Iris Zhang
December 4, 2018

Effects of Sea Surface Temperature and Beach Seine Locations on Abundance of Fish

Abstract

Bays and estuaries are essential fish habitats, because these areas are constantly changing environments. In southern California, estuaries varied a lot in sea surface temperature (SST) in different locations. With global climate change becomes one of the most concerned problem, fish populations may result from the physiological response to changes in environment, such as SST. Five beach seine locations in southern California were used and mean density of fish was used as a measurement of abundance of fish. Both beach seine location and SST significantly correlate with the mean density of fish.

Introduction

Estuary is a river mouth, fjord, salt bay or other semi-enclosed body of salt water that has a free connection with the ocean. It is diluted with fresh water so that the average salinity is less than adjacent sea. Bays and estuaries are more challenging environment to fishes than marine do, because estuaries have highly variable physical and chemical conditions that change over space and time (Allen et al., 2006). The constantly changing environments make bays and estuaries as important fish habitats for spawning, nursery sites, and migration routes. (McHugh, 1967; Haedrich, 1983; Elliott, 2002).

Estuaries in southern California typically have low trophic complexity with three to four trophic levels (Kwak and Zedler 1997; Zedler et al. 2001) in which are usually marine associated species, like topsmelt (*Atherinops affinis*), northern anchovy (*Engraulis mordax*), and California corbina (*Menticirrhus undulatus*). Also, these fishes transfer energy and nutrients within different coastal areas in southern California estuaries (Irlandi and Crawford 1997). However, fish populations vary under different environments and have significant implications on marine ecosystem as fishes affect ecosystems through different ways, like food web interactions, alterations to species and functional richness.

Belmont shore, Cabrillo Beach Bay, Cabrillo Beach Surf Zone, Marina del Rey and Naples Island are five different beach seine locations in Southern California (**Figure 1.1**). Belmont Shore and Naples Island both are in the Long Beach area (**Figure 1.2**). Mother's Beach on Naples Island faces Alamitos Bay which is the inner part of an estuary. Belmont Shore is at marine outfall and faces ocean. Cabrillo Beach Bay and Surf Zones are at southwest of the long beach area (**Figure 1.3**). They are separated by a manmade pier. Cabrillo Beach Bay is closed off by inside the pier that prevents water from circulating through the area, so it has fewer sediments and less water flow. The Cabrillo Beach Surf Zone is on the other side of the pier, so it has shallower water than bay does. Marina del Rey is northwest of other beach seine locations and is in a protected inlet of a non-ocean facing lagoon.

Meanwhile, global climate change becomes one of the most concerned problem which has huge impact on marine population and ecosystems. With global warming, fish populations may result from a physiological response to changes in environment, such as sea surface temperature (SST). Fish have different tolerance for temperatures within species or between species (Rijnsdorp et al., 2009). The effect of change in SST would differ in different species of fish, which will depend on the ability of the animal to detect environmental gradients and navigate accordingly. The mean density of the fish may give a first approximation of the relative effects of climate-driven temperature changes (Ault, 2017). Peck et al., 2013 showed that there is evidence of an ontogenetic shift in temperature tolerance of a species, such that optimum temperatures for growth decrease with increasing body size of juveniles and adults. Also, Lluch-Belda et al., 2009 found that sardine relative abundance coincides well with estimated SST, increasing during the cooling intervals and declining through the warming periods in the Gulf of California as it is the southernmost limit of its distribution

This project will study the effect of sea surface temperature (SST) on fish density in different beach seine locations. Data from 5 different beach seine locations are used in order to get a generalized result. I hypothesize that the fluctuations in SST as well as geographic regions would influence mean density of all types of fish. I would expect that the mean density of the fishes would be high than that of the higher SST as most fishes prefer colder water which have comparatively higher nutrients.

Methods

From 2002 to 2018, we sampled using a large beach seine (30.3 m x 2.5 m) fitted with a 1.82 m x 30.3 m x 30.3 m bag (0.5 cm bag square, 0.7 cm bag stretch in the bag; 1 cm square, 1.4 cm stretch in the 28.5 cm wing length) at 5 stations (**Figure 1.1-3**). At least 1 net (replicate) was employed at each station. Each station was sampled multiple times, 14 times for Belmont Shore (33.75224 N, -118.13463 W), 25 times for Cabrillo Beach Bay (33.71098 N, -118.28237 W), 9 times for Cabrillo Beach Surf Zone (33.70856 N, -118.28459 W), 19 times for Marina del Rey (33.98121 N, -118.45810 W), and 10 times for Naples Island (33.75884 N, -118.12022 W). Nets were set perpendicular to the coastline according to a stratified random design. Sampling were made between 9 in the morning and 4 in the afternoon. The months for each sampling stations also varied. All stations were chosen at random along the beach. Mean density was calculated as the number of individuals capture per replicate per 100 m^2 at each beach seine location. All statistical analyses were completed in ®RStudio. Long-term trends were described using regressions. Prior to regression, data were tested for normality using the Shapiro-Wilks test and plotted histograms to visualize the data. All mean density data sets were found not to be normally distributed, so the data sets underwent the logarithmic transformation and were still not normally distributed but are better than the untransformed data. Temperature data were collected on site for each replicate. We neglect the replicates that do not have temperature data.

