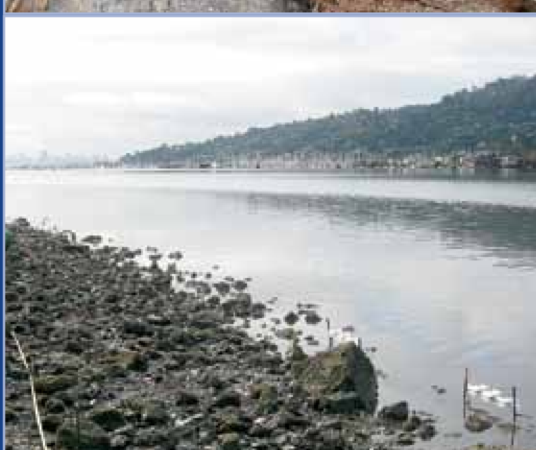


A Guide to Olympia Oyster Restoration and Conservation

APPENDIX 2
FIELD MONITORING: METHODS AND RESULTS

Coastal Conservancy
NOAA
Elkhorn Slough Foundation Since 1982
California Fish & Wildlife
UC DAVIS
San Francisco State University

APPENDIX 2 Field monitoring: methods and results.

Field Sites

Table 1: List of field sites, site codes, and location by bay.

Bay	*Site Name*	*Site Code*	*GPS Coordinates*
San Francisco	China Camp State Park	CC	38.0042 -122.4667
San Francisco	Point Pinole Regional Shoreline*	PP	38.0007 -122.3662
San Francisco	Loch Lomond Marina	LL	37.9722 -122.4768
San Francisco	San Rafael Shoreline*	SRS	37.9559 -122.4898
San Francisco	Richmond (Point Orient)	PO	37.9554 -122.4220
San Francisco	Aramburu Island*	ABI	37.8896 -122.5009
San Francisco	Berkeley Marina	BK	37.8632 -122.3122
San Francisco	Strawberry (Brickyard Cove)	BY	37.8809 -122.5043
San Francisco	Sausalito (Dunphy Park)	DY	37.8611 -122.4882
San Francisco	Oyster Point	OP	37.6616 -122.3744
San Francisco	Coyote Point Recreation Area	CP	37.5914 -122.3188
San Francisco	Eden Landing Ecological Reserve*	EL	37.5822 -122.1443
Elkhorn	Hudson Landing	HL	36.8564 -121.7561
Elkhorn	Azevedo Pond North	AZN	36.8485 -121.7549
Elkhorn	Kirby Park	KP	36.8414 -121.7472
Elkhorn	North Marsh	NM	36.8343 -121.7371
Elkhorn	Whistlestop	WS	36.8249 -121.7385
Elkhorn	Bennett Slough	BSW	36.8221 -121.7933
Elkhorn	South Marsh	SMF	36.8208 -121.7358
Elkhorn	Vierra	VS	36.8114 -121.7783
Elkhorn	Moss Landing	MLN	36.8007 -121.7844

* Three groups of collaborators monitored a total of four field sites in San Francisco Bay: The San Francisco Bay Living Shorelines Project (SRS, EL), The Watershed Project (PP), and Richardson Bay Audubon (ABI). See Field Parameters table for efforts at sites.

Table 2: List of continuous water quality stations, station institution, and location by bay.

Bay	*Station Name*	*Station Institution*	*GPS Coordinates*
San Francisco	Fort Point	BML, UC Davis	37.8066 -122.4662
San Francisco	China Camp	NERR	38.0012 -122.4604
San Francisco	Romberg Tiburon Center	RTC, SFSU	37.8914 -122.4464
San Francisco	Richmond Bridge	USGS	37.9353 -122.4464
San Francisco	San Mateo Bridge	USGS	37.5844 -122.2497
San Francisco	Alcatraz	USGS	37.8272 -122.4217
Elkhorn	Azevedo Pond	NERR	36.8457 -121.7538
Elkhorn	North Marsh	NERR	36.8346 -121.7384
Elkhorn	South Marsh	NERR	36.8179 -121.7394
Elkhorn	Vierra Mouth	NERR	36.8111 -121.7792
Elkhorn	Kirby Park	MBARI	36.8405 -121.7463

Field Parameters

Table 3: List of parameters measured as part of this guide. Please refer to Table 1 for site codes. Timescales: Q = Quarterly, M = Monthly, B = Summer Biweekly, C = Continuous.

