# EFFECT OF CLIMATE CHANGE ON CALIFORNIA FISH SPECIES

*Allison N. Scavo and Ramesh P. Singh*
School of Life and Environmental Sciences, Schmid College of Science and Technology, Chapman University, Orange, CA 92866, USA
E-mail rsingh@chapman.edu

## ABSTRACT

Increasing anthropogenic activities have direct connections to global warming and climatic change. The land and ocean temperature show an increasing trend throughout the globe. In this paper, we have analyzed satellite derived ocean temperature data to study the impacts of climate change on the fish catch along the west coast of California during years 2005-2014. We have considered monthly fish landing data of five different species from three different coastal California cities: Eureka, San Francisco, and Los Angeles. The different populations of fish landing were compared with the ocean temperature and other controlling parameters. The detailed analysis of these parameters show a close relation with the different species of fish landing. The increasing ocean surface temperature shows positive and negative correlations with the different species of fish catch, and some fish species seem to decline with the increasing ocean surface temperature.

**Index Terms** – Climate change, fish landing, fish species, sea surface temperature, California coast

## 1. INTRODUCTION

Climate change impacts ocean water currents, freshwater intake, and seawater levels which alter the temperature and productivity of oceans [1]. This phenomenon has already produced significant biological and physical impacts to marine ecosystems [2]. Importantly, different fish species are found to show strong dependence on the sea surface temperature (SST) [3] which can impact their migration patterns [4]. The temperature controls important processes in fish and it is one of the important factors to determine the niches and resulting spatial distribution. A detailed analysis based on 16 years temperature data and fish species landing have been carried out in the US Northeast region by Dunn et al. [5]. In the present study, we have considered ocean color parameters (chlorophyll-a and skin sea surface temperature) from three locations along the western coast adjacent to California. Detailed analysis of monthly satellite SST and chlorophyll-a (Chl-a) data for the period 2005-2014 have been analyzed. Different fish species show dependence on the SST and Chl-a, some of the species landing show an increasing and other species shows declining trend.


Figure 1 shows three locations along the US west coast.

### 2.1 STUDY AREAS

We have considered five fish species from three different sites: Eureka, San Francisco (SF), and Los

Angeles (LA) along the California coast (figure 1). These three locations represent the northern, central, and southern areas of the California state. The study sites consist of two degree latitude by two degree longitude around covering the ocean and coastal regions.

### 2.2 CLIMATIC CHANGE PARAMTERS

The Chl-a concentration (mg m-3) and skin SST (°C) data for the period (2005-2014) are considered at three locations (Figure 1) through NASA Giovanni website (giovanni.gsfc.nasa.gov). The skin SST represents the measurements of a thin layer of the ocean, usually few centimeters, with an effective temperature of the ocean surface layer measured by Atmospheric Infrared Sounder (AIRS) launched into orbit on May 4, 2002 aboard NASA's Aqua satellite (http://airs.jpl.nasa.gov/). Generally the land temperature is higher compared to ocean temperature.

### 2.3 DETAILS OF DATA USED

To investigate how various fish respond to climate change, five marine fish species, halibut, rockfish, sablefish, albacore tuna, and Pacific bonito are considered at three locations along the western US coast. The rockfish data were classified as a slope group, meaning that all rockfish with habitats along the continental shelf and the continental slope were grouped together. Annual and monthly fish landing data of different species at three locations are taken from the California Department of Fish and Game (www.wildlife.ca.gov) for the period 2005-2014.

We have also studied variability of MODIS-Aqua satellite Chl-a concentrations retrieved from the NASA Giovanni portal at the three locations along the western coast of California. The Chl-a concentrations provide information about algae and phytoplankton prevalence. It also directly provides information about nutrient prevalence. Higher Chl-a concentrations indicate higher levels of phytoplankton or algae and also show a large presence of nutrients in the ocean. The Chl-a concentrations are very sensitive to number of parameters, the most dominating parameter being sea surface temperature. The yearly and monthly SST variations along the coast of California are very dynamic in nature due to ocean currents and cold water coming from melting in the Arctic polar region.

## 3. RESULTS AND DISCUSSION

Figure 2 shows monthly fish landings for the five studied species for the period 2005 to 2014. In San Francisco, fish landings are very high compared to the other two studied locations. This could be related to sea surface temperature, however, a detailed analysis is required to find out an optimum sea surface temperature for each species of fish.

