Graphical Exploration of the Deep-Water Horizon Oil Spill

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Abstract

1 Introduction

April 20th, 2010 marked the beginning of the largest and worst oil spill in the history of off-shore drilling. Following an explosion in the Deep-water Horizon drilling rig and failure of all emergency systems, crude oil began to gush into the ocean. After an estimated 4.9 million barrels of oil spilled into the sea, the leak was finally stopped on July 15th of 2010 when the well head was capped. The completion of the relief well took until September 19, 2010. The immediate impact of the oil spill on people and wildlife alike was overwhelming and can still be felt. The oil destroyed many habitats for birds, turtles, and other marine wildlife. Waters had to be closed for fishing, affecting the livelihood of the people that depended on the fishing industry. Longterm effects are certain. It is of course impossible to do an analysis that can reflect the breadth and complexity of the effects of the oil spill. However, based on the data provided by government sources we want to demonstrate the impact of the spill on wildlife, measured salinity - which has a major influence in determining oceanic flow, and environmental pollution through chemicals found in oil, in particular Polycyclic Aromatic Hydrocarbons (PAHs).

1.1 Data and Sources

Data on dead and alive animal sightings came from several sources: US Fish and Wildlife (Southeast Region) provided the Cumulative Avian Observations (USFWS). Data on Turtle & Marine Mammal Observations were reported by NOAA (National Oceanic and Atmospheric Administration) and its offices NMS (National Marine Sanctuary) and OPR (Office of Protected Resources).

Each of the files contains records of live and dead animal sightings, geographic location, exact species identification, if known, the date of the sighting, and, for the bird counts, a status variable regarding the oiling condition of the bird (*** what status levels are there? ***).

The EPA (US Environmental Protection Agency) provided water chemistry data focused on petrochemical products, sampled near the coastline in the months since the oil spill.

XXX Structure of this paper:

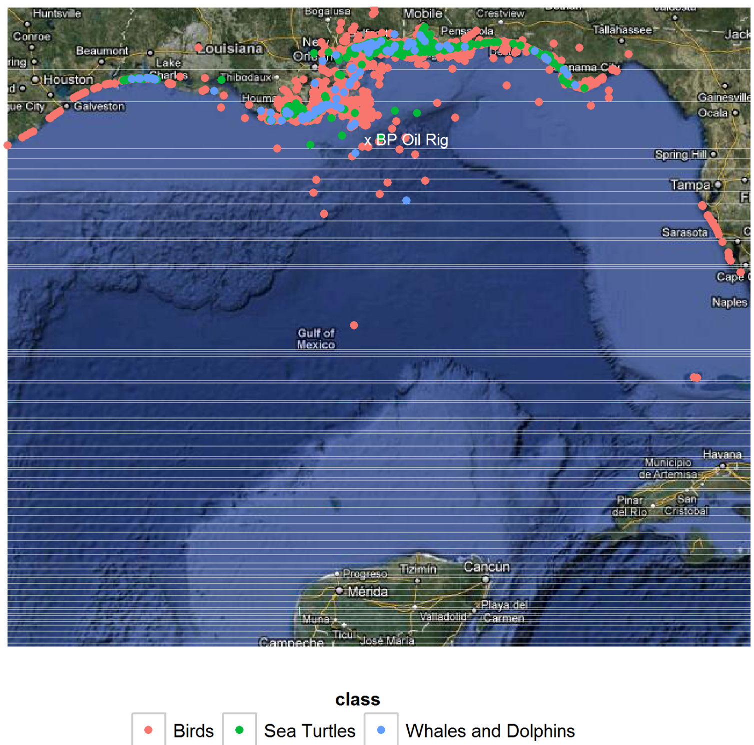

Figure 1: Affected area: the graphic shows a satellite map of some of the area directly affected by the oil spill. The dots on top show locations of dead animal sightings.

2 Animals

Figure 1 shows a satellite map, overlaid by a dotplot indicating locations of animal sightings. Red dots correspond to birds, green dots to sea turtles, and blue dots to dolphins and whales. Birds appeared to be most affected as a total of 5,552 dead birds were found and recorded during the data collection period. A total of 546 sea turtles were found dead. All of the four identified sea turtle species are considered to be highly endangered. 95 dolphins and 3 whales were found and recorded, all of which were dead. The highest concentration of dead animals was found along the shore of Louisiana, closest to the oil rig.