Oyster Attributes	*Sites and Timescale*
Density	All sites (Q) except AZN, NM, WS, VS, BSW
Size	All sites (Q) except AZN, NM, WS, VS, BSW
Growth	All sites (Q) except EL, SRS
Survival	All sites (Q) except EL, SRS

Recruitment rate	All sites (Q); also CC, PO, LL, BY, DY, BK, OP, CP (SB)
Fecundity and larval export	SR (M), PO, LL, BY, BK, OP, SMF, KP (SB)

Environmental Factors	*Sites and Timescale*
Available substrate	All sites (Q) except AZN, NM, WS, VS, BS
Sediment grain size	All sites (Spr'13) except ABI, PP, EL, SRS
Potential sediment accretion rate	LL, BK, OP, KP, MLN, SMF (M)
Sediment height	All sites (Q) except ABI, PP; also LL, BK, OP, KP, MLN, SMF (M)
Sessile organism abundance	All sites except AZN, NM, WS, VS, BSW (Q)
Air and water temperature	All sites (C)
Salinity	All sites (M) except ABI, PP, EL, SRS
Dissolved oxygen	All sites (M) except ABI, PP, EL, SRS
Chlorophyll *a*	All sites (M) except ABI, PP, EL, SRS
Turbidity	All sites (M) except ABI, PP, EL, SRS

Field Methods

Oyster Attributes

Adult oyster density and size

We monitored oyster density and size distribution at each site on a quarterly timescale. We established a permanent 30 m transect within the densest oyster area and as close to 0 m MLLW as possible. At ten random points along this transect, we counted total number of oysters within a ¼ m^2 quadrat to determine density and measured up to 10 random oysters to calculate size distribution. If a quadrat fell on a point with < 50% suitable habitat for oysters, the quadrat was shifted laterally along the transect to reach suitable habitat. Size distribution data were used to calculate both the size-class diversity index and the mean upper quartile of oyster size. Density data were used in calculations for population estimates on suitable substrate over a 1 m by 300 m area at each site.

Growth and survival

We monitored growth and survival of natural recruits at each site that were settled on nine 10 x 10 cm ceramic tiles deployed at 0 m MLLW at our sites in Spring 2012. Quarterly, we cleaned and photographed tiles. Photographs of oysters on tiles were analyzed using the program ImageJ, with individual oysters followed over time. At each timepoint, each individual was measured and noted as live or dead to determine growth and survival rates. For analysis, because growth rate is expected to decrease as oysters increase in size, growth rate calculated for each quarter was standardized by initial starting size.

Recruitment

Six 10 cm x 10 cm tiles were deployed at each site starting in Spring 2012 at 0 m MLLW. Each quarter, these tiles were exchanged for new clean tiles. Collected tiles were brought back to the lab and viewed under the microscope. Total number of oysters was counted on each tile, which was used to calculate recruitment rate per quarter. The reliability of recruitment was calculated as the coefficient of variation of recruitment rate. During summers, six additional tiles were deployed at select sites (Table 3) and exchanged every other week. Juveniles from these tiles were collected for shell chemistry analysis (see Fecundity and larval export section, below).

Fecundity and larval export

At select sites during summers, we collected up to 30 oysters every other week to determine fecundity rate. Oysters were opened with a shucking knife, and brood presence/absence and stage were observed to establish what proportion of the population was brooding for a given site. If broods were present, larvae were collected for shell chemistry analysis. Larval export values were calculated base fecundity rate, density, an estimated larval production per oyster (Hopkins 1936), and evaluations of larval movement using shell micro-chemistry analysis. Shell micro-chemistry methods allow for tracking larvae from natal site to settlement site using analysis of trace element signatures present in larval and juvenile shell (Carson 2010).

Environmental Factors

Available substrate

Along our permanent 30 m transect at each site (see Adult oyster density and size section, above), we evaluated available substrate for oysters at 10 random points within a ¼ m^2 area. We recorded percent cover of substrate type as follows: mud (< 0.2 mm), sand (0.2 – 2 mm), gravel (2 – 63 mm), cobble (63 – 200 mm), and rock (> 200 mm). Mud and sand were considered unsuitable (soft) substrate, while gravel, cobble, and rock were considered suitable (hard) substrate.

Sediment grain size

Using a syringe corer, we took five sediment samples per site of the top 2 cm of sediment at the same tidal height as recruitment tiles (above). Samples were processed in the lab to separate grain size fractions of silt, sand, and gravel (Bale and Kenny 2005).

