2015

# An Examination of El Niño's and Agricultural Runoff's Effect on Harmful Algal Blooms and California Sea Lion (Zalophus Californianus) Health in Monterey Bay

Nadine Lafeber
*Scripps College*

# AN EXAMINATION OF EL NIÑO'S AND AGRICULTURAL RUNOFF'S EFFECT ON HARMFUL ALGAL BLOOMS AND CALIFORNIA SEA LION (*ZALOPHUS CALIFORNIANUS)* HEALTH IN MONTEREY BAY

by

**NADINE F. LAFEBER**

**SUBMITTED TO SCRIPPS COLLEGE IN PARTIAL FULFILLMENT OF THE DEGREE OF BACHELOR OF ARTS**

**PROFESSOR THOMAS KIM**
**PROFESSOR BRANWEN WILLIAMS**

**12 DECEMBER 2014**

**AN EXAMINATION OF EL NIÑO'S AND AGRICULTURAL RUNOFF'S EFFECT ON HARMFUL ALGAL BLOOMS AND CALIFORNIA SEA LION (*ZALOPHUS CALIFORNIANUS)* HEALTH IN MONTEREY BAY**

**Nadine Lafeber**
Scripps College, 1030 Columbia Avenue, Claremont, California 91711, USA

*Abstract*
An increase in marine mammal stranding and die-off events has been observed along the California coast. The exact cause to explain for these recent events is unknown, but El Niño and harmful algal blooms are established sources for temporary decreases in marine mammal health. To determine whether El Niño could be causing and amplifying harmful algal blooms, particularly in Monterey Bay where they occur frequently, data was analyzed from the Marine Mammal Center in Sausalito, California. Data analysis focused on California sea lions (*Zalophus californianus*), because they have the largest data set and are directly affected by harmful blooms from domoic acid. Results indicated that El Niño events could be significantly harming California sea lions in Monterey Bay during the fall season. Because agricultural runoff is a known factor in causing harmful algal blooms and Monterey Bay experiences them consistently, online research was conducted on agricultural activity, agricultural runoff and nitrogen contamination from fertilizer in the water-sheds surrounding Monterey Bay. Nitrogen contamination from agricultural use is a prominent issue, therefore, I proposed some possible solutions, including cap and trade, a water recycling plant, and eco-certification, to minimize nitrogen's impact on the environment and wildlife while allowing farmers to continue using nitrogen on crops.

*Key words:* El Niño, algal bloom, California sea lion, domoic acid, agricultural runoff, Monterey Bay, marine mammal health, nitrogen, eco-certification, cap and trade, water recycling.

## 1. Introduction

Marine mammals indicate the overall health of ocean environments (National Oceanic and Atmospheric Administration [NOAA], 2012). Marine mammals, particularly California sea lions, elephant seals, and harbor seals, are top-level predators (NOAA, 2012). This top-level predation means that when these animals are ill or end up stranded on the beach, ocean environments are experiencing changes which could also indicate that the ecosystem health is suffering as well (NOAA,

2012). Therefore, monitoring and analyzing their numbers provide valuable insights toward evaluating ocean health.

In the past forty years, there has been an increase in the frequency and number of marine mammal die-offs along the California coast (Guland & Hall, 2007). At the Marine Mammal Center (TMMC), one of the world's largest rescue, rehabilitation, and release centers for marine mammals along 600 miles of the central California coast, increases in strandings is an inexplicable and current issue. Even though their data illustrates the number of sea lions stranded, causes of mass mortality events are difficult to pinpoint due to the lack of sufficient data. The causes could be natural environmental changes, such as El Niño events, but the changes could be human-related as well, such as agricultural runoff. El Niño brings drastic weather changes every 2-7 years, such as bringing warm water from Asian Pacific waters and raising the temperature along the coast of California (NOAA, 2014). There is reason to believe that human influence is having an increasingly significant impact on the increase of ill marine mammals. As the farming industry uses massive quantities of fertilizer, which includes high amounts of nitrogen, agricultural runoff and submarine groundwater discharge, groundwater entering a body of water through the ground, contain large amounts of that nitrogen. This concentration of nitrogen is an issue because of its growth enhancing abilities on plants (Tajul et al. 2013). The overflow of nitrogen means that plants on land and in the ocean, particularly algae, have the capacity to grow explosively and potentially cause algal blooms, which have been known to harm marine mammals (National Ocean Service).