Then, I am going to use a generalized linear model to standardize mean density to analyze the relationship between fluctuations of SST, differences in beach seine locations and density. GLM is a suitable model, because it extends the linear regression for multiple explanatory variables that are categorical and numerical. GLM is going to include influential effects of SST, geographic regions and the interactive effects among these two factors. The expected result would be that the differences in SST as well as geographic region would affect the mean density of fish. I would also expect a significant relationship between all the influential factors with fish density. Although it may be argued that it is impossible to draw the conclusion as there too many influential factors for the density of fish and SST is not the only one determined factor. However, the study still provides a good insight for environmental awareness and guidance for strategies to mitigate the global warming problem.

Results

I first ran a Shapiro Wilk test to test the normality of mean density of all beach seine locations. There were 5 groups of data, which are mean density of fish in Belmont Shore ($W=0.200$, p-value=$7.22*10^{-16}$), mean density of fish in Cabrillo Beach Bay ($W=0.613$, p-value=$4.50*10^{-15}$), mean density of fish in Cabrillo Beach Surf Zone ($W=0.606$, p-value=$6.80*10^{-9}$), mean density of fish in Naples Island ($W=0.7873$, p-value=$3.80*10^{-5}$), and mean density of fish in Marina del Rey ($W=0.743$, p-value=$6.72*10^{-10}$). I plotted histograms to detect whether the data are normally distributed or not visually.

As the data are all significantly different from the normal distribution, so I did a logarithmic transformation on all data. After the logarithmic transformation, I performed another Shapiro Wilk test on the data, which shows that the mean density in Belmont Shore ($W=0.950$, p-value=0.021), mean density in Cabrillo Beach Bay ($W=0.972$, p-value=0.026), mean density in Cabrillo Beach Surf Zone($W=0.962$, p-value=0.228), mean density in Naples Island ($W=0.979$, p-value=0.458), and mean density in Marina del Rey ($W=0.964$, p-value=0.039). I then plotted histograms to visually detect the normality of each group (**Figure 2**). Thus, I used the logarithmic transformation of mean density data for analysis the project.

Before testing the interaction effects of beach seine location and SST on mean density of fish. I test the effect of beach seine location on mean density of fish, because the times and replicates of sampling differed at each location. I first created a boxplot to visualize the mean density in different beach seine locations (**Figure 3**). The mean density of fish varied in beach seine locations, for Belmont shore logarithmic transformed mean density is 1.293, for Cabrillo Beach Bay logarithmic transformed mean density is 1.466, for Cabrillo Beach Surf Zone logarithmic transformed mean density is 0.923, for Marina del Rey logarithmic transformed mean density is 1.846, and for Naples Island logarithmic transformed mean density is 2.054. I then performed an ANOVA test to test the effect of different beach seine location on the logarithmic transformed mean density (F-value=22.7, p-value$<2*10^{-16}$).

Then, I test the effect of SST on mean density at each beach seine location individually to examine the effect of SST on mean density of fish. To test the linear regression between SST and mean density, I used Pearson correlation test to test for the coefficients between two variables (**Table 1**). Then, I created scatter plots with the regression line to visualize the linear relationship between SST and logarithmic transformed mean density (**Figure 4**). I generated the equations of the regression lines to statically analyze the linear relationship, for Belmont Shore is y=0.093x - 0.5643, R^2 = 12.76%; for Cabrillo Beach Bay is y = 0.08x + 0.081, R^2 = 8.94%; for Cabrillo Beach Surf Zone is y = 0.0182x + 0.5812, R^2 = 0.79%; for Marina del Rey is y = 0.0328x + 1.1873, R^2 = 2.31%; and for Naples Island is y = 0.0134x + 1.7647, R^2 = 0.96%.

Lastly, in order to test the effect of SST on mean density of fish at different beach seine locations, I used a GLM (**Table 2**). There are three significant p-value, which is between Marina del Rey (t value=2.133, p-value=0.034), Naples Island (t value=2.556, p-value=0.011) and SST (t value=3.398, p-value=0.001) to logarithmic transformed mean density of fish from all historical data (F value=12.31, p-value=$2.37*10^{-16}$, R^2=28.87%, df=9, 273). I plotted a scatter plot to summarize the data (**Figure 5**).

Discussion and Conclusions

Mean density measurements should be a good measurement to provide a good estimate of the true abundance of beach seine nearshore fish species. However, the Shapiro-Wilk test showed that the mean density data were all significantly different from the normal distribution. The normality tests are used to determine if the mean density data is well-modeled by a normal distribution and to test the difference between population and sample. If the datasets fit normal distribution, this would make the hypothesis testing easier and more accurate. The 5 groups of data all had very low p-values, which are mean density of fish in Belmont Shore (W=0.200, p-value=$7.22*10^{-16}$), mean density of fish in Cabrillo Beach Bay (W=0.613, p-value=$4.50*10^{-15}$), mean density of fish in Cabrillo Beach Surf Zone (W=0.606, p-value=$6.80*10^{-9}$), mean density of fish in Naples Island (W=0.7873, p-value=$3.80*10^{-5}$), and mean density of fish in Marina del Rey (W=0.743, p-value=$6.72*10^{-10}$). This means they are significantly different from normal distribution. The histograms for these data did not show symmetrical shape and most of them skewed to the right, which indicates the data are not normally distribute as well. This indicates that the mean density measurements in this case may not provide a good estimate of the true abundance of fish of beach seine nearshore fish species. This may due to the catch rates per replicate per beach seine location were significantly different from each other and the month and time we went to beach seine were also different which would influence the density of fish.