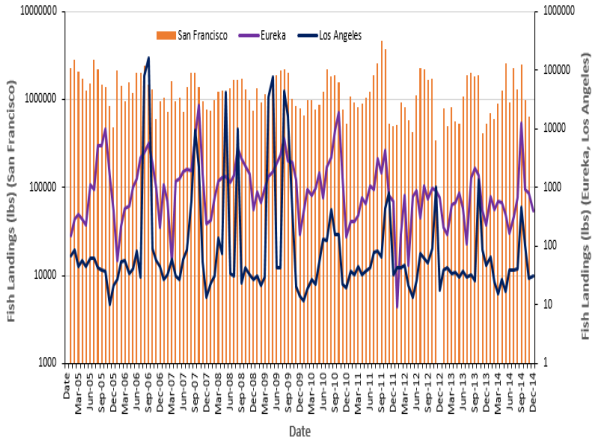


Figure 2. Average total monthly fish landings of all five species at the three locations (shown in Figure 1) along the west coast of California during the period 2005 to 2014.

### *3.1 Skin Sea Surface temperature*

The skin SST of three locations show an increasing trend from 2005 to 2014 (figure 3) and the trend and SST range differ between locations. Skin SST was highest at LA and lowest at Eureka. The SST at San Francisco thus fell in between the SST at LA and Eureka. The higher SST at LA and lower SST at Eureka are associated, respectively, to the cities' close proximity with equator and to the Arctic region.

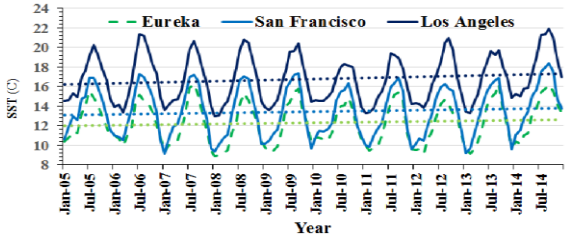


Figure 3. Skin SST variations at three locations during 2005 to 2014.

At each of the three locations, skin SST temperature has increased steadily over the ten year time frame. Based on the slopes of the trend lines in each plot, the SST in San Francisco (SF) and Los Angeles (LA) show a faster increase compared to Eureka.

### *3.2 Monthly Chl-a concentrations*

Figure 4 shows the highest Chl-a concentrations were seen in SF with values close to 9.0 mg m-3. In contrast, the Eureka and LA Chl-a concentrations only vary up to 4 mg m-3. Overall Chl-a concentrations show strong monthly variability. The highest variability is observed in SF, whereas Chl-a concentrations show similar variability at LA and Eureka locations. The maxima peaks at these three locations show small time lags. The Chl-a concentrations in LA and SF show a decreasing trend over the ten year time period. The Chl-a concentrations near Eureka are observed to be almost constant. In both Eureka and SF, Chl-a concentrations show higher concentrations during summer months, while LA shows high concentrations during winter months (figure 4).

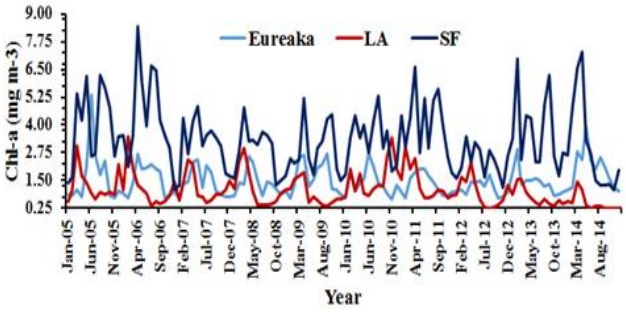


Figure 4 shows monthly Chl-a (mg m-3) concentrations at three locations during 2005-2014.

### *3.3 Chl-a concentration, SST and fish landings*

Seasonal cycles of SST and Chl-a differ in California coastal areas farther to the north or south and Chl-a concentrations are thought to be highest in during mid to late winter season when surface temperatures are low [6]. In order to determine if Chl-a concentrations at three locations show a similar trends in coastal waters, Chl-a concentrations and skin SST were compared. At each of the three locations, scattered plots between Chl-a concentrations and SST data were plotted to determine if any relationship between the two parameters exists. Only in Los Angeles (LA) was the correlation between Chl-a and SST found to be reasonably good ($R^2$=0.38). This correlation shows that Chl-a concentrations tend to decrease with the increase of SST. This supports the observations made by Legaard and Thomas [6]. Only California halibut in Los Angeles displayed a correlation between landings and Chl-a with $R^2$=0.20. This correlation was positive.