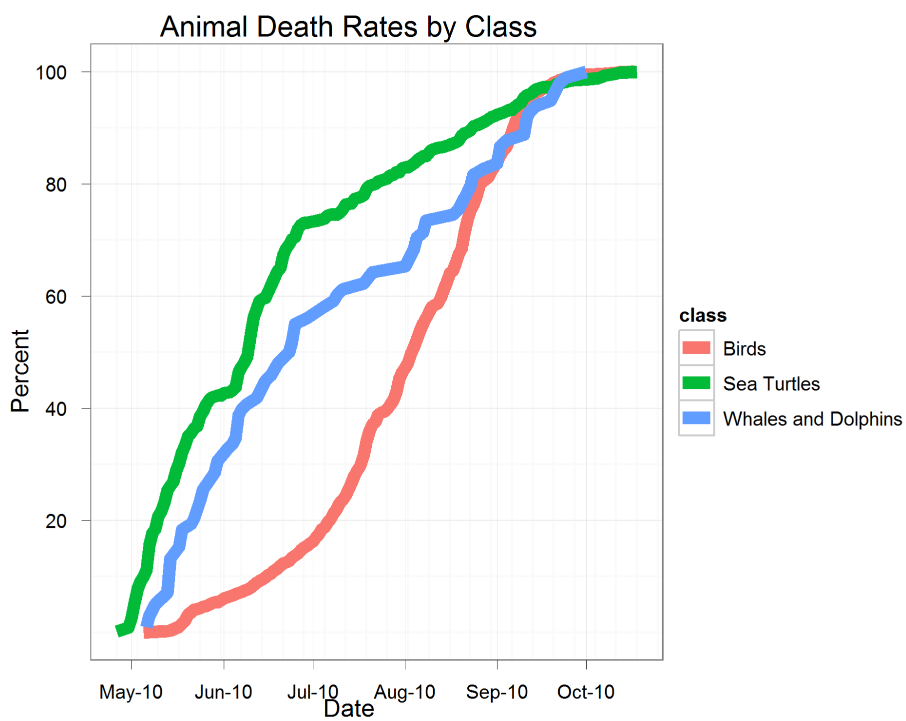

Figure 2: Death rates of birds, dolphins and whales, and sea turtles.

Birds, sea turtles, and dolphins and whales had unique death patterns during the data collection period as Figure 2 illustrates. In this figure, the to-date death toll was divided by the total death toll for each class of animal. The birds had a relatively low death rate from May to July and then the rate began to increase. Sea turtles and dolphins and whales, on the other hand, had the highest death rates from May to July and from there it began to flatten out. For sea turtles, dolphins and whales, the highest death counts per day occurred mainly in the earlier weeks and then decreased over time. The majority of dead bird findings occurred later in time and their death counts per day began to climb rapidly around July. From July to September, the birds experienced a wide range of death counts per day and then began do decrease at the end of September.

Four species of sea turtles were found and identi

ed during the data collection period, all of which are considered endangered. These species are: Lepidochelys Kempii (Kemp's ridley), Eretmochelys Imbricata (Hawksbill Sea Turtle), Chelonia Mydas (Green Sea Turtle), and Caretta Caretta (Loggerhead Sea Turtle).

