of wet mass and ash free dry mass using ratios developed from tissue samples collected for common taxa. Wet mass and ash free dry mass of less common taxa were calculated using conversions for proxy taxa, when necessary. Decalcified dry to wet mass, decalcified dry to ash free dry mass, decalcified dry to carbon mass, and decalcified dry to nitrogen mass conversions are provided in data package https://portal.edirepository.org/nis/mapbrowse?scope=knb-lter-sbc&identifier=127. Proxy species for these measures are presented in Table 1. Biomass for the seagrass, *Zostera marina*, was converted from de-calcified dry mass to wet mass using the relationship of Wickham et al. 2018 and was converted from de-calcified dry mass to carbon, nitrogen, and ash-free dry mass using the relationship of Van Lent et al. 1991.

Size data for understory species whose abundance is measured as density (i.e., the kelps *Pterygophora californica* and *Laminaria farlowii*, and the fucoid, *Stephanocystis osmundaceae*) were not collected prior to 2008. To estimate the biomass of these species prior to 2008 we derived relationships between decalcified dry mass and density for adult and juveniles of each species using data from all sites and transects from 2008-2018. We applied the slope of these relationships to measured adult and juvenile densities to estimate the dry mass of these species from 2000-2007.

Table 1: SBC algal species list and the species code of the taxa used to: (1) estimate de-calcified dry mass (BMASS_PROXY) from size-specific density or percent cover, and (2) convert de-calcified dry mass to wet mass, C mass or N mass (WET_C_N_PROXY) and ash free dry mass (AFD_PROXY).

SP_CODE	GENUS	SPECIES	BMASS_PROXY	WET_CN_PROXY	AFD_PROXY
AMZO	*Amphiroa*	*zonata*	BO	BO	CF
ANPA	*Anisocladella*	*pacifica*	R	R	R
AU	*Acrosorium*	*uncinatum*	CF	BF	BF
BF	*Cryptopleura*	*farlowianum*	BF	BF	BF
BLD	Unidentified juvenile kelp	spp.	MPJ	PTCA	PTCA

SP_CODE	GENUS	SPECIES	BMASS_PROXY	WET_CN_PROXY	AFD_PROXY
BO	*Bossiella*	*orbigniana*	BO	BO	CF
BPSE	*Botryocladia*	*pseudodichotoma*	POLA	R	R
BR	Blady red	spp.	BR	CC	POLA
BRA	Branching Red Algae	spp.	R	R	R
CAL	*Calliarthron*	*cheilosporioid*	BO	CO	CF
CC	*Chondracanthus*	spp.	CC	CC	BF
CF	*Callophyllis*	*flabellulata*	CF	CF	CF
CG	*Cladophora*	*graminea*	RAT	RAT	RAT
CO	*Corallina*	*officinalis*	CO	CO	RAT
COF	*Codium*	*fragile*	GS	GS	GS
CP	*Colpomenia*	spp.	POLA	POLA	POLA
CRYP	*Cryptopleura*	spp.	BF	BF	BF
CYJ	*Stephanocystis*	*osmundaceae* - juvenile	CYJ	CYOS	CYOS
CYOS	*Stephanocystis*	*osmundaceae* - adult	CYOS	CYOS	CYOS
CYOS_R	*Stephanocystis*	*osmundaceae* - reproductive frond	CYOS_R	CYOS	CYOS
CZ	*Chondracanthus*	*spinosa*	CC	CC	GS
DIAT	Diatom	Mat	EC	FB	FB
DL	*Desmarestia*	*ligulata*	DL	DL	DL
DP	*Dictyota*	spp.	DP	DP	DP
DU	*Dictyopteris*	*undulata*	DP	DP	DP
EA	*Eisenia*	*arborea* - adult	EA	PTCA	PTCA
EAJ	*Eisenia*	*arborea* - juvenile	EAJ	PTCA	PTCA
EC	Encrusting	*coralline*	EC	CO	CF
EGJ	*Egregia*	*menziesii* - juvenile	MPJ33	PTCA	PTCA
EGME	*Egregia*	*menziesii* - adult	EGME	PTCA	PTCA
ER	Encrusting	red	EC	CO	CF
FASP	*Fauchea*	spp.	R	R	R
FB	Filamentous brown	spp.	FB	DL	FB
FG	Filamentous green	spp.	FR	DL	FB
FR	Filamentous red	spp.	FR	RAT	RAT
FTHR	*Neoptilota* *Ptilota* *Rhodoptilum*	spp.	CF	RAT	RAT
GEL	*Gelidium*	spp.	GS	GS	R
GR	*Gelidium*	*robustum*	GS	GS	GS
GS	*Gracilaria*	spp.	GS	GS	GS
GYSP	*Gymnogongrus*	spp.	R	GYSP	GS
HAGL	*Halosaccion*	*glandiforme*	POLA	R	R