Potential sediment accretion rate

At three sites in each estuary, we deployed three 5 cm diameter vertical columns so that their upper open ends were at 0 m MLLW. Monthly, we measured the height of accumulated sediment. Columns were emptied for the next month.

Sediment height

Three PVC poles were deployed vertically in the sediment at each site at 0 m MLLW. During site visits (Table 3), pole height was measured to determine change in sediment height at each site.

Sessile organism and oyster drill abundance

We evaluated sessile species abundance and presence quarterly within 10 cm x 10 cm quadrats placed at 10 random points along a permanent 30 m transect at each site (see Adult oyster density and size section, above). Given the complexity of communities, we recorded species presence and abundance for three layers falling directly under one of 25 points: attachment point (connected to rock), primary canopy (first layer of species overlaying substrate), and secondary canopy (second layer of species overlaying substrate and primary canopy). We also periodically monitored oyster drill abundance (*Urosalpinx cinerea*, the only species seen) along a permanent 30 m transect at 10 random points within a ¼ m^2 area (see Adult oyster density and size section, above).

Air and water temperature

Onset tidbit temperature loggers (www.onset.com) were deployed at each site at 0 m MLLW to measure water or air temperature (depending on tide height at any given timepoint) continuously every 15 min. Data was downloaded from loggers periodically and paired with tide level data for each site to parse out air or water temperatures for each site.

Water temperature, salinity, dissolved oxygen, chlorophyll a, turbidity

Monthly spot samples were taken for each of these environmental parameters during an ebb tide. Data from Elkhorn Slough were obtained from a monthly monitoring program coordinated by Elkhorn Slough NERR. Continuous data (Table 2) were accessed from each institution's website. For more information on these water quality data, see Appendix 4.

Summary Figures of Oyster Attributes

Figure 1: Adult oyster density: Density (number per square meter) of oysters at each site averaged over the monitoring period from Spring 2012 – Fall 2013.

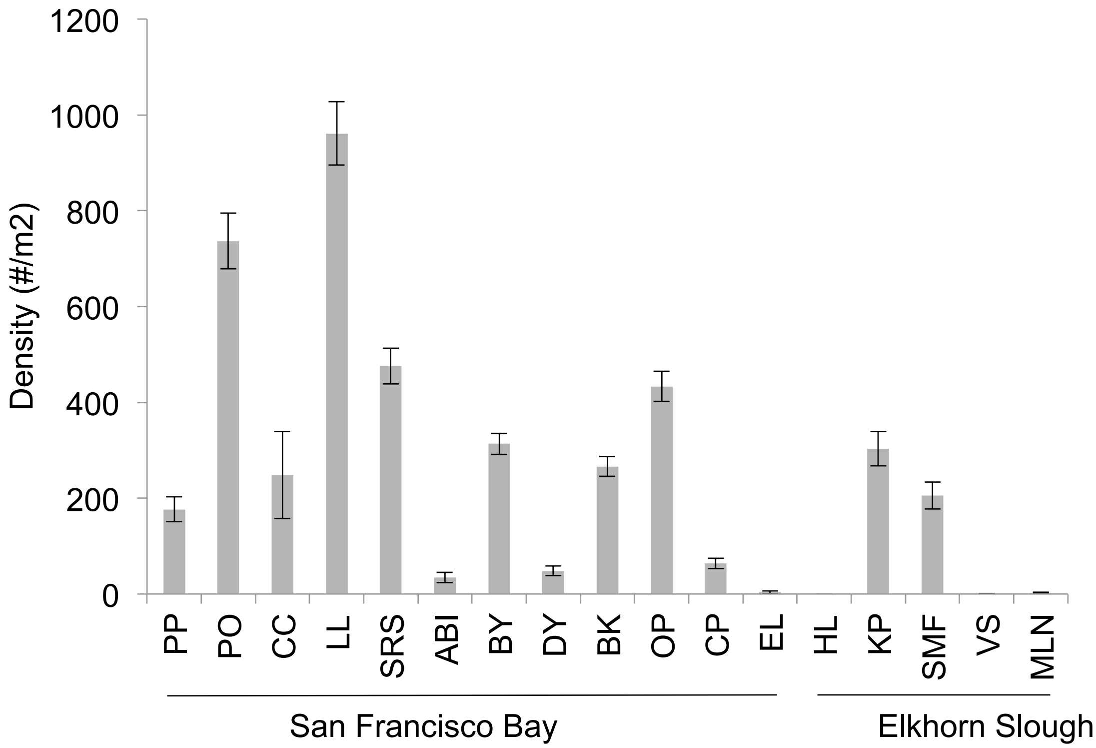


Figure 2: Adult oyster size frequency distribution: Number of oysters present per size class at each field site over the monitoring period Spring 2012 – Fall 2013. Size classes are in 10mm bins starting with 0-10mm. Note that frequency along the y-axis varies with site based on the number of oysters that were possible to measure.