For the non-normally distributed data, I logarithmically transformed all the mean density, which is to change each measurement in a variable in the same way. After the logarithmic transformation, I performed another Shapiro Wilk test on the data, which shows that the mean density in Belmont Shore (W=0.950, p-value=0.021), mean density in Cabrillo Beach Bay (W=0.972, p-value=0.026), mean density in Cabrillo Beach Surf Zone(W=0.962, p-value=0.228), mean density in Naples Island (W=0.979, p-value=0.458), and mean density in Marina del Rey (W=0.964, p-value=0.039). Although, all the p-values are still smaller than 0.05, but they are better than the data that are not transformed. I then plotted histograms to visually detect the normality of each group (**Figure 2**). For Belmont Shore and Cabrillo Beach Bay, the logarithmic transformation of mean density data was not normally distributed, visually but data in Cabrillo Beach Bay, Naples Island and Marina del Rey were normally distributed visually. I decided to ignore the non-normality of the logarithmic transformed of mean density data, because there were no major outliers and the histograms showed that most of the data were normally distributed.

As I hypothesized that the different beach seine locations would influence the mean density of fish, I created a boxplot to visualize the visualize the logarithmic transformed mean density in different beach seine locations (**Figure 3).** We can see that the mean density after transformation were all different, Naples Island has the highest mean density of 2.054. This means that most fish prefer to stay in Naples Island the most. I would expect density to be higher at Naples Island, because Mother's Beach on Naples Island faces Alamitos Bay which is the inner part of an estuary (**Figure 1.2**), and it is shallower than the other beach seine areas, so it has more sunlight and sediment, runoff which contains nutrients and habitat, so there would be more primary producers and leads to high productivity with higher density. Also, the wave effect is the smallest, so the sampling would be easier and fish collection would be easier results in higher density. Marina del Rey has the second highest mean density of 1.846, which was also expected as it is in a protected inlet of a non-ocean facing lagoon, that also has small wave effect and leads to higher density. Cabrillo Beach Surf Zone has the lowest mean density of 1.846. I might expect the density to be the lowest in the surf zone site because it is on the other side of the pier, so it has shallower water (**Figure 1.3**) and the wave has greater effect than in surf zone than in other beach seine locations which makes sampling much harder, so the fish collection would be harder and results in lower density. I performed an ANOVA test to statistically analyze the relationship between beach seine location and logarithmic transformed mean density, as ANOVA test is powerful enough that non-normality group is unlikely to influence the results. The results of ANOVA test show that there are significant differences in mean logarithmically transformed density of fish in at least one beach seine location (F-value=22.7, p-value$<2*10^{-16}$). Therefore, differ in beach seine location would significantly influence the mean density of fish that is the abundance of fish.

Fish also have different tolerance for temperatures within species or between species (Rijnsdorp et al., 2009). The effect of change in SST would differ in different species of fish, which will depend on. In order to test the hypothesis that change in SST would have effect in the mean density of fish. I used Pearson correlation test to test for the coefficients between two numerical variables SST and logarithmically transformed mean density (**Table 1**). The Pearson correlation coefficient between SST and logarithmic transformed mean density in replicates sampled in five beach seines nearshore showed all positive numbers which indicate a positive correlation between two variables. As SST increase the mean density of fish would also increase. However, only SST from Belmont Shore and Cabrillo Beach Bay show significant p-values, indicate positive correlation between SST and mean density only in these two locations. The p-values from other locations were not significant, indicating SST and mean density are correlated in Cabrillo Beach Surf Zone, Marina del Rey, and Naples Island. The reason why that Cabrillo Beach Surf Zone, Marina del Rey and Naples Island had insignificant p-values may because the data in these locations were less normally distributed than data of Belmont Shore and Cabrillo Beach Bay.

Then, I created scatter plots with the regression line to visualize the linear relationship between SST and logarithmic transformed mean density (**Figure 4**). The scatter points on the graph were very dispersed for all beach seine locations. For Belmont Shore, the SST data were between 10 °C to 27 °C. The mean density of fish was lowest at SST below 23 °C, but the highest SST was at about 18 °C. However, the points still show a general linear trend. At higher SST, mean density are generally higher. For Cabrillo Beach Bay, there are great variability in mean density for SST between 10 °C to 20 °C and the highest mean density was between 17 °C to 20 °C. For Cabrillo Beach Surf Zone, the mean density was generally low and much fewer points on the graph compare to other graphs. This means that we have fewer mean density data for Cabrillo Beach Surf Zone than other locations. The mean density of fish in Cabrillo Beach Surf Zone were almost the same among all SST, this may due to lack of data. For Marina del Rey, SST mainly between 15 °C to 27°C, and the mean density also shows a generally increased trend. For Naples Island, the higher SST was about 30 °C. There were only few points and the mean density were mostly same and did not show an obvious linear trend as other locations. This may also because we did not gather enough data for Naples Island. On the contrary, we had many data for Belmont Shore and Cabrillo Beach Bay, so the trends may be more representative to the effect of SST on mean density of fish. Also, Belmont Shore and Cabrillo Beach Bay, they both face ocean. For Belmont Shore is at marine outfall and Cabrillo Beach Bay is closed off by inside the pier but still faces ocean. The linear relationship I expected was not as linear as I expected, because Lluch-Belda et al., 2009 found that sardine relative abundance coincides well with estimated SST, increasing during the cooling intervals and declining through the warming periods in the Gulf of California. I generated the equations of the regression lines to statically analyze the linear relationship, for Belmont Shore is $y=0.093x - 0.5643$; for Cabrillo Beach Bay is $y = 0.08x + 0.081$; for Cabrillo Beach Surf Zone is $y = 0.0182x + 0.5812$; for Marina del Rey is $y = 0.0328x + 1.1873$; and for Naples Island is $y = 0.0134x + 1.7647$. The R^2 value explains the variability of the mean density around the mean. The R^2 values are all extremely low, for Belmont Shore 12.76% of variance in mean density is due to SST; for Cabrillo Beach Bay 8.94% of variance in mean density is due to SST; for Cabrillo Beach Surf Zone 0.79% of variance in mean density is due to SST; for Marina del Rey is 2.31% of variance in mean density is due to SST; and for Naples Island is 0.96% of variance in mean density is due to SST. Overall, SST data do not explain very well of the variability of the mean density.

