# Investigating Changes in Whale Shark Abundnace in the Gulf of Mexico Over Time

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## Dataset Information

The Whale Shark Abundance data used in this analysis is from OBIS-SEAMAP. This was one of the only datasets that had multiple records over a long time period which is why we chose to use it. The whale shark data set spans from 1964 to 2010 and has 8,408 records of whale shark sightings. These sightings include chance encounters and individual catalogues. The encounters and photographs were mainly collected by the general public but the database is maintained by professional scientists.

The Sea Surface Temperature data is from the National Oceanic and Atmospheric Administration (NOAA). They have data on the global annual and monthly measure of sea surface temperature anomaly which is how different the temperature is from the average sea surface temperature. The time frame is from 1854 to present day and the data comes from the International Comprehensive Ocean-Atmosphere Dataset (ICODAS). We chose to download monthly data between the latitudes of 20N and 90N because that includes the Gulf of Mexico which is what we are interested in.

Table 1: Table 1: Information on Datasets

| Dataset Name | Data Source | Data Range | Units | Variables used |
|---|---|---|---|---|
| Whale Shark Abundance | OBIS-SEAMAP | 1964-2010 | Number of whale sharks | latitude, longitude, date-time |
| Sea Surface Temperature (Anomaly) | NOAA | 1854-Present | Kelvin | year, month, anomaly |

## Data Wrangling

First the whale shark dataset was filtered by latitude (17 to 30) and longitude (-98 to -79) to only include observations from the Gulf of Mexico. Date and time were separated into different columns and lubridate was used to turn the date into a date class. For the time series and linear regression analyses, we needed the count of whale sharks found each month. This was done by creating a column for just month and year. Then, a new column was created called total_sightings which was grouped by the month-year column. Lastly, the "distinct" function was used to only include the month-year column and sightings once for each month instead of for each day. Since, there is missing data points for certain months, we created a new data set of all the months between August 2002 and December 2009. This data set was then joined to the whale shark data set. All the months that didn't have data were NA so for the time series the NAs were replaced with zeros.

The sea surface temperature data was wrangling by removing unnecessary columns and the time range was filtered to only include data between August 2002 and December 2009. A month-year column was made

similar to the column created for the whale shark data. The sea surface temperature data was combined (using left_join) with the whale shark data using the month-year column and all NAs were omitted.

## Exploratory Analysis

Upon beginning the analysis, our main questions were these: has the abundance of whale sharks in the Gulf of Mexico changed over time? If so, did they change in relation to warming sea surface temperatures (SST)? To find out, we first visualized the total sightings of whale sharks in the Gulf of Mexico across our entire study period (2002-2009; Figure XX). This visualization confirmed that a large increase in whale shark abundance appeared to occur after 2008, which gave us the confidence to proceed with our analysis. We then investigated how SST had changed in the Gulf over the course of our study period to confirm that the water temperature had indeed changed (Figure XX). Upon seeing that it had (check this!!), we knew that there was merit to our investigation, and proceeded to look at more nuanced questions within our study.

After seeing that there appeared to be an overall increase in whale shark abundance, we were curious to see if whale shark abundances had changed within the Gulf of Mexico. Was it possible that the warming waters were causing them to potentially migrate to the Gulf in larger numbers? If so, could the changing water have any impact on which region of the Gulf that they favored? We divided the study area into northern and southern halves, along with eastern and western halves, to see if there appeared to be any sort of trade off between the regions over time (Figure XX). The results showed that there was no clear trade off that could be seen. Instead, it appeared that abundance generally increased across all four regions over time. As one last attempt to view any sort of habitat usage trade off, we then compared the abundance of whale sharks over the study period between each latitude parallel of the Gulf of Mexico (Figure XX), along with their abundance between every two longitute parallels (Figure XX). Again, there was no distinct trade off in usage seen; instead, it again appeared that the whale shark abundance simply increased overall in almost every area. This confired that we should not conduct an analysis to see if habitat preferences had changed, and instead simply focus on whether the number of sighted whale sharks had significantly increased over time or not.