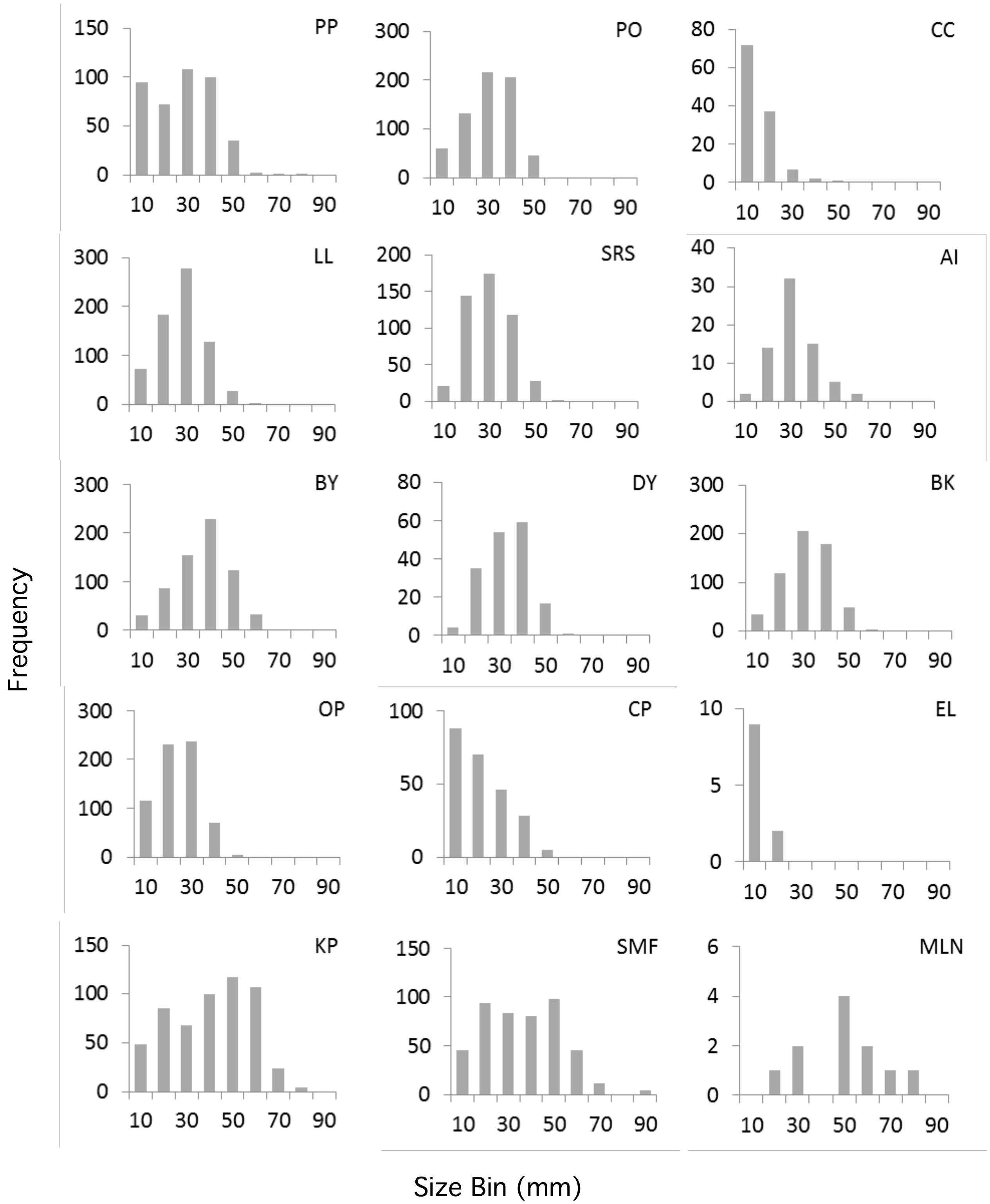


Figure 3: Large adult oyster size: Average size (mm) of oysters in the upper quartile at each site as averaged over the monitoring period Spring 2012 – Fall 2013.