Lastly, to test the effect of SST and beach seine location on mean density of fish, I used a GLM as there are two explanatory variables. There are three significant p-value, indicating there is significant correlation between Marina del Rey, Naples Island and mean density and SST and mean density (**Table 1**). The data suggested that there was a significant correlation between beach seine locations, SST and mean density (F value=12.31, p-value=$2.37*10^{-16}$). Thus, beach seine location and SST are correlated with mean density of fish and the model explains 28.87% variability of response variables around its mean (R^2=28.87%, df=9, 273). The R^2 value is still very low which does not very well explain the model. This may due to variability in the data we collected. I plotted a scatter plot to summarize our data (**Figure 5**). From the graph, we can know that Belmont Shore and Cabrillo Beach Bay have similar slopes, Marina del Rey and Naples Island have similar slopes. However, the mean density among these areas were not significantly different from each other. This may because the lack of mean density and SST data for analysis. Also, we went to different beach seines at different months and time, so fish density would also be different.

In conclusion, there is a correlation between SST, beach seine location and density of fish. However, the data were not significant due to multiple reasons. First, we do not have controlled variables for data. For beach seine locations, we did not control the times went to each beach seine location and did not control the month, replicates, for each beach seine location. As different month would influence the SST a lot. Second, we do not gather enough data. For some mean density data, SST data was not available. Third, the fish sampling ability varied every replicate. Different amount of people would influence the amount of fish sampled and influence the abundance of fish. Most importantly, there are just too many influential factors for the density of fish. SST and beach seine location are not the two determined factors. Thus, it is nearly impossible to draw the conclusion. However, the study still provides a good insight for environmental awareness and guidance for strategies to mitigate the global warming problem. As we know that SST do influence the density of fish in a great extent. With global warming, fish populations may result from a physiological response to changes in environment. The effect of change in SST would differ in different species of fish, which will depend on the ability of the animal to detect environmental gradients and navigate accordingly.

As there are many limitations for this analysis, the samples sizes for each replicate are different and we had a large sample size, the Shapiro-Wilk histograms indicated non-normality. Also, as I chose to ignore the non-normality for the data and ran the GLM. Running a GLM on data that is not normally distributed is an increased risk of a false positive result. For the future experiment and analysis, the variables should be controlled. Also, fish density may be too general as different fish have different tolerance for temperatures within species or between species (Rijnsdorp et al., 2009). More experiments and analysis can be done in the future. For example, to test more influential factors like salinity, seasons rather than just SST. Also, the variables should all be controlled so we can have a more accurate and insightful results.

Literature Cited

Ault, J. 2007. The Ecology of Marine Fishes: California and Adjacent Waters. Edited by Larry G Allen, Daniel J Pondella II, and Michael H Horn. Berkeley (California): University of California Press. xi 660 p; ill.; index. 2006. *The Quarterly Review of Biology*, *82*(3), 293-294.

Cao, J., Chen, X., & Chen, Y. 2009. Influence of surface oceanographic variability on abundance of the western winter-spring cohort of neon flying squid *Ommastrephes bartramii* in the NW Pacific Ocean. *Marine Ecology Progress Series*, 381, 119-127.

Carey, M. P., & Zimmerman, C. E. 2014. Physiological and ecological effects of increasing temperature on fish production in lakes of Arctic Alaska. *Ecology and Evolution*, 4(10), 1981–1993.

Haggarty, D. R., & King, J. R. 2006. CPUE as an index of relative abundance for nearshore reef fishes. *Fisheries Research*, 81(1), 89-93.

Hargrave, C. W. 2009. Effects of fish species richness and assemblage composition on stream ecosystem function. *Ecology of Freshwater Fish*, 18(1), 24–32.

Horn, M. H., Allen, L. G., & Pondella, D. J. 2006. Chapter 5 Bays and Estuaries in *Ecology of Marine Fishes: California and Adjacent Waters*. University of California Press. p.119-148.

Lluch-Belda, D., Monte-Luna, P. D., & Lluch-Cota, S. E. 2009. 20th century variability in Gulf of California SST. *CalCOFI*, 50.

Lu, H. J., Kao, S. C., & Cheng, C. H. 2008. Relationships between CPUE fluctuation of southern bluefin tuna and ocean temperature variability in the Central Indian Ocean. *Fisheries Science*, 74(6), 1222–1228.

Rijnsdorp, A. D., Peck, M. A., Engelhard, G. H., Mollmann, C., & Pinnegar, J. K. 2009. Resolving the effect of climate change on fish populations. *ICES Journal of Marine Science*,*66*(7).