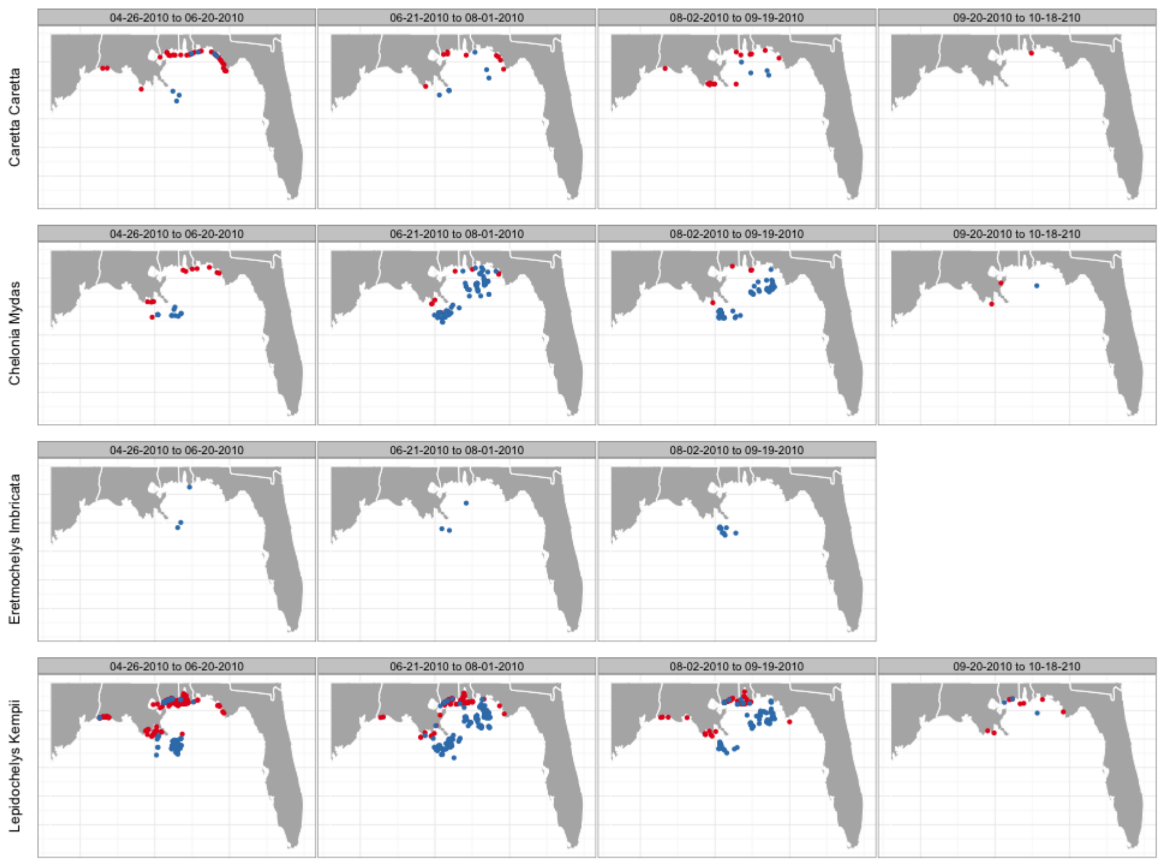

Figure 3: Four species of sea turtles found in the Gulf of Mexico. Blue dots indicate turtles found living and red dots indicate those found dead.

Figure 4 shows when and where these turtles were found and whether they were living or dead. Most dead turtles, of all species, were found along the shoreline. This is most evident among Chelonia Mydas and Lepidochelys Kempii.Most turtles that were found alive were found or the coastline. There were two main areas on the coasts of Louisiana and Florida in which the bulk of live sea turtles were found. Very few turtles were found after September. The species with the greatest number of casualties found was Lepidochelys Kempii, often called Kemp's ridley, a critically endangered species which lives in the Gulf of Mexico.

Although there is no doubt the oil spill caused a tremendous amount of damage, we have no information on the actual cause of death of these animals. We also do not have past data to compare these findings with and so we can only reasonably assume that this quantity of dead turtles, dolphins and whales, and birds is unusual.

3 Chemicals

Many chemicals were sampled in the Gulf of Mexico during the months following the oil spill. This analysis focuses on Polycyclic Aromatic Hydrocarbons because of their direct relationship with oil and because of their toxicity to wildlife. Polycyclic Aromatic Hydrocarbons, or PAHs, are semi-volatile organic substances which come from oil and the burning of oil. Many of these substances are considered carcinogenic, mutagenic, and teratogenic and all are considered harmful to the health of living organisms. New information on each PAH substance was found from the EPA website and put into the data set for this analysis. In order to do a proper analysis on the existence of these chemicals after the spill and how they may have effected life in the Gulf of Mexico it was necessary to put the measurements into an interpretable form. Measurements of the PAHs at unique locations will be looked at in terms of their acute and chronic potency. An area is considered at a chronic level when the amount of harmful substances is thought to bring harmful effects over a long period of time. An area is considered at an acute level when the amount of harmful substances rapidly induces a negative effect in an organism.