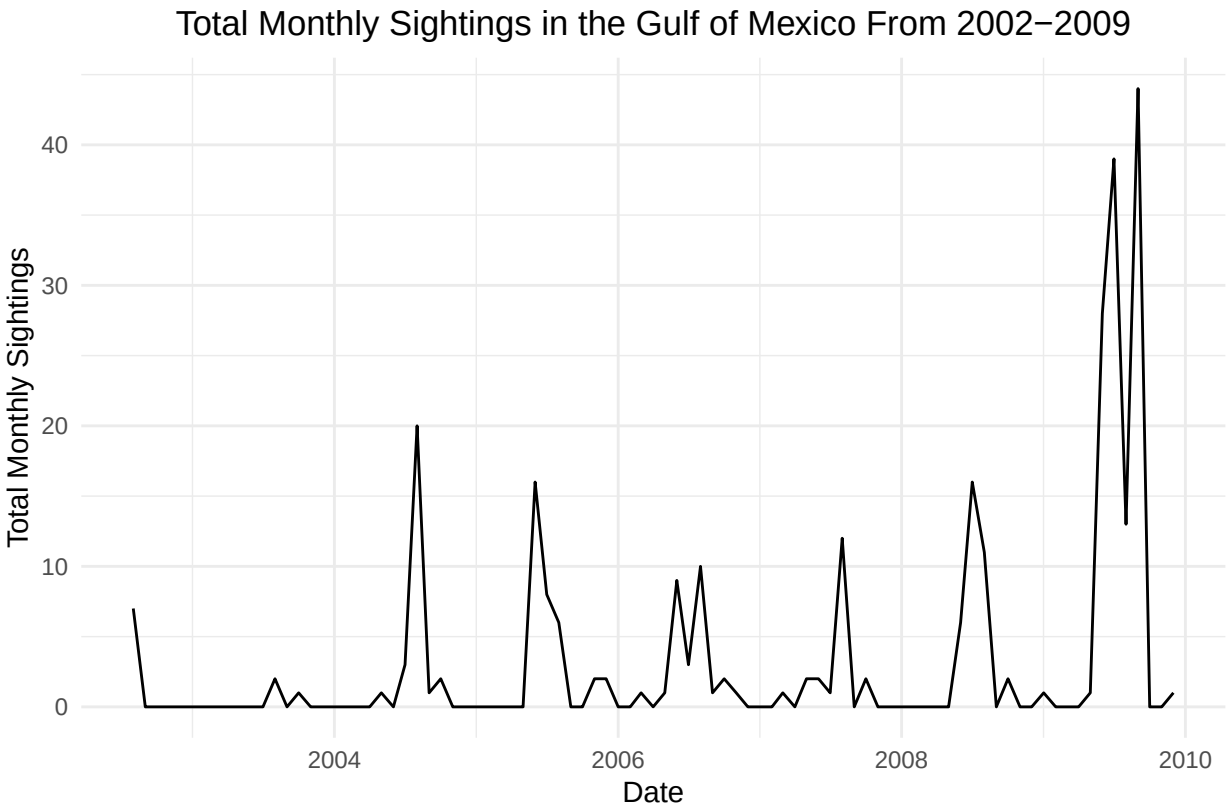



Fig. 1. Time series of montly whale shark sightings in the Gulf of Mexico for the entire study period

Figure 2. Shows that sea surface temperature anomaly is increasing slightly over time.

