Analysis of San Francisco Bay Environmental Conditions as they relate to Organismal Abundance

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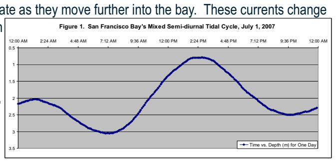
Abstract

The purpose of this study is to analyze trends in environmental conditions in the San Francisco Bay and to determine whether these environmental factors have a significant impact on organismal growth. This study analyzed temperature, salinity, and ocean current data collected from six different field sites located in the central region of the San Francisco Bay throughout July, 2010. This environmental data was compared to organismal growth on recruitment devices at each site. The recruitment devices consisted of two 6"x12" PVC plates and one mesh wrap containing two Tuffy kitchen scrub pads. Settled organisms included native and invasive crustaceans, bryozoans, polychaetes, nudibranchs, and tunicates. Protected field sites in the East Bay experiencing maximum currents between 20-30 cm/s and average temperatures of 18.2-18.4 °C demonstrated the most overall organismal growth. The relationship between variation in salinity and organismal growth is unclear and further study addressing tidal considerations is necessary.

Physical and Biological Conditions in the San Francisco Bay

The San Francisco Bay is the largest estuary on the Pacific Coast. An estuary is a body of water where fresh water from rivers and lakes mix with salt water from the ocean. San Francisco Bay is a slightly stratified (partially mixed) estuary with two layers of water. The upper layer is supplied by river water and is less-dense and brackish while the deep layer is supplied by the ocean and is denser and more saline. Salinity in this type of estuary varies longitudinally as opposed to vertically creating a unique environment of nutrient-rich water and soil where an abundance of life can thrive. Since the estuary is partially protected by large land masses, strong ocean currents push through the narrow bay entrance under the Golden Gate Bridge and quickly dissipate as they move further into the bay. These currents change direction approximately twice a day according to the ocean cycle (see Figure 1).



Temperature and salinity are not as easily linked in the San Francisco Bay as they are in the open ocean. In the ocean, cold water sinks due to its high salinity and density, while in the bay, the coldest water comes from different places depending on the season (either from snow runoff or the ocean). Because of mixing in the water column and the relative contributions of fresh and salt water, temperature and salinity change drastically both spatially (at different locations in the Bay) and temporally (in different seasons and different years).

Due to ever increasing trade and traffic in the SF Bay, a phylogenetically diverse assemblage of non-native species, including various invertebrates, fish, and plants, have been introduced into the bay.[1] This study investigates several physical characteristics of six different field sites in the central bay and compares these physical characteristics to species growth. For this study, we quantified the distribution and abundance of phylogenetically and functionally diverse organisms, including crustaceans, bryozoans, polychaetes, nudibranchs, and tunicates (see Table 1), that thrive in various bay conditions.

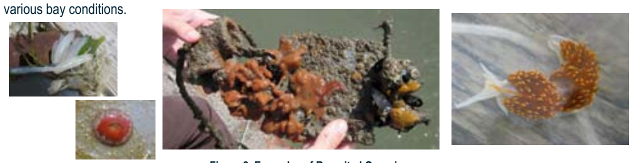


Figure 2. Examples of Recruited Organisms

Physical Methods and Monitoring

To analyze San Francisco Bay environmental conditions, three main sources for data collection were used. Since field sites were studied during the month of July, snapshots including daily, weekly, and monthly averages in July were used to estimate typical tidal, current, temperature and salinity ranges.

For ocean current data, Coastal Ocean Currents Monitoring Program (COCMP)[7] and Central and Northern California Ocean Observing System (CeNCOOS) maintain a state-wide network of high frequency (HF) radar instruments to monitor coastal ocean surface currents in real-time and provide surface current forecasting. The current maps in Figure 6 show the averaged hourly currents over a one day period on July 21, 2010. Tidal exchange for this day is fairly extreme but not the absolute highest or lowest tides for that month.

Figure 3. San Francisco Bay Field Sites Map

For long term data collected at various field sites, the San Francisco Bay Environmental Assessment and Monitoring Station (SF-BEAMS)[5] website has downloadable data for 2004-2008. SF-BEAMS is run through the Romberg Tiburon Center (RTC) and monitors bay water quality and weather conditions at the RTC pier, located approximately 200 ft offshore. RTC is also one of the locations that utilizes high frequency (HF) radar to measure currents in the bay. Bodega Marine Laboratory's database provided Crissy Field data for 2008-2010.