SP_CODE	GENUS	SPECIES	BMASS_PROXY	WET_CN_PROXY	AFD_PROXY
IR	*Iridaea*	spp.	CC	CC	BF
LAFA	*Laminaria*	*farlowii* - adult	LAFA	LAFA	LAFA
LFJ	*Laminaria*	*farlowii* - juvenile	LFJ	LAFA	LAFA
LI	*Lithothrix*	spp.	CO	CO	CF
LS	*Laurencia*	spp.	LS	RAT	LS
LX	*Osmundea*	*spectabilis*	LS	RAT	LS
MAPY	*Macrocystis*	*pyrifera* - adult	MAPY	MAPY	MAPY
MPJ	*Macrocystis*	*pyrifera* - juvenile	MAPY	MAPY	MAPY
NA	*Nienburgia*	*andersoniana*	CF	BF	BF
NEO	*Neoagardhiella*	*baileyi*	GS	GS	GS
PHSE	*Phycodrys*	*setchellii*	R	BF	BF
PHTO	*Phyllospadix*	*torreyi*	DL	ZOMA	ZOMA
PL	*Prionitis*	*lanceolata*	CC	GYSP	R
POLA	*Polyneura*	*latissima*	POLA	POLA	POLA
PRSP	*Prionitis*	spp.	CC	GYSP	R
PTCA	*Pterygophora*	*californica*	PTCA	PTCA	PTCA
PTJ	*Pterygophora*	*californica* - juvenile	PTJ	PTCA	PTCA
PTL	*Pterygophora*	*californica* - subadult	PTL	PTCA	PTCA
R	*Rhodymenia*	*californica*	R	R	R
RAT	Red Algal Turf	spp.	RAT	RAT	RAT
SAFU	*Sarcodiotheca*	*furcata*	CF	CF	CF
SAGA	*Sarcodiotheca*	*gauchaudii*	SAGA	SAGA	GS
SAHO	*Sargassum*	*hornerii - adult*	SHJ	SHJ	CYOS
SAMU	*Sargassum*	*muticum*	SAMU	PTCA	CYOS
SCCA	*Scinaia*	*confusa*	GS	GS	GS
SELO	*Scytosiphon*	*lomentaria*	DP	DL	DL
SHJ	*Sargassum*	*horneri* -juvenile	SHJ	PTCA	CYOS
SMJ	*Sargassum*	*muticum*	SMJ	PTCA	CYOS
STIN	*Stenogramme*	*interrupta*	R	R	R
TALE	*Taonia*	*lennebackerae*	DP	DL	DP
UBB	Unidentified brown blade	spp.	BR	CYOS	CYOS
UEC	Unidentified erect coralline	spp.	CO	CO	CF
UV	*Ulva*	spp.	DP	DL	DL
ZOMA	*Zostera*	*marina*	DL	ZOMA	ZOMA

Divers also counted the density of *M. pyrifera* fronds $\geq$ 1 m in height in the 40 m x 2 m transects. The density of *M. pyrifera* fronds $\geq$ 1 m in height was converted to the biomass of giant kelp by

applying the relationship between frond density (no. m^{-2}) in August and dry mass density (dry kg m^{-2}) developed by Rassweiler et al. (2018).