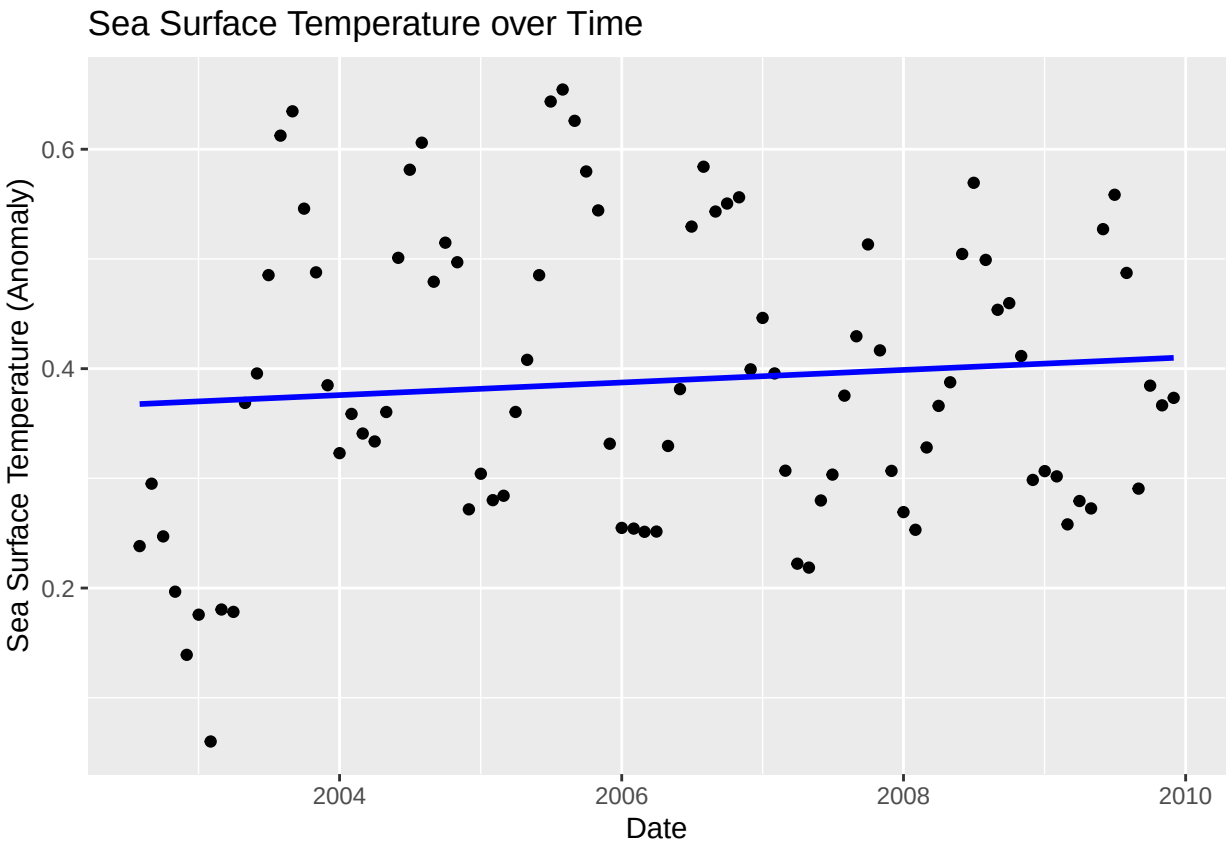
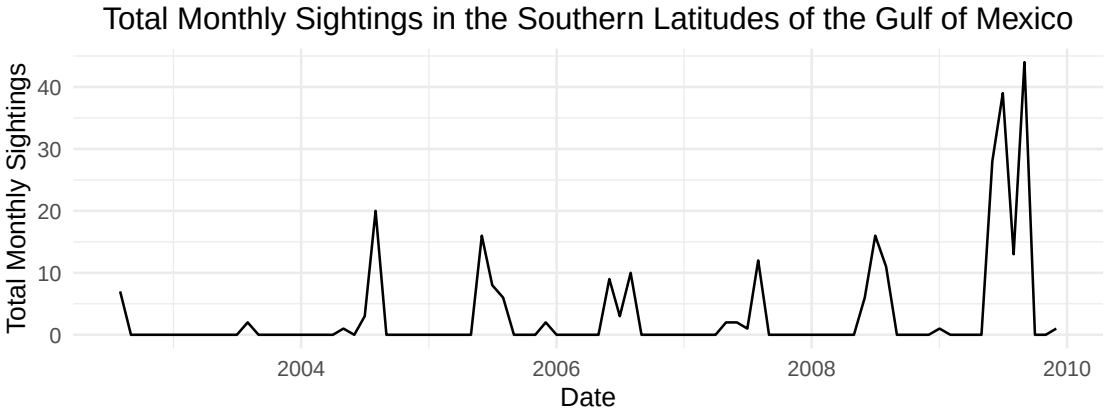
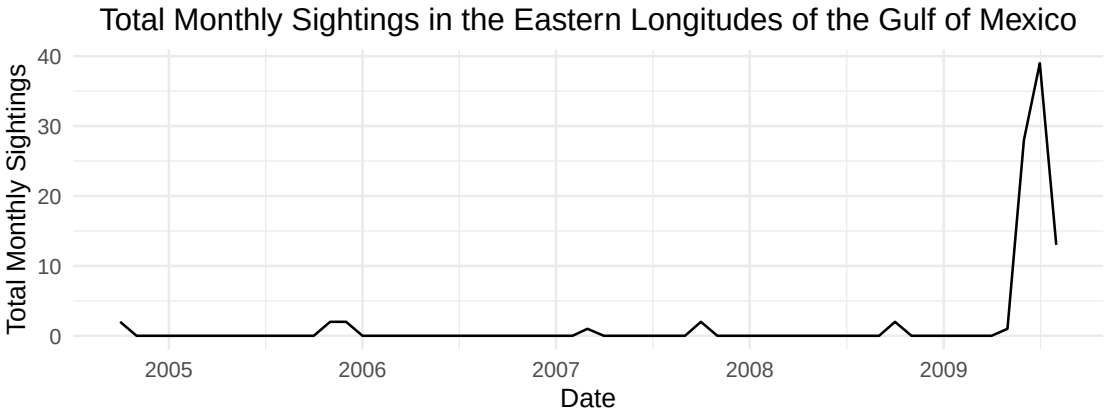



Figure 1: Figure 1: Sea Surface Temperature over Time


Total Monthly Sightings in the Northern Latitudes of the Gulf of Mexico
Total Monthly Sightings
0
10
20
30
40
2004
2006
2008
Date