Biological Materials, Methods and Monitoring

Recruitment devices were designed to collect data on organismal abundance. Each field site had two devices at two different locations along the dock. The top plate was approximately one meter above the bottom plate to allow for differentiation at separate depths. A refractometer and temperature logger were used to measure real-time salinity and temperature. The temperature logger was attached to the top loop of the device and a brick was attached to the bottom to keep the settling plates and Tuffy oriented vertically in the water column.

Figure 4. Lower Settling Plate with Growth

Physical and biological measurements were taken weekly. For this study, organism abundance was recorded in the following categories: "abundant" if more then 100 specimens were visible, "present" if between 10-100 specimens were visible, "few" if less than 10 were visible, and "absent" if none were visible on the settling plate.

Figure 5. Recruitment Devices

Surface Current Maps of the San Francisco Bay

The current maps (Figure 6) show averaged hourly currents over the 21st of July, 2010. Analysis shows that though the Crissy Field and Fort Baker sites are both slightly protected by a barrier they are still highly exposed to strong currents (over 50 cm/s) which cycle between flowing in and out of the bay. While the RTC and Angel Island sites are located much further from the open ocean, they are still exposed to strong currents (over 50 cm/s) which whip through Raccoon strait located between them. The Berkeley Marina is protected from some of the strongest currents, but the area just outside the marina shows currents up to approximately 30 cm/s. The Richmond Marina is protected by an island, though the area just outside the marina does experience currents up to 20 cm/s. Both of the East Bay sites appear to have a recirculation pattern separating them from the West Bay sites which appear to circulate around the outer bay and the corridor under the Golden Gate Bridge leading to the open ocean.[4]

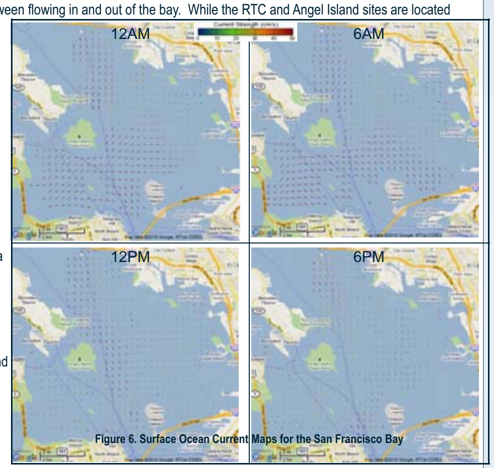
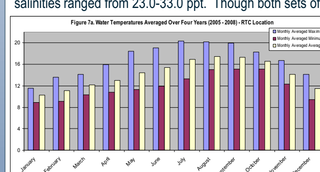
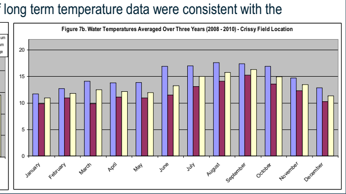


Figure 6. Surface Ocean Current Maps for the San Francisco Bay

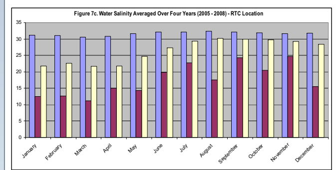
Long Term Physical Trends

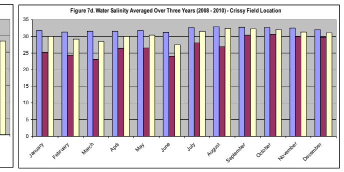
The following graphs show monthly maximum, minimum, and average values for temperature and salinity at the RTC and Crissy Field locations (Figure 7). All years of accessible data were analyzed for the field sites. RTC temperatures ranged from 8.0-20.0°C while salinities ranged from 11.0-32.5 ppt. Crissy Field temperatures ranged from 9.5-17.0°C while salinities ranged from 23.0-33.0 ppt. Though both sets of long term temperature data were consistent with the





temperature logger data of the short term study, long term salinity data for RTC had noticeably more variation than the short term data. This is most likely because the years averaged (2005-2008) included an El Niño year (2005) where excessive rainfall might have resulted in lower minimums and averages for salinity data throughout the winter and spring.