Biomass of invertebrates

Annual measurements of the abundance of macroinvertebrate species were converted to shell free (i.e., decalcified) dry mass using taxon-specific relationships with size-specific density or percent cover developed for the 78 most common taxon (invertebrate biomass relationship data table in https://portal.edirepository.org/nis/mapbrowse?scope=knb-lter-sbc&identifier=127. Size data for invertebrates were not collected prior to 2008. Thus for 2000 to 2007 we estimated species-specific biomass of invertebrates for each transect using the long-term (2008 to present) mean size of juveniles and adults for that transect multiplied by their measured density. The conversion of abundance to mass for less common invertebrate taxa was done by proxy using the relationship generated for a morphologically similar species (Table 2).

Table 2. List of uncommon taxa of benthic invertebrates recorded in permanent plots and the proxy species used to convert their abundance to biomass.

SP_CODE	GENUS	SPECIES	PROXY SP_CODE	PROXY GENUS	PROXY SPECIES
ANSP	*Anthopleura*	spp.	URLO	*Urticina*	*lofotensis*
APVA	*Aplysia*	*vaccaria*	APCA	*Aplysia*	californica
ARUD	*Discophyton*	*rudyi*	PLUM	*Plumularia*	sp.
BOW	*Amathia*	*gracilis*	TC	*Thalamoporella*	*californica*
BRSP	*Barentsia*	sp.	TC	*Thalamoporella*	*californica*
CECO	*Centrostephanus*	*coronatus*	SFL	*Sebastes*	*flavidus*
COST	*Celleporina*	*robertsoniae*	DC	*Diaperoforma*	*californica*
CROC	*Crisia*	*occidentalis*	TC	*Thalamoporella*	*californica*
CUPI	*Cucumaria*	*piperata*	LINU	*Lissothuria*	*nutriens*
ECB	*Bryozoa*	spp.	CESP	*Cellaria*	sp.
HACO	*Haliotis*	*corrugata*	HARU	*Haliotis*	*rufescens*
HACR	*Haliotis*	*cracherodii*	HARU	*Haliotis*	*rufescens*
HADE	*Halcampa*	*decemtentaculata*	HARU	*Haliotis*	*rufescens*
HAKA	*Haliotis*	*kamtschatkana*	HARU	*Haliotis*	*rufescens*
HC	*Acanthancora*	*cyanocrypta*	ES	*Demospongiae*	spp.
HIP	*Primavelans*	*mexicana*	DC	*Diaperoforma*	*californica*
HPAC	*Heteropora*	*pacifica*	DC	*Diaperoforma*	*californica*
LIGS	*Lithopoma*	spp.	LIGL	*Lithopoma*	spp.
MISE	*Metridium*	*dianthus*	CY	*Corynactis*	*californica*
MT	*Jellyella*	*tuberculata*	CESP	*Cellaria*	sp.
MUFR	*Muricea*	*fruticosa*	MUCA	*Muricea*	*californica*
OBSP	*Obelia*	sp.	PLUM	*Plumularia*	sp.
OKL	*Orthasterias*	*koehleri*	PGL	*Pisaster*	*giganteus*
PHOR	*Phoronida*	spp.	SABW	*Sabellidae*	spp.
PHSP	*Phyllactis*	spp.	CY	*Corynactis*	*californica*
PIEL	*Pista*	*elongata*	SABW	*Sabellidae*	spp.

SP_CODE	GENUS	SPECIES	PROXY SP_CODE	PROXY GENUS	PROXY SPECIES
PLAB	*Phidolopora*	*labiata*	DC	*Diaperoforma*	*californica*
SC	*Spheciospongia*	*confoederata*	ES	*Demospongiae*	spp.
UAB	*Bryozoa*	spp.	TC	*Thalamoporella*	*californica*
UM	*Arthropoda*	spp.	ATM	*Amphipoda*	spp.
URPI	*Urticina*	*piscivora*	URLO	*Urticina*	*lofotensis*
WASP	*Phidolopora*	*labiata*	DC	*Diaperoforma*	*californica*