Total Monthly Sightings in the Southern Latitudes of the Gulf of Mexico
Total Monthly Sightings
0
10
20
30
40
2004
2006
2008
2010
Date


Total Monthly Sightings in the Eastern Longitudes of the Gulf of Mexico
Total Monthly Sightings
0
10
20
30
40
2005
2006
2007
2008
2009
Date

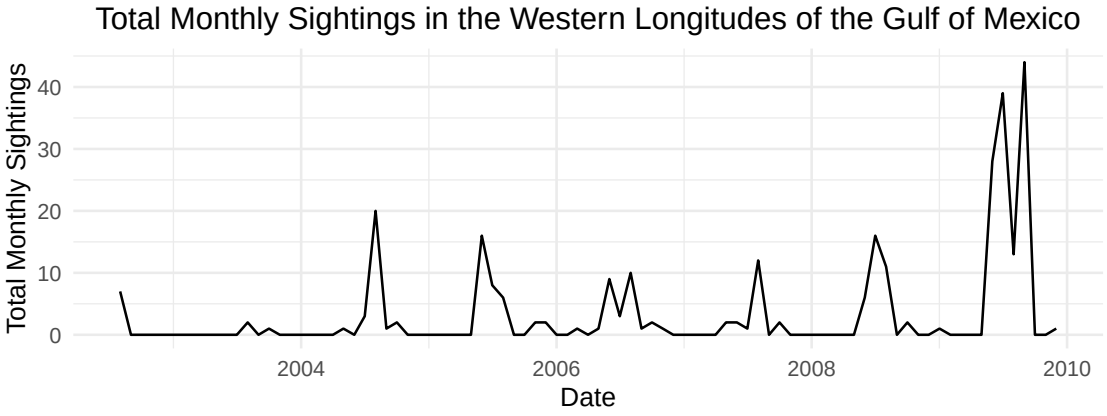

Total Monthly Sightings in the Western Longitudes of the Gulf of Mexico
Total Monthly Sightings
0
10
20
30
40
2004
2006
2008
2010
Date

Figure 3. A four-panel comparison of whale shark sightings in the northern and southern halves of the Gulf of Mexico, followed by the Eastern and Western halves. Each category of sightings had different time periods associated with them, so note the differences in the x axes.