Xu, J., Chen, X., Chen, Y., Ding, Q. & Tian, S. 2016. The effect of sea surface temperature increase on the potential habitat of *Ommastrephes bartramii* in the Northwest Pacific Ocean. *Acta Oceanologica Sinica*, 35, 109-116.

Tables and Figures

Table 1. Pearson Correlation Test between SST (°C) and logarithmic transformed mean density (per 100 m^2) in replicates sampled in beach seines nearshore from five locations in southern California from all historical data. Note that replicates for which no fish were caught, or temperature data was not available were excluded from the analysis. There are 2 significant p-value (*), indicating there is a positive correlation between logarithmic transformed mean density in Belmont Shore and Cabrillo Beach Bay.

Location	**r**	**p-value**
Belmont Shore	0.32	0.013 *
Cabrillo Beach Bay	0.30	0.004 ***
Cabrillo Beach Surf Zone	0.09	0.595
Marina del Rey	0.15	0.242
Naples Island	0.10	0.521

Table 2. GLM results for interaction effects between beach seine locations, SST (°C) and logarithmic transformed mean density (per 100 m^2) in replicates sampled in beach seines nearshore from five locations in southern California from all historical data. Note that replicates for which no fish were caught, or temperature data was not available were excluded

from the analysis. There are three significant p-value (*), indicating there is significant correlation between beach seine location, SST and mean density from fish sampled from these 5 beach seine locations.

Coefficients	**Estimate**	**Standard error**	**t value**	**Pr (>|t|)**
Intercept	-0.5645	0.5385	-1.048	0.296
Location: Cabrillo Beach Bay	0.6453	0.7100	0.909	0.364
Location: Cabrillo Beach Surf Zone	1.1458	0.8608	1.331	0.184
Location: Marina del Rey	1.7515	0.8212	2.133	0.034 *
Location: Naples Island	2.3292	0.9113	2.556	0.011 *
Sea Surface Temperature	0.0930	0.0274	3.398	0.001 ***
Cabrillo Beach Bay : SST	-0.0131	0.0380	-0.344	0.731
Cabrillo Beach Surf Zone : SST	-0.0748	0.0442	-1.694	0.091
Marina del Rey : SST	-0.0603	0.0404	-1.492	0.137
Naples Island : SST	-0.0797	0.0453	-1.759	0.080

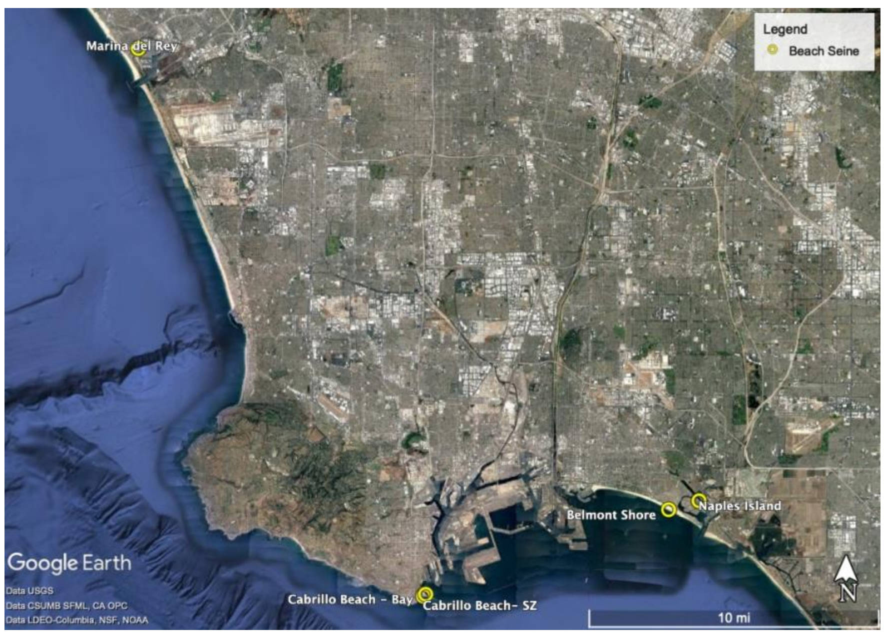

Figure 1.1 Five beach seine sampling locations (yellow circles). Map created in ®Google Earth2018.

Figure 1.2. Cabrillo Beach Bay and Cabrillo Beach Surf Zone beach seine sampling locations (yellow circles). Map created in ®Google Earth2018.