Biomass of fish

Annual measurements of the abundance and size of reef fish (i.e., those observed within 2m of the benthos) was converted to wet mass (g) using species-specific relationships obtained from the literature (fish biomass relationship data table in https://portal.edirepository.org/nis/mapbrowse?scope=knb-lter-sbc&identifier=127. For some species, relationships were derived for standard length to mass. In these cases, we used information provided from the author to convert measurements of total length to standard length prior to estimating wet mass. The wet mass of bony fishes was converted to de-boned dry mass (g) and ash free dry mass (g) using the average of conversion ratios for all reef fish provided in Taylor (1997). Wet mass of cartilaginous fishes was converted to dry biomass (g) using the conversion factor of Thorson 1976. No information was found to convert wet mass to ash free dry mass for cartilaginous fishes. Published relationships were not available for every fish species encountered on SBC LTER reefs. Therefore, we estimated the biomass of these species by proxy using the relationship published for a morphologically similar species (Table 3). *Note, the accuracy of sampling fish may vary with water clarity and data collected during sampling events when horizontal visibility was < 2 m should be used with caution*.

Table 3. List of reef fish recorded in permanent plots lack a published relationship between size and mass and the proxy species used to convert their abundance to biomass.

SP_CODE	GENUS	SPECIES	PROXY SP_CODE	PROXY GENUS	PROXY SPECIES
AHOL	*Alloclinus*	*holderi*	CLIN	*Gibbonsia*	sp.
BOTH	*Bothid*	spp.	PCAL	*Paralichthys*	*californicus*
CAGG	*Cymatogaster*	*aggregata*	EJAC	*Embiotoca*	*jacksoni*
COTT	*Cottidae*	spp.	CNIC	*Rhinogobiops*	*nicholsii*
CSTI	*Citharichthys*	*stigmaeus*	PCAL	*Paralichthys*	*californicus*
CVEN	*Cephaloscyllium*	*ventriosum*	HEFR	*Heterodontus*	*francisci*
ELAT	*Embiotoca*	*lateralis*	EJAC	*Embiotoca*	*jacksoni*
EMBI	*Embiotoca*	spp.	EJAC	*Embiotoca*	*jacksoni*
HARG	*Hyperprosopon*	*argenteum*	EJAC	*Embiotoca*	*jacksoni*
LHIR	*Leiocottus*	*hirundo*	OPIC	*Oxylebius*	*pictus*
NBLA	*Neoclinus*	*blanchardi*	CNIC	*Rhinogobiops*	*nicholsii*
SCAL	*Squatina*	*californica*	RPRO	*Pseudobatos*	*productus*
SCHR	*Sebastes*	*chrysomelas*	SAUR	*Sebastes*	*auriculatus*
SCSP	*Sebastes*	spp.	SCAR	*Sebastes*	*carnatus*

STRE	*Sebastes*	*serriceps*	SCAR	*Sebastes*	*carnatus*
XCAL	*Haemulon*	*californiensis*	DVAC	*Rhacochilus*	*vacca*

References:

Rassweiler, A., D. C. Reed, S. L. Harrer, and J. C Nelson. 2018. Improved estimates of net primary production, growth, and standing crop of *Macrocystis pyrifera* in Southern California. Ecology, 99(9), 2132-2132. doi: 10.1002/ecy.2440.

Taylor, R. B. 1997. The role of mobile epifauna in subtidal rocky reef ecosystems (Dissertation). University of Auckland.

Thorson, T. B. 1976. Partitioning of body fluids in the Lake Nicaragua shark and three marine sharks. Investigations of the ichichthyofaunal Nicaraguan lakes. Paper 43.

Van Lent, F. P.H. Nienhuis, P.H., and J. M. Verschuure 1991. Production and biomass of the seagrasses *Zostera noltii* Hornem. and *Cymodocea nodosa* (Ucria) Aschers. at the Banc d'Arguin (Mauritania, NW Africa): a preliminary approach. Aquatic Botany 41:353-367.

Wickham, S. B., C. T. Darimontb, J. D. Reynolds, B. M. Starzomskia. 2018. Species-specific wet-dry mass calibrations for dominant Northeastern Pacific Ocean macroalgae and seagrass. Aquatic Botany 152: 27-31.