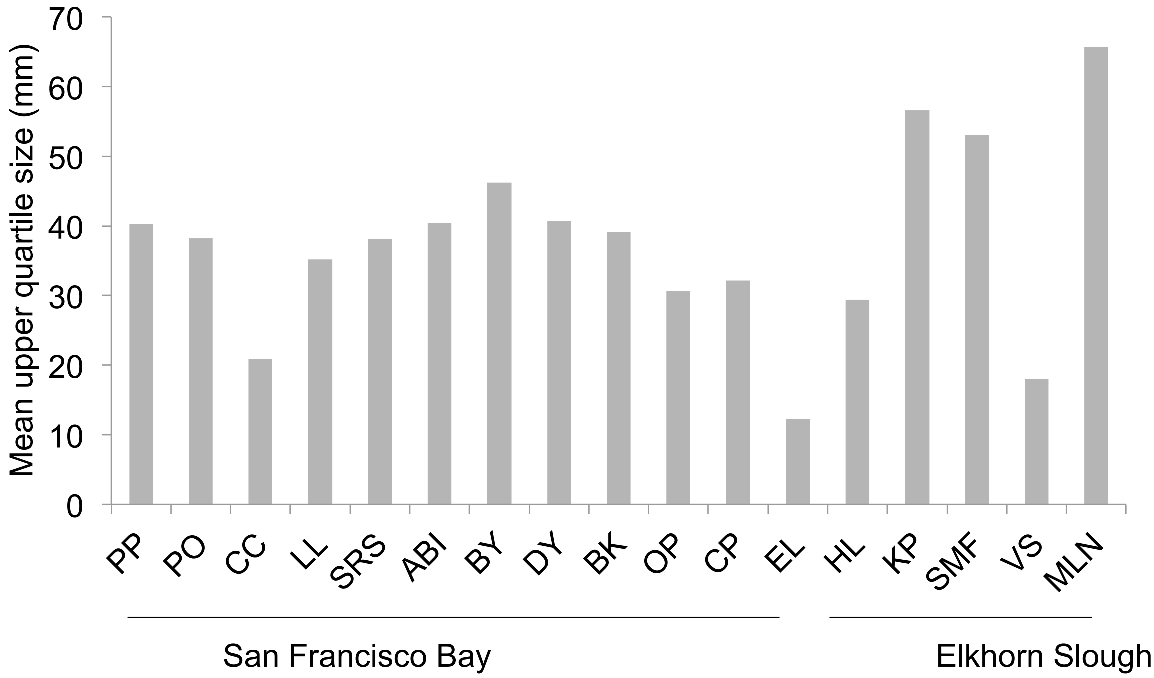


Figure 4: Recruitment rate: Average quarterly recruitment rate over the course of the monitoring period Spring 2012 – Fall 2013, expressed as number of recruits per square meter per day.