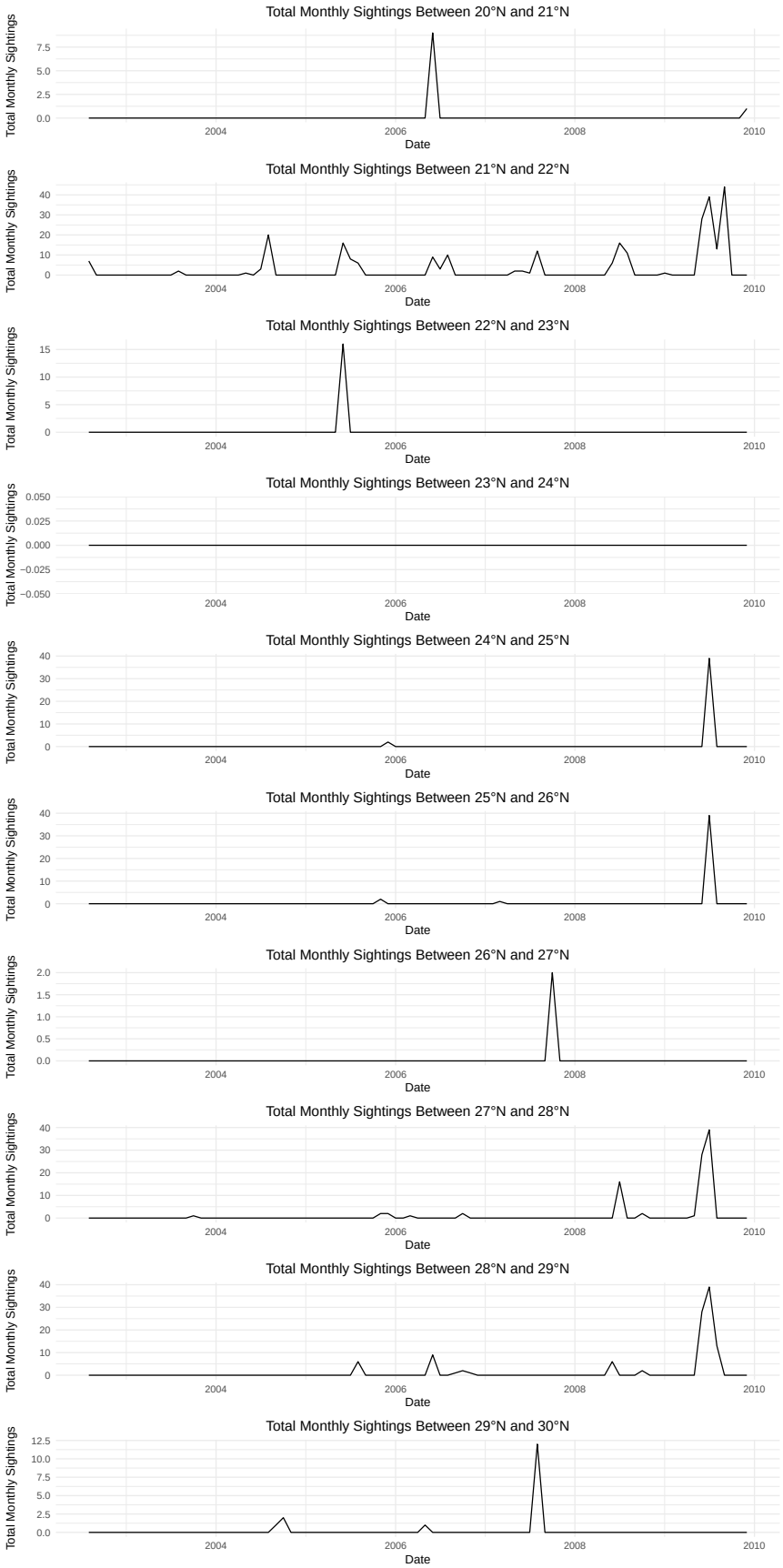

Total Monthly Sightings Between 20°N and 21°N
Total Monthly Sightings
Date
Total Monthly Sightings Between 21°N and 22°N
Total Monthly Sightings
Date
Total Monthly Sightings Between 22°N and 23°N
Total Monthly Sightings
Date
Total Monthly Sightings Between 23°N and 24°N
Total Monthly Sightings
Date
Total Monthly Sightings Between 24°N and 25°N
Total Monthly Sightings
Date
Total Monthly Sightings Between 25°N and 26°N
Total Monthly Sightings
Date
Total Monthly Sightings Between 26°N and 27°N
Total Monthly Sightings
Date
Total Monthly Sightings Between 27°N and 28°N
Total Monthly Sightings
Date
Total Monthly Sightings Between 28°N and 29°N
Total Monthly Sightings
Date
Total Monthly Sightings Between 29°N and 30°N
Total Monthly Sightings
Date

Figure 4. A comparison of whale shark sightings within each latitude parallel of the Gulf of Mexcio.