### *3.4 SST and fish landings*

The effects of increasing surface temperatures on the five species were investigated by overlaying the monthly fish landing data over the surface skin temperature data from 2005 to 2014. Out of the total fifteen fish groups studied (five fish species at each of the three study locations), only six species show a relatively high correlation between surface temperature and landings. All but one of these correlations were positive. Sablefish were the only species to show relatively high correlations between surface temperature and landings in all three areas of study. All of these correlations were positive. Sablefish landings in San Francisco show the highest correlation with $R^2$= 0.39 while landings in Los Angeles show the lowest correlation with $R^2$=0.11.

Our detailed analysis has shown that different fish species respond differently to sea surface temperature.

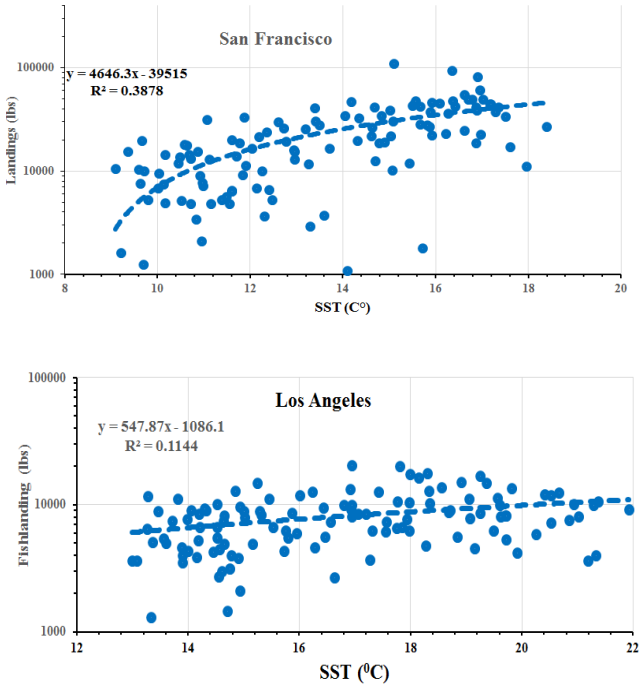


Figure 5 shows correlation between fish landings and SST at San Francisco and Los Angeles locations.

## 4. CONCLUSIONS

Based on our detailed analysis of fish catch, sea surface temperature, and chlorophyll-a, we found that the landings of different fish species show different correlations to these variables. Though this was not evident for all species investigated, a handful of fish species in various locations along the coast were sensitive to changes in surface temperature while only one species was found to be sensitive to chlorophyll-a changes. This may imply that fish are more sensitive to changes in surface temperature compared to Chl-a concentrations. Different fish species landings clearly show positive and negative correlations, as some fish species population enhances with the ocean temperature, such as sablefish, and some of the fish population decline, such as California Halibut. Fish species clearly show sensitivity to climate change in the fish landings along the California coast. The present study shows that some of the species may vanish in this region if the sea surface temperature continues to rise.

## ACKNOWLEDGMENT

The authors thank the California Department of Fish and Game (www.wildlife.ca.gov) for providing fish landing data and the NASA Giovanni team for providing ocean and atmospheric satellite data.

## 5. REFERENCES

[1] Met Office, Climate: observations, projections and impacts—Bangladesh. *Met Office Hadley Centre and Department of Energy and Climate Change of the United Kingdom*, 2011.

[2] J.C. Field, and R.C. Francis, "Cooperating with the environment: case studies of climate and fisheries in the northern California current". In *Fisheries in a changing climate*, (Bethesda, MD, USA: American Fisheries Society Symposium 32), pp. 245-259, 2002.

[3] W.W.L. Cheung, R. Watson, and D. Pauly, "Signature of ocean warming in global fisheries catch", *Nature*, vol. 497, pp. 365-368, doi 10.1038/nature12156, 2013.

[4] M.M. Islam, S. Sallu, K. Hubacek and J. Paavola, "Migrating to tackle climate variability and change? Insights from coastal fishing communities in Bangladesh", *Climate Change*, vol. 124, no. 4, pp. 733-744, doi 10.1007/s10584-014-1135-y, 2014.

[5] D.C. Dunn, J.H. Moxley and P.N. Halpin, "Temperature-based targeting in a multispecies fishery under climate change", *Fisheries and Oceanography*, vol. 25, no. 2, pp. 105–118, 2016.

[6] K.R. Legaard, and A.C. Thomas, "Spatial patterns in seasonal and interannual variability of chlorophyll and sea surface temperature in the California Current", *J. Geophys. Res.: Oceans*, vol. 111, doi 10.1029/2005JC003282, 2006.