In Monterey Bay, an algal bloom hotspot, the layer of warm water from El Niño could keep the natural flushing process and upwelling process, nutrients coming from deep cold waters, from occurring, leaving the nitrogen-filled agricultural runoff in the Bay area. Algal blooms in Monterey Bay are known to be harmful and negatively affect California sea lions (*Zalophus californianus)* by creating a neurotoxin which leads to Domoic Acid Toxicity (Goldstein et al. 2007). Because the neurotoxin bioaccumulates up the food chain, sea lions affected by Domoic Acid Toxicity become lethargic and disorientated and have seizures that can result in death (Lelong et al. 2012). Therefore, my hypothesis is that El Niño conditions combined with agricultural runoff are causing harmful algal blooms in Monterey Bay, which by affecting California sea lion strandings, could account for the increase in marine mammal strandings overall.

Because agricultural runoff has been linked to causing algal blooms (National Ocean Service), I then propose possible solutions to minimize agricultural runoff's impact in case it is a factor towards causing the harmful algal blooms in Monterey Bay. The political conflict over the amount of nitrogen used by farmers has been a heated issue since groundwater has been severely contaminated; especially since 2004, when the first agricultural waiver was passed by the Central Coast Water Quality Control Board to monitor water quality in the region. With the second one passed in 2012, known as the "ag waiver," dissatisfaction between environmentalists and farmers still runs high as environmentalists want stricter regulation while farmers believe the waiver demands too much. My proposal is to implement a cap and trade program as an initial, short-term reduction in nitrogen use to then follow with a recycled water treatment center and an eco-certification and marketing campaign to

create demand for produce grown sustainably without nitrogen.

## 2. Methods

In order to test my hypothesis that the combined effect of El Niño and agricultural runoff are causing algal blooms in Monterey Bay, I first analyzed data from the Marine Mammal Center in Sausalito, California. I traveled to the center and copied their data, with their permission, from their electronic database onto my USB drive to allow for portable analysis. I copied data on all of the elephant seals, California sea lions, and harbor seals, which includes data such as admit date, location picked up, length of stay, gender, and age. They gather this data from a network of volunteers who pick up the animals from the beach and from a full-time staff of veterinarians who classify biological information about the animal. Each patient has a physical chart with this information, and the data is also entered into their electronic database.

I created one comparing the number of animals stranded as an overall trend and by species over time. Then, I calculated the ratio of seal lions that stranded in Monterey Bay in comparison to the total number of sea lions picked up during certain time periods from each year, 1990-2012 as well as 1982, 1983, 1987 and 1988. These time periods included the fall, September to November, and the spring, April to July. I graphed these ratios in two graphs, where one compares years of El Niño to years when El Niño did not occur, and the other compares actual numbers of sea lions picked up from Monterey Bay. Both used data during each season, spring and fall, and for the same time period, 1990-2012, 1982, 1983, 1987, and 1988. Multiple t-Tests were done to determine if overall numbers of all three species and sea lion numbers

during El Niño were significant and if sea lion ratios and stranding numbers during each season were significant as well.

Subsequently, I researched online for published scientific articles about El Niños, agricultural runoff, and algal blooms for their history, causes, effects in Monterey Bay and their relationship with each other. I also searched for articles that stated harmful algal blooms directly affected California sea lions to ensure that algal blooms could have a large enough effect to account for the increase in marine mammal strandings. I used the Honnold-Mudd online article database and Google searches to find current scholarly articles on Domoic Acid Toxicity, California sea lion health, and evidence of algal blooms in Monterey Bay. This research included noting physical features of Monterey Bay.

Regarding nitrogen, I already knew agricultural fertilizer was a source for algal blooms in other parts of the world, so I searched for high agricultural activity near and around Monterey Bay. Unfortunately, I could not collect my own data from the Bay's waters to find amounts of nitrogen, so I used scientific findings of nitrate contamination in groundwater in the area surrounding Monterey Bay as a proxy for a presence of nitrogen in the Bay's waters. I found other scientific reports that found agricultural runoff and submarine groundwater discharge into Monterey Bay contained high amounts of nitrate contamination. My online research led me to government-published and university-published reports on nitrate contamination in the Monterey Bay-Salinas Valley area.

In order to determine possible solutions for nitrogen contamination, I analyzed legislation and researched the current political conflict between farmers and

environmentalists. I found current legislation toward marine mammal protection, clean water standards and coastal management in California online, and I found online articles reporting on the tensions and issues surrounding the agricultural contamination issue. I then consulted with Professor Marc Los Huertos at Pomona College about the agriculture politics in the region. Once he approved my ideas for possible solutions in the area, I researched information and successful campaign with eco-certification, and I reviewed previous notes I took about marketing campaigns. Regarding nitrogen, I researched its reactions with water and soil and found how nitrogen could be cleaned from water by accessing information available on the Center for Disease Control's website.

## 3. Background on El Niño and Harmful Algal Blooms

El Niño is a weather-changing event that occurs every 2-7 years and brings warm waters from the Asian Pacific to the coasts of South America and the U.S. (NOAA, 2014). This movement of warm water increases surface temperatures and precipitation and displaces nutrient-rich cold water deeper into the ocean due to the layer of warm water on top (Latif & Keenlyside, 2008). The loss in nutrients from the upwelling movement does affect fish populations from loss of food (Barber & Chavez, 1983); however, nutrients, like nitrogen, coming in from agricultural runoff, could create harmful algal blooms which would mean toxic algae is available in abundance as compared to other plant sources (Barber & Chavez, 1983). This would be significant, because then the sea lions' prey, which eats the toxic algae, contains the neurotoxin that sickens them with Domoic Acid Toxicity.

While El Niño is a global climate event, a harmful algal bloom is an environmental event that affects only its local surroundings (National Ocean Service). *Pseudo- nitzschia australis* is the main species of algae that produces the toxin Domoic Acid along the California coast (Lelong et al. 2012). Even though this species and effects of harmful algal blooms are known, exactly how the causing factors interact to create a harmful algal bloom are not understood (National Ocean Services), and the timing and expected extent of damage are hard to predict (Bargu et al. 2010). Because my hypothesis states that El Niño's warm waters and increased precipitation with agricultural runoff is causing algal blooms and thus, causing more sea lion strandings, the results from my data may help to answer the uncertainty behind algal blooms as well.

## 4. Monterey Bay: Algal Bloom Hot Spot

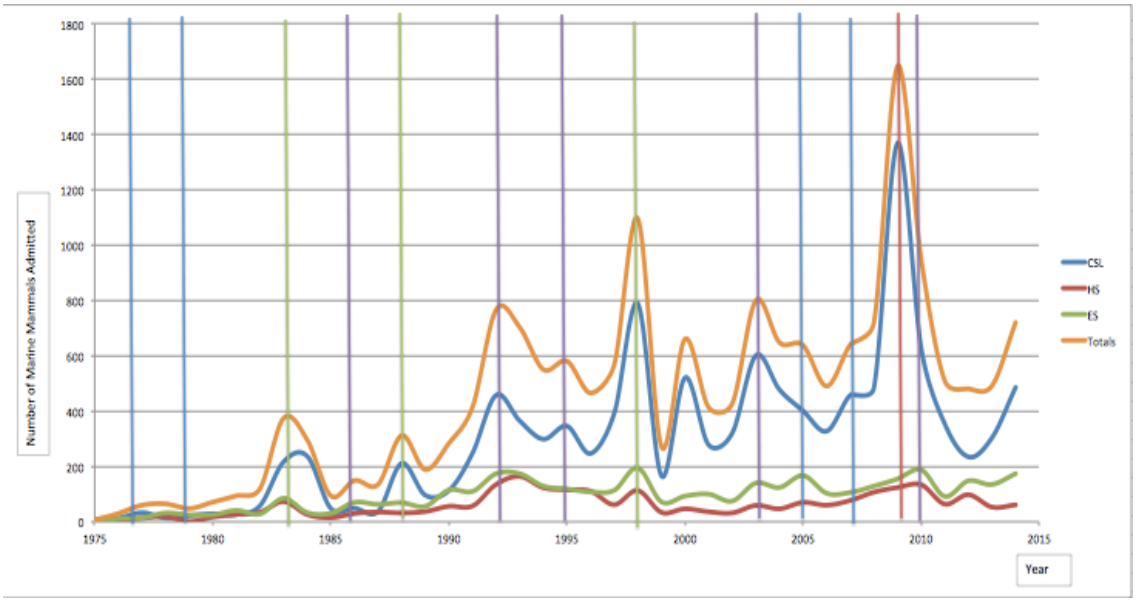
Monterey Bay accounts for 128 miles out of the 600 miles that The Marine Mammal Center monitors and receives its cold-water nutrients from two upwelling systems north and south of the Bay (Gaines & Airame, 2012). El Nino's interference