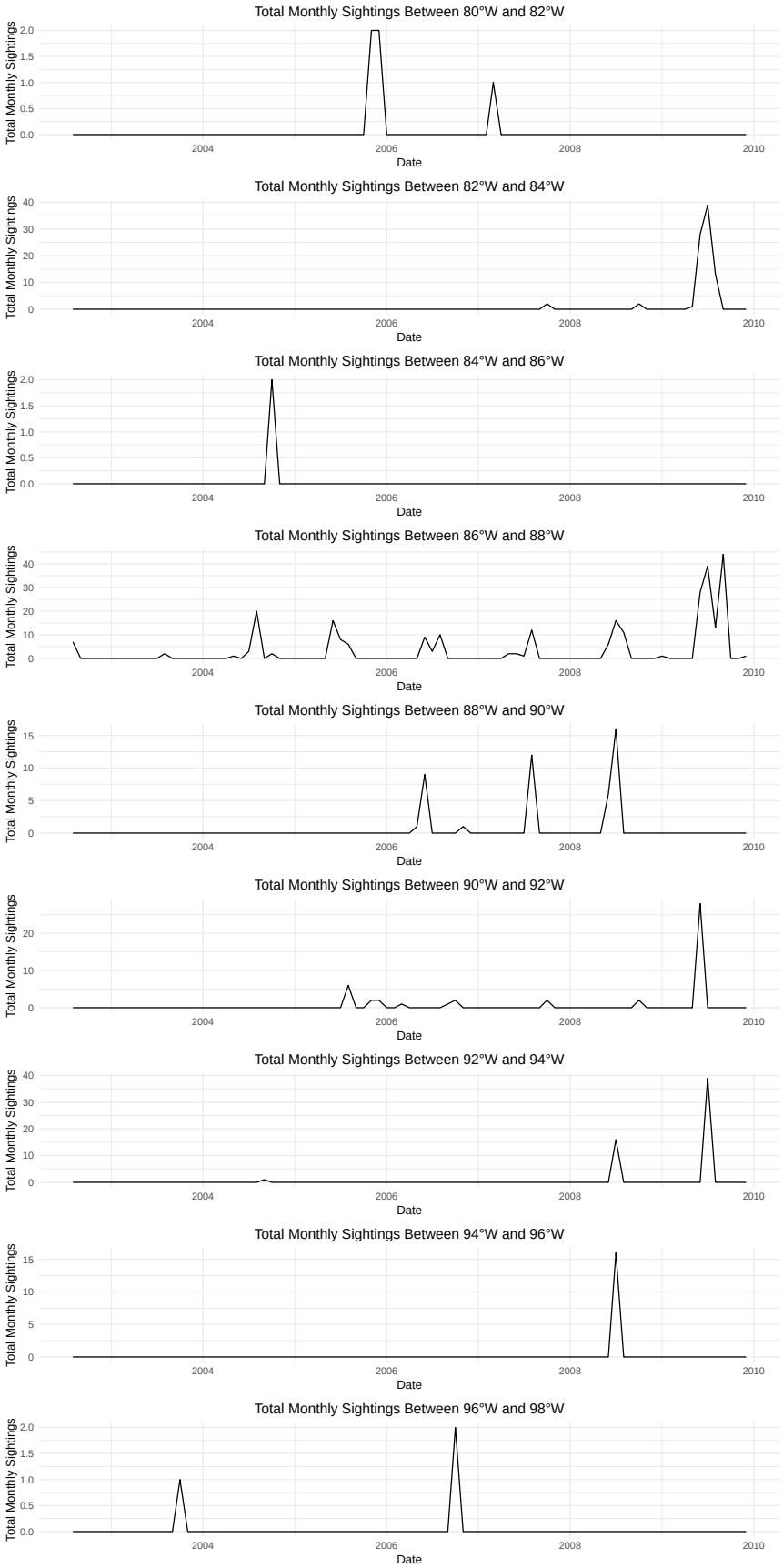

Total Monthly Sightings Between 80°W and 82°W
Total Monthly Sightings
Date
Total Monthly Sightings Between 82°W and 84°W
Total Monthly Sightings
Date
Total Monthly Sightings Between 84°W and 86°W
Total Monthly Sightings
Date
Total Monthly Sightings Between 86°W and 88°W
Total Monthly Sightings
Date
Total Monthly Sightings Between 88°W and 90°W
Total Monthly Sightings
Date
Total Monthly Sightings Between 90°W and 92°W
Total Monthly Sightings
Date
Total Monthly Sightings Between 92°W and 94°W
Total Monthly Sightings
Date
Total Monthly Sightings Between 94°W and 96°W
Total Monthly Sightings
Date
Total Monthly Sightings Between 96°W and 98°W
Total Monthly Sightings
Date

Figure 5. A comparison of whale shark sightings within every two longitude parallels of the Gulf of Mexico.