A comparison of temperature and salinity measurements between long and short term data was consistent for the month of July (see Table 1).

RTC Comparison Table for July	Temp (° C)	Salinity (ppt)
Long Term	16.9	29.4
Short Term	16.8	29.3

Crissy Field Comparison Table for July	Temp (° C)	Salinity (ppt)
Long Term	15.0	31.5
Short Term	15.5	31.5

Table 1. Comparison of Long and Short Term Measurements

Short Term Physical and Biological Trends

Salinity measurements were taken weekly with a refractometer to determine the overall average salinity at each field site. The temperature loggers attached to the recruitment devices measured July temperature ranges which were then averaged every twenty minutes. These measurements were used to determine an overall average water temperature at each field site, shown in Table 2 below. RTC and Crissy Field short term averages are compared to long term averages in Table 1.

Field Site	Weeks of Growth	Ave Water Temp	Ave Water Salinity	Max Current	Colonial Tunicates	Solitary Tunicates	Amphipods	Bryozoans	Polychaetes	Nudibranchs	Crabs	Barnacles
Crissy Field*	5	15.5 °C	31.5 ppt	50+ cm/s	absent	absent	absent	absent	absent	absent	absent	present
Fort Baker	5	16.7 °C	32.0 ppt	50+ cm/s	present	few	present	present	present	few	present	present
RTC	5	16.8 °C	29.3 ppt	50+ cm/s	absent	absent	present	absent	absent	few	present	present
Angel Island**	3	16.6 °C	31.0 ppt	50+ cm/s	few	absent	few	few	absent	absent	absent	present
Richmond	5	18.4 °C	29.8 ppt	20 cm/s	abundant	present	abundant	abundant	present	absent	absent	absent
Berkeley	5	18.2 °C	31.2 ppt	30 cm/s	abundant	present	abundant	abundant	present	absent	absent	absent

*Crissy Field plates were exposed to air during extremely low tides in mid-July. This may have affected organismal growth.
**Due to permission issues, Angel Island plates were only put out for three weeks. This may affect organismal growth.

Table 2. Comparison of Temperature, Salinity, Currents and Organismal Growth

This study investigated organismal growth at the end of a five week period. The protected field sites in the East Bay (Richmond and Berkeley Marinas) showed the greatest abundance of organisms. At the Crissy Field site, the recruitment device's attachment point was in the shallow intertidal and was temporarily exposed to air at extremely low tides, resulting in a strong environmental difference in comparison to the other plates which were completely submerged at all times. Additionally, Angel Island abundance is likely skewed low due to a 2 week later deployment at that site, after permission was obtained. For a more detailed analysis of weekly organismal growth at these field sites, refer to Jacqueline Hill's poster Observing Organismal Settlement in the San Francisco Bay at Various Time Intervals.

Conclusions, Future Research and Next Steps

Protected field sites in the East Bay experiencing maximum currents between 20-30 cm/s and average temperatures of 18.2-18.4 °C demonstrated the most overall organismal growth. This might mean organisms respond to this level of current or that the East Bay has a different circulation pattern than the West Bay. Further investigation into possible recirculation patterns along the East Bay and whether this effect might increase abundance is needed. Further study addressing tidal considerations is also necessary to understand how salinity correlates with growth, including examining how the tidal cycle influences temperature and salinity and whether horizontal or vertical stratification is occurring in the San Francisco Bay. Future work might include looking at T-S data for both a floating and fixed device at the same location, next to a water station. Another study might look at one or more locations with plates at four depths, each approximately a meter apart with its own temperature and salinity logger or YSI device. Underwater cameras could also be used to check on plate orientation as the current passes.

References and Resources Cited

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5. RTC Water Data provided by San Francisco Bay Environmental Assessment and Monitoring Station (SF-BEAMS), http://sfbeams.sfsu.edu/
6. Crissy Field Water Data provided by the University of California, Davis, Bodega Marine Laboratory, http://www.bml.ucdavis.edu/boon/
7. Ocean Current Data provided by Coastal Ocean Currents Monitoring Program (COCMP), http://www.cocmp.org/

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