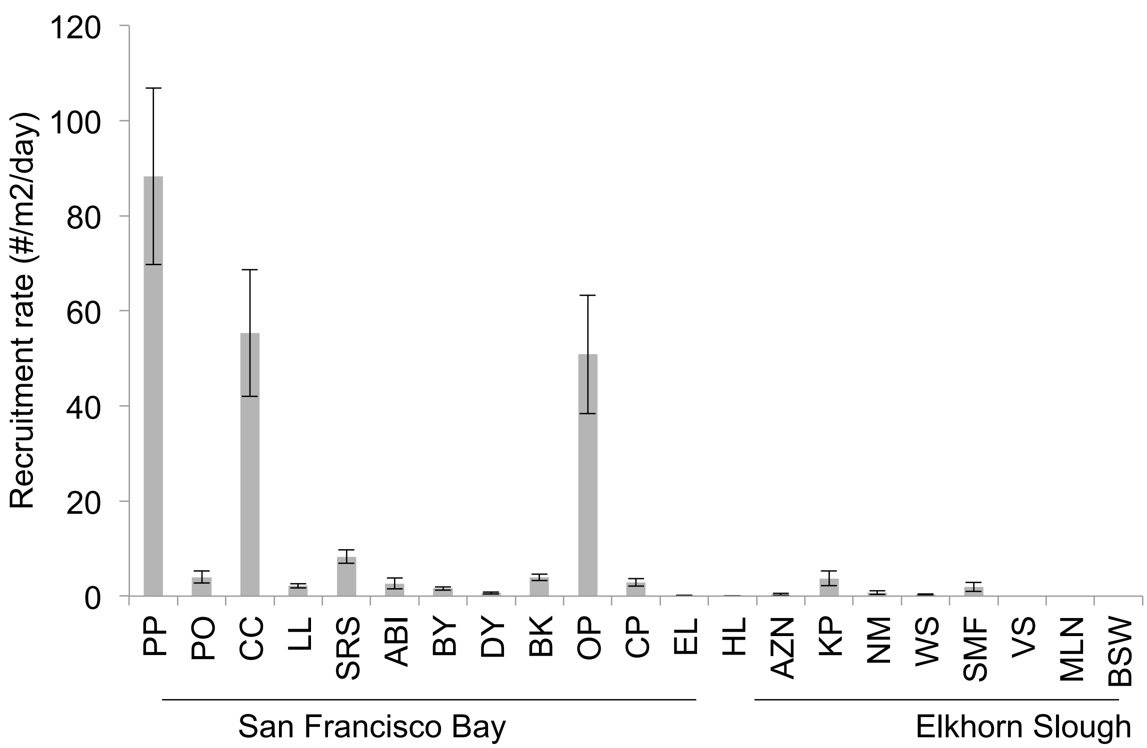


Figure 5: Growth: Average growth rate of oysters (mm/day) observed at each site.

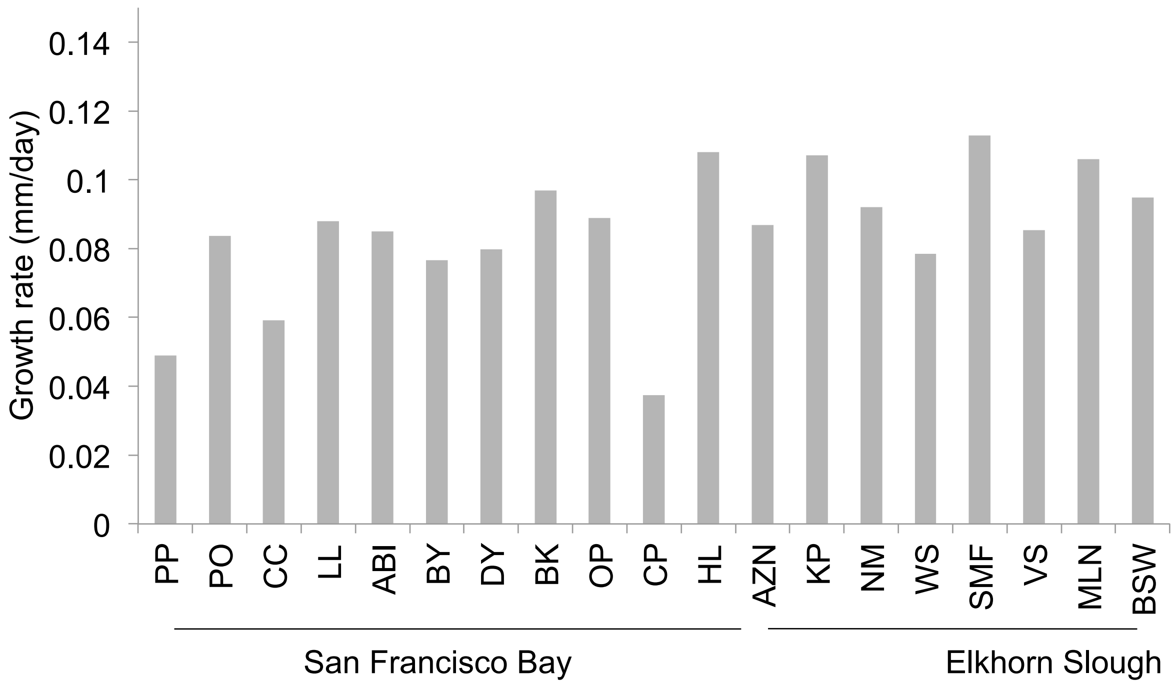


Figure 6: Survival: Survival rate of oysters (presented as percent alive per day) observed at each site. Note adjusted y-axis.