## Analysis

### Time Series Analysis of Whale Shark Sightings Over Time

### Sea Surface Temperature vs. Whale Shark Sightings

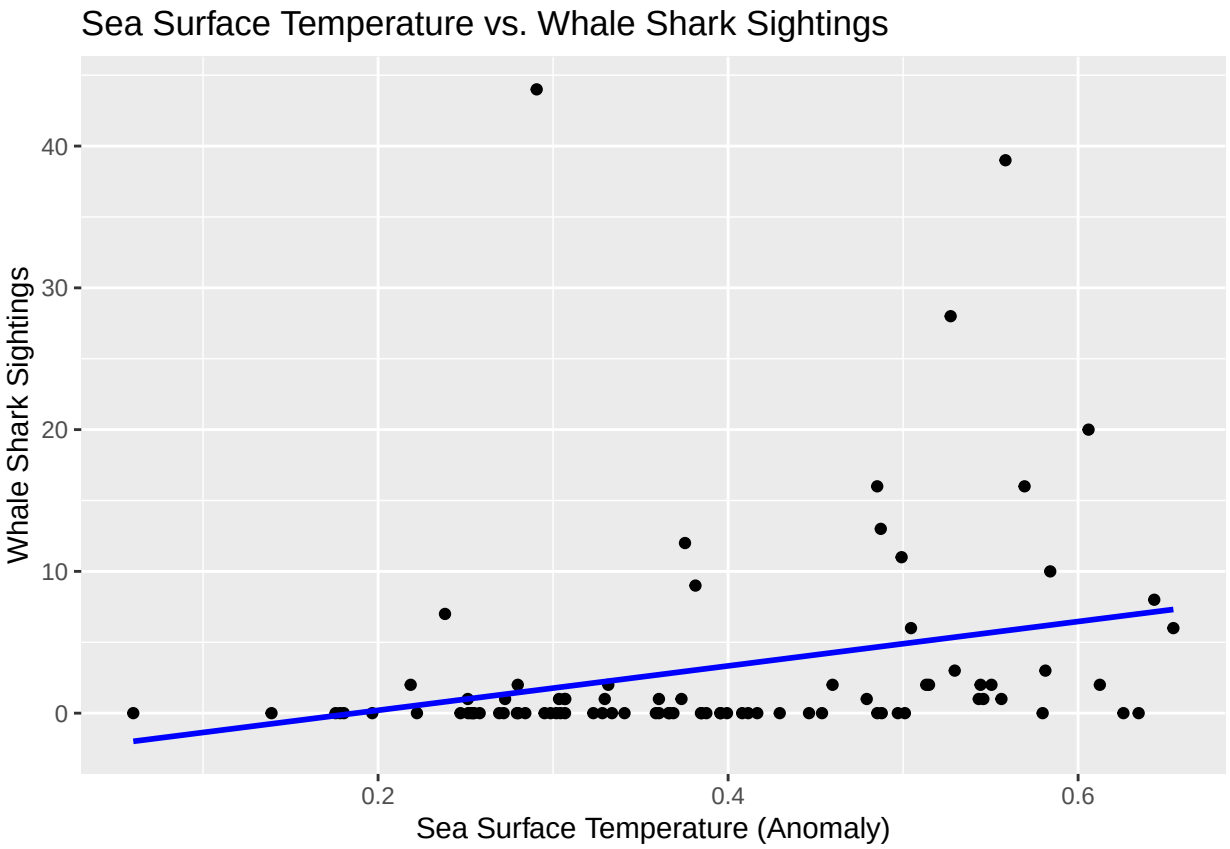
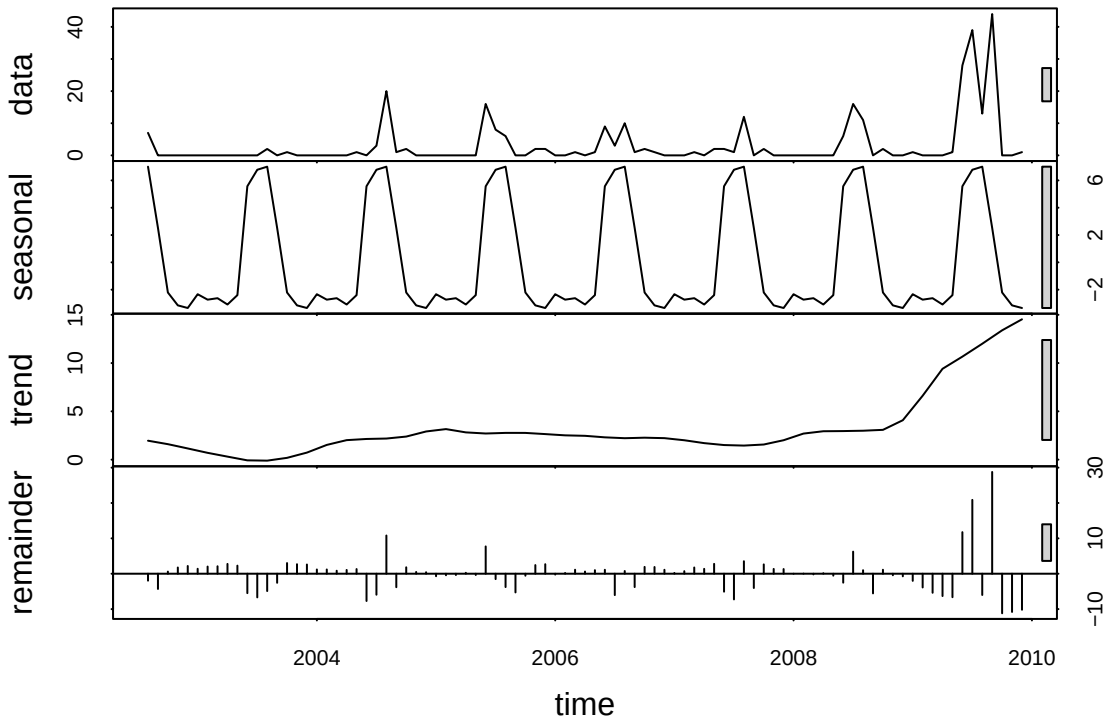



Figure 2: Figure 2: Sea Surface Temperature vs. Whale Shark Sightings

Figure 6. Shows that there is an increase in whale shark sightings as sea surface temperature anomaly increases.