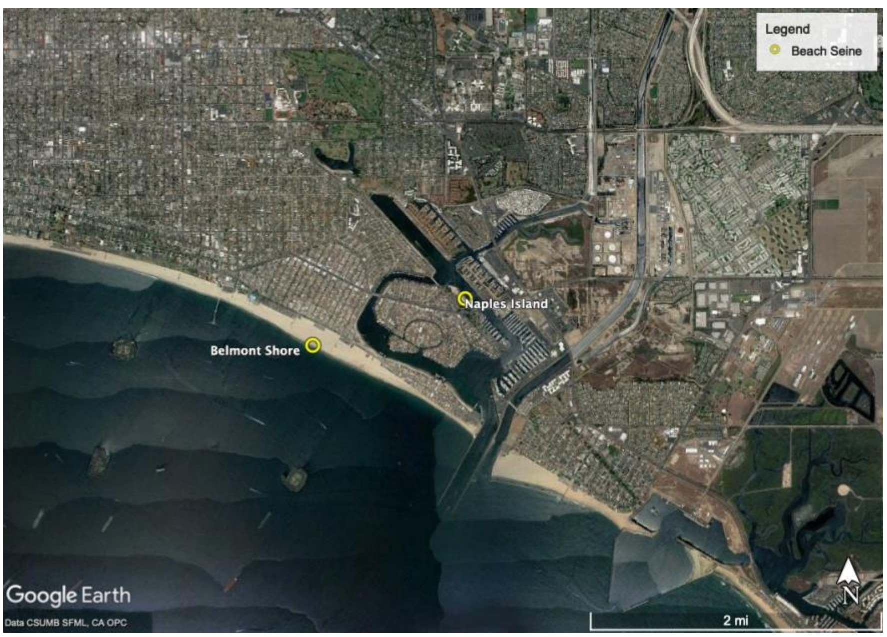

Figure 1.3. Belmont Shore and Naples Island beach seine sampling locations (yellow circles). Map created in ®Google Earth2018.

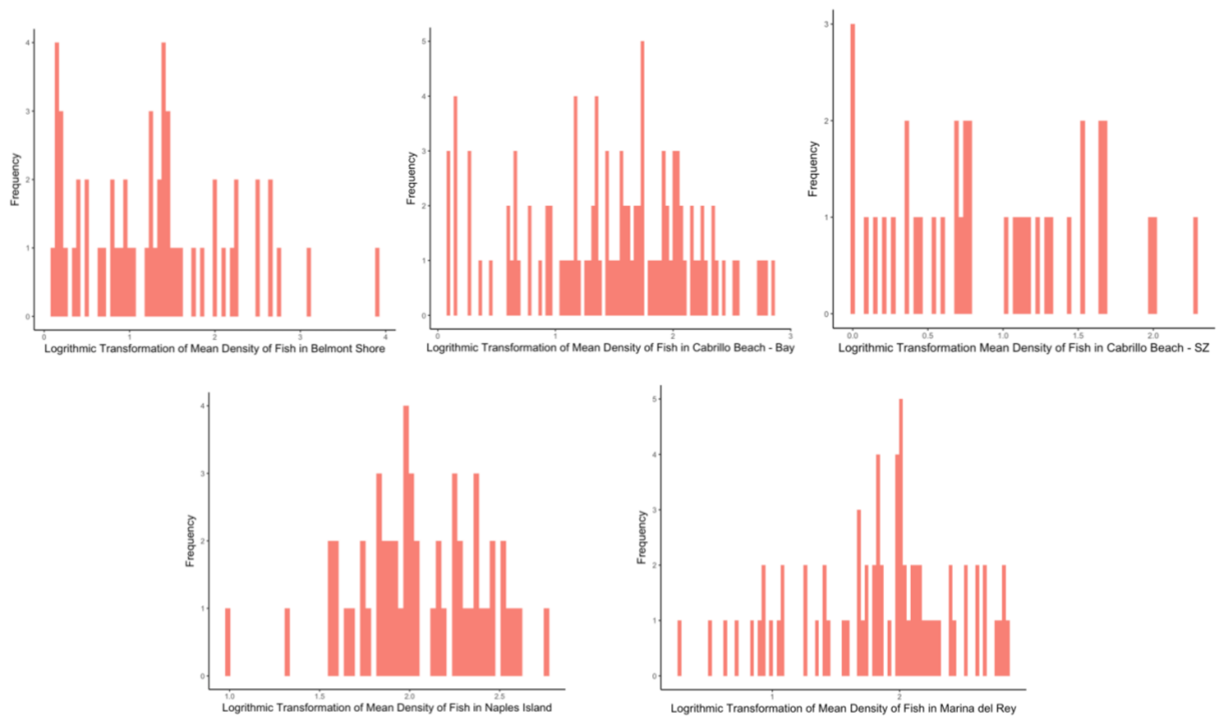

Figure 2. The logarithmic transformation of mean density of fish (per 100m^2) in replicates sampled in beach seines nearshore from five locations in southern California from all historical data. Note that replicates for which no fish were caught were excluded from the analysis. For Belmont Shore and Cabrillo Beach Bay, the logarithmic transformation of mean density data was not normally distributed, visually but data in Cabrillo Beach Bay, Naples Island and Marina del Rey were normally distributed visually. A Shapiro-Wilk test was done on the data to statistically test whether the data fit a normal distribution. (Belmont Shore: W=0.950, p-value=0.021; Cabrillo Beach Bay: W=0.972, p-value=0.026; Cabrillo Beach Surf Zone: W=0.962, p-value=0.228; Naples Island: W=0.979, p-value=0.458; Marina del Rey: W=0.964, p-value=0.039)