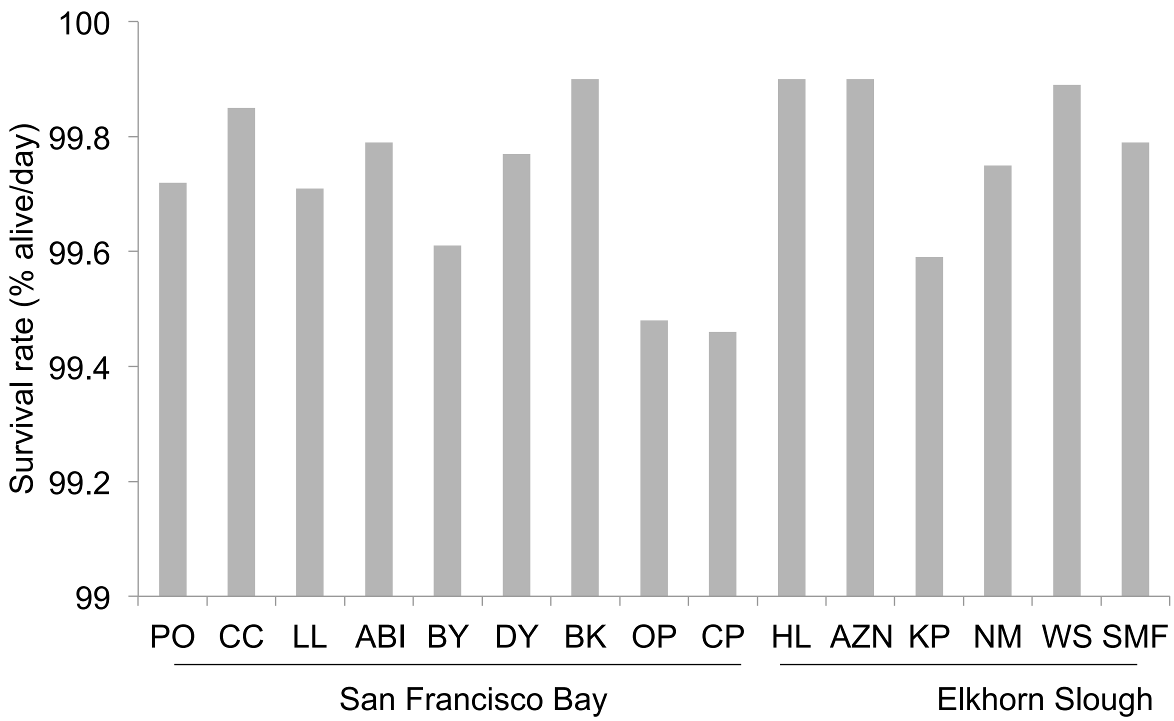
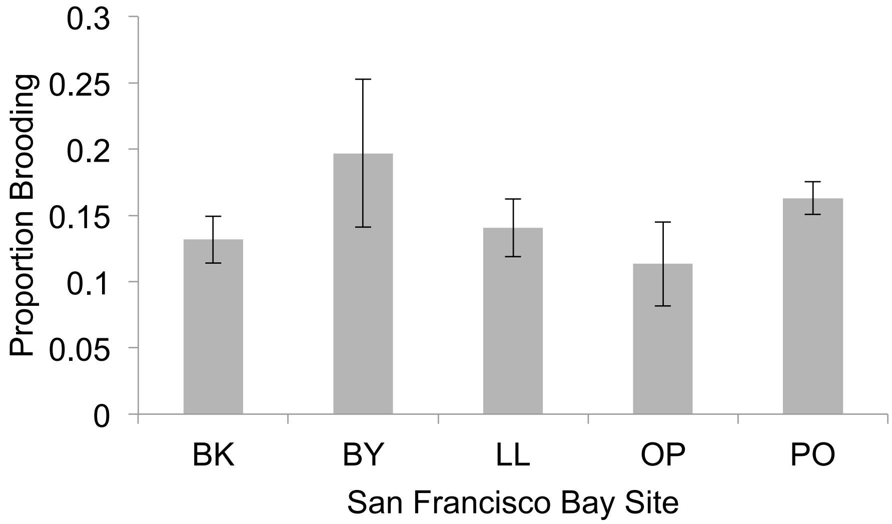


Figure 7: Fecundity: Proportion of oysters brooding at select sites in San Francisco Bay in summer in 2012 and 2013. Brooding oysters had either white or gray sic present. These data were used along with site density, an estimate of larval production per oyster, and evaluations of larval movement from origin site to settlement site.



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