Each PAH substance has a unique acute and chronic potency divisor which is used to find the acute and chronic potency ratio, respectively. The potency divisors, which are used in the calculations, can be thought of as the amount of the substance that can be considered dangerous by itself. So, each measured amount of a substance is divided by the chronic and acute potency divisors so that, at each location, we have a ratio of the danger. In other words, areas in which the sum of the chronic or acute ratios is greater or equal to 1 are considered at a chronic or acute level, respectively. For substances measured in water, the process was simple. The measured concentration of each substance for each unique location was multiplied by the Alkylation Multiplier. This number is given for each substance and was added to the chemicals data set. Multiplying by the Alkylation Multiplier gives the Alkyl Adjusted Concentration (ug/L). From there, each of these values are divided by the acute potency divisor and the chronic potency divisor to find the acute potency ratio and chronic potency ratio, respectfully. For substances measured in sediment, the amount of organic carbon for that area must also be used to find the acute and chronic potency ratios. Taking the organic carbon into consideration is important for sediment samples because, when it is present in the sediment, the PAHs bind to it, thus making the PAHs less toxic. Organic carbon, like any other substance, was measured at each location. These concentrations of organic carbon at each unique location were put into a separate data set. Then, the organic carbon data set and the PAH sediment data set could be horizontally merged by unique combinations of Latitude and Longitude. This is done so that each measured concentration of a PAH substance has an accurate corresponding organic carbon measurement. By dividing the original PAH concentrations by the organic carbon, we find the organic carbon normalized concentrations (ug/kg OC). From here, the process is the same as it was for PAH substances measured in water. We multiply by the Alkylation Multiplier and then divide by the acute and chronic potency divisors to obtain the acute and chronic potency ratios, respectfully. For surface water and sediment samples alike, these ratios are additive and each substances' contribution must be summed up for each unique location in order to determine the complete effect.

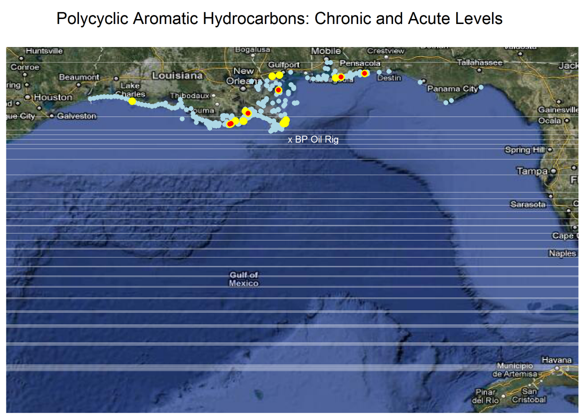

Figure 4: Map showing PAH measurements. Yellow dots represent those considered at a chronic level, red dots represent those considered at an acute level. Light blue dots indicate all samples. Most dangerous area seems to be around the outermost shore of Louisiana as there are many points which had PAH levels at or above chronic or acute benchmarks.

Figure 4 shows areas which meet or exceed the chronic and acute benchmarks. The yellow dots represent areas which meet or exceed the chronic benchmark and the red dots represent areas which meet or exceed the acute benchmark. The light blue dots indicate all areas which were tested. For this graphic, average values of each substance for each unique location were used. This way, there is exactly one measurement of each substance at each location. There were several areas which had dangerous levels of these PAH substances. Particularly along the outer coast of Louisiana, many of the observed PAH values exceeded the benchmarks. This is the area which may have received the most direct contact with the oil.

Figure 5 shows the log of the acute potency ratios not equal to 0 for measurements taken from May 2010 to August 2010. The log was taken so that we could more easily see the variation, as many of the samples near 0. Some measurements of PAH substances exceeded the acute potency ratio alone, meaning that, even if there were no other PAH substances in the area, that one substance was enough to be acutely dangerous. These three acutely dangerous measurements are labeled on the timeline as C1-Chrysenes, C2-Chrysenes, and Chrysene. The Chrysene family is considered a carcinogenic substance. There seems to be a period of time between June and July in which the measurements of these PAH substance had higher values than during the rest of the time.