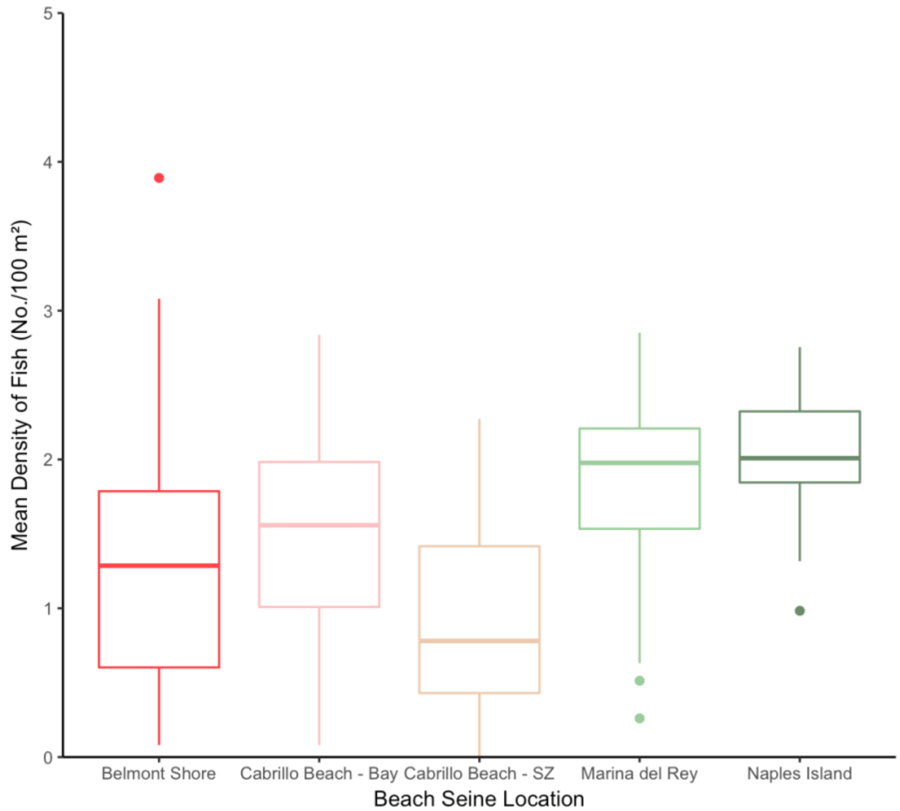

Figure 3. Box plot of logarithmic transformed mean density of fish (per 100m^2) in replicates sampled in beach seines nearshore from five locations in southern California from all historical data. Note that replicates for which no fish were caught were excluded from the analysis. The logarithmic transformed mean density of fish at 5 different beach seine locations are shown in five different colors. The ANOVA test was performed and shows that there is significant different in mean density of fish at different beach seine locations (F-value=22.7, p-value<$2*10^{-16}$).

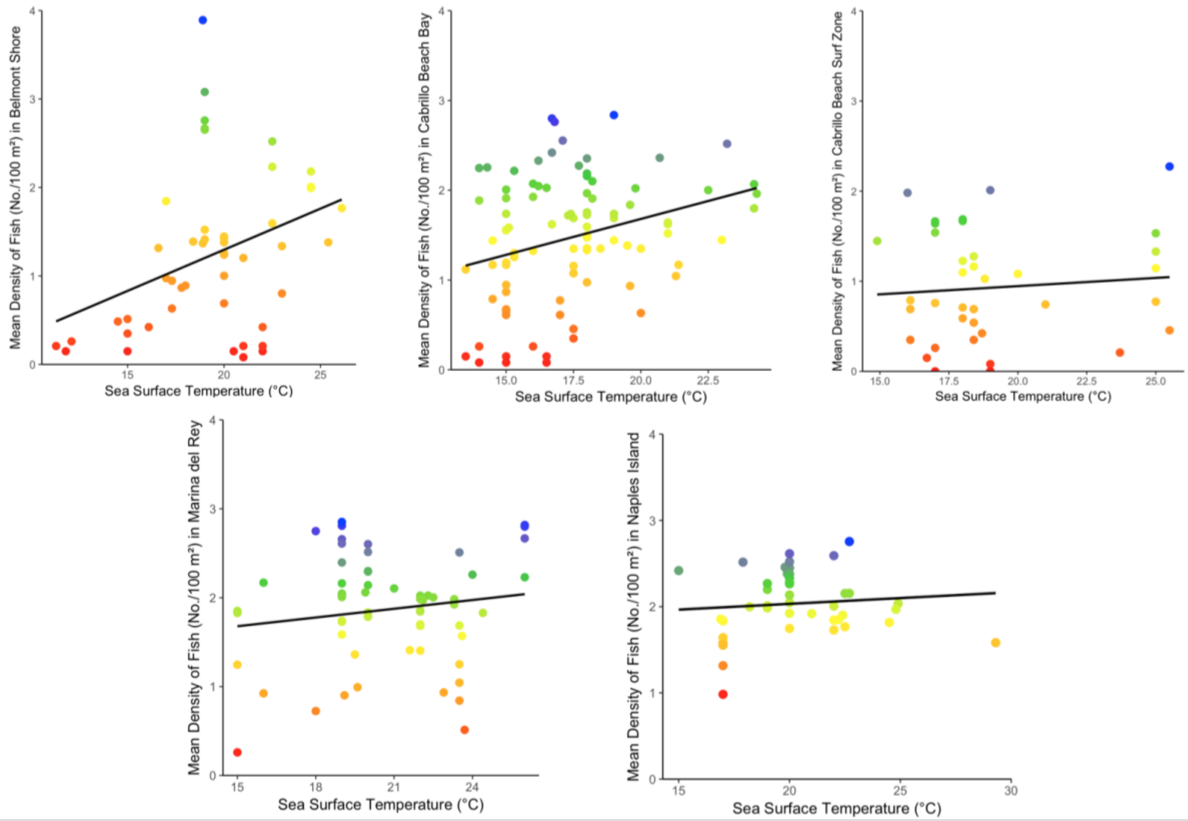

Figure 4. The relationship between SST(°C) and the logarithmic transformation of mean density of fish (per 100 m^2) in replicates sampled in beach seines nearshore from five locations in southern California from all historical data. Each point represents a single beach seine replicate. The mean density of fish at each beach seine location increase in color gradient. A trend-line was fitted to the data. Note that replicates for which no fish were caught, or temperature data was not available were excluded from the analysis. A linear model was done on the data to statically analyze the relationship. (Belmont Shore: y=0.093x - 0.5643, R^2 = 12.76%; Cabrillo Beach Bay: y = 0.08x + 0.081, R^2 = 8.94%; Cabrillo Beach Surf Zone: y = 0.0182x + 0.5812, R^2 = 0.79%; Marina del Rey: y = 0.0328x + 1.1873, R^2 = 2.31%; Naples Island: y = 0.0134x + 1.7647, R^2 = 0.96%)