To analyze this increase we used a GLM. The results of the GLM showed that this increase is not significant (p-value = 0.4093, DF=36, R-squared= 0.019).




```
## WARNING: Error exit, tauk2. IFAULT =  12
## WARNING: Error exit, tauk2. IFAULT =  12

## tau = 0.322, 2-sided pvalue =0.0017759

## Score =  63 , Var(Score) = 406.3333
## denominator =  195.4925
## tau = 0.322, 2-sided pvalue =0.0017759
```

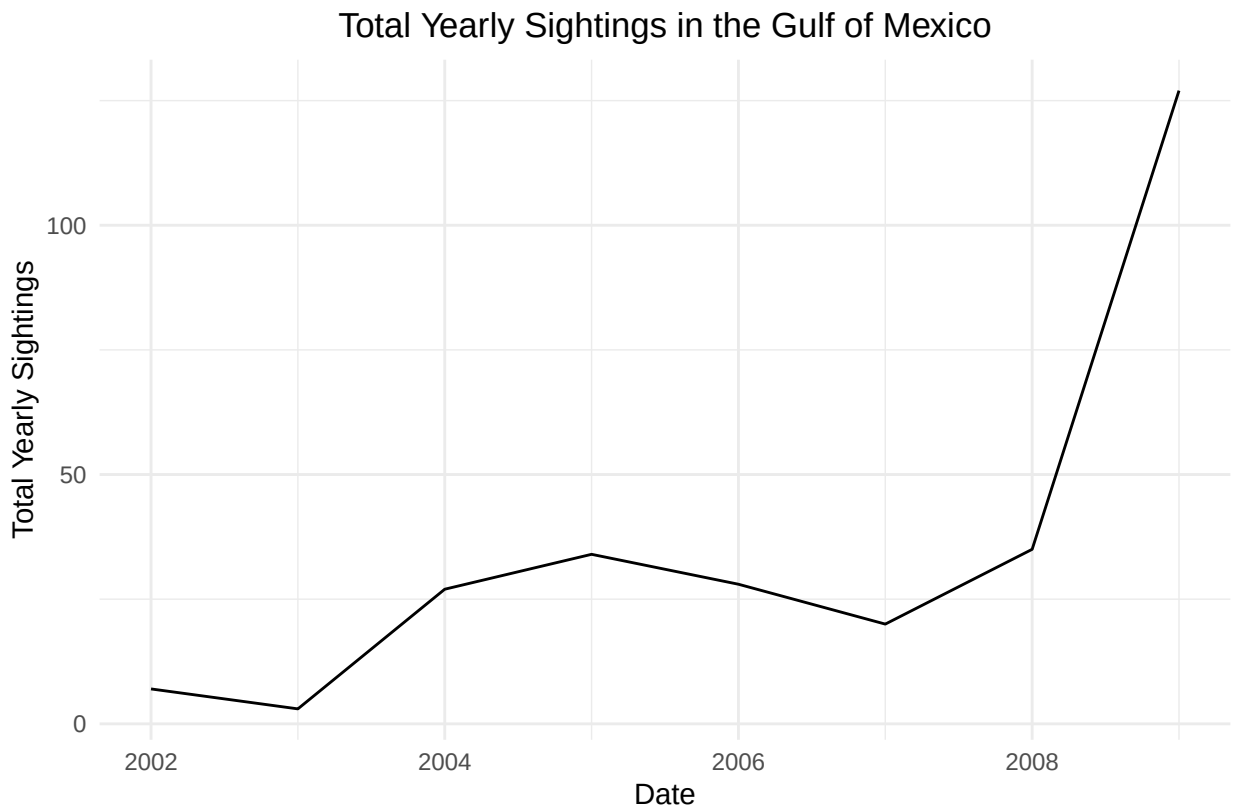



Fig. XX. Total sightings in the Gulf of Mexico for the entire study period, aggregated by year

```
## tau = 0.429, 2-sided pvalue =0.17355

## Score =  12 , Var(Score) = 65.33334
## denominator =  28
## tau = 0.429, 2-sided pvalue =0.17355

##
## Call:
## lm(formula = year ~ total_sightings, data = yearly_sightings)
##
## Coefficients:
##     (Intercept)  total_sightings
##       2.004e+03        4.585e-02

##
## Call:
## lm(formula = year ~ total_sightings, data = yearly_sightings)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -2.2105 -1.0522 -0.5804  1.1684  2.5057
##
## Coefficients:
##                  Estimate Std. Error  t value Pr(>|t|)
## (Intercept)     2.004e+03  8.899e-01 2251.767   <2e-16 ***
```

```
## total_sightings 4.585e-02  1.759e-02    2.607   0.0403 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.812 on 6 degrees of freedom
## Multiple R-squared:  0.5311, Adjusted R-squared:  0.4529
## F-statistic: 6.796 on 1 and 6 DF,  p-value: 0.04029
```

```
## tau = 0.384, 2-sided pvalue =0.0041013
```

## Summary

Sea surface temperature did not affect whale shark sightings significantly. This could be because the data we looked at only spanned a few years or because the whale shark data was opportunistic so there may have been more whale sharks than counted.