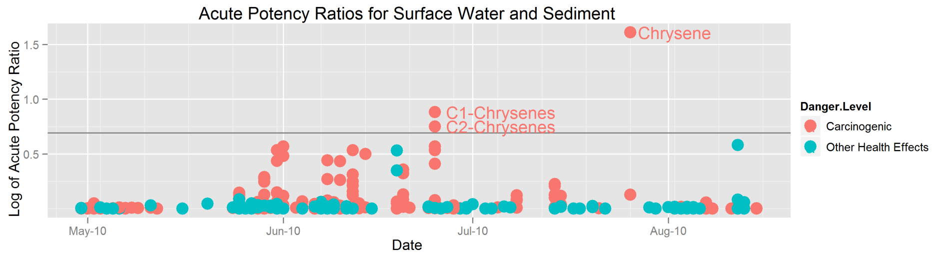

Figure 5: Timeline of logarithm of acute potency ratios. Points are colored by whether they are considered a carcinogenic substance. There is a period of time between June and July in which the acute value is heightened.

4 Salinity

Boats, floats, and gliders recorded salinity, temperature, and depth measurements at various locations in the Gulf of Mexico. The floats tended to stay in the deeper water while the boats and the gliders were free to go all around the gulf. You can see the patterns of these three measuring methods in Figure **??**. Each measuring device would take measurements at the surface and then take measurements at various depths at each location.

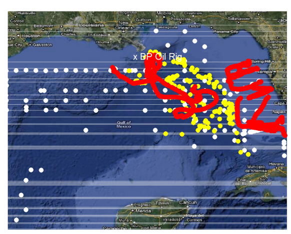

Figure 6: Paths of Boats, Floats, and Gliders.

In Figure 8 you can see all salinity measurements over the data collection period. The vast majority of these measurements stayed within set boundaries. Other points varied from the rest and seemed to be unusually low. In figure 8 you can see when and where these unusual values occurred. In both the left and right graphic, the points are color coordinated by time. The right graphic shows only points where salinity levels are below 34 mg/l. The highest concentration of these points is found near the rig during June and July.

Depth and salinity form a close relationship as you can see in Figure ??. Very strange deviations from this relationship were observed by the two boat measuring devices. The surface water measurement was far below normal observations and from there salinity dropped rapidly with depth. Also, these two observation points only reached a depth of about 200 feet below sea level which is unusually shallow compared to the other measurments taken around it.

5 Conclusions

What we could not do because the data was not available to us: comparable baseline data.

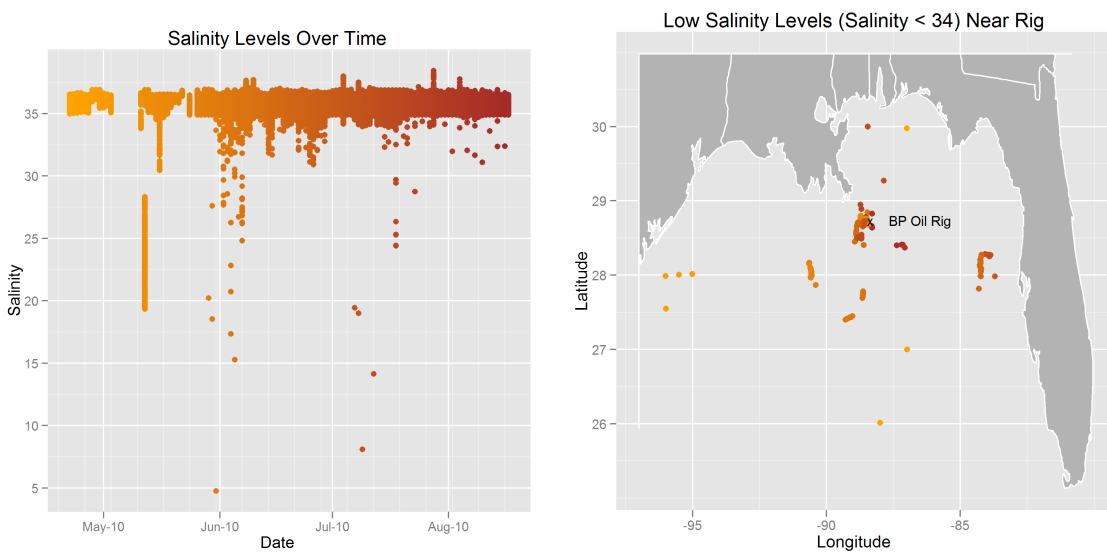

Figure 7: Salinity measurements: over time (left) and by location (right)¿ Salinity measurements only rarely fall below 34 mg/l. In the months after the start of the oil spill salinity frequently drops below 34 mg/l. For later weeks this happens in particular in locations close to the oil rig.