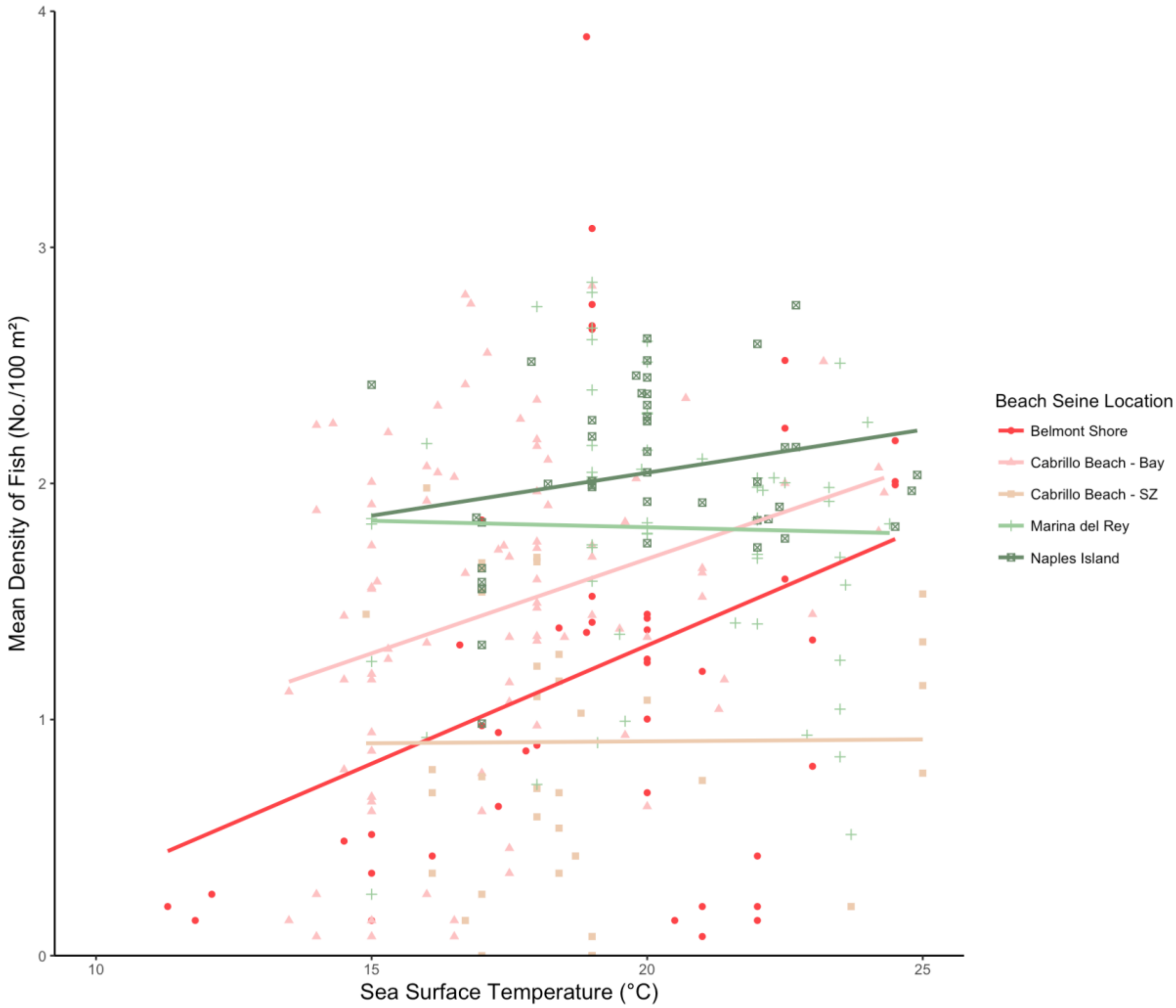

Figure 5. The interaction effects of SST(°C) and logarithmic transformed mean density of fish (per 100m²) in replicates sampled in beach seines nearshore from five locations in southern California from all historical data. Each point represents a single beach seine replicate. Trend-lines were fitted to the data. Note that replicates for which no fish were caught, or temperature data was not available were excluded from the analysis. The data from 5 beach seine locations are shown in 5 different colors and labels with linear regression lines (Belmont Shore: y=0.093x - 0.5643, R^2 = 12.76%; Cabrillo Beach Bay: y = 0.08x + 0.081, R^2 = 8.94%; Cabrillo Beach Surf Zone: y = 0.0182x + 0.5812, R^2 = 0.79%; Marina del Rey: y = 0.0328x + 1.1873, R^2 = 2.31%; Naples Island: y = 0.0134x + 1.7647, R^2 = 0.96%). There is an interaction between the logarithmic transformed mean density of fish and SST. (t value=-1.048, p-value=0.29551, R^2=28.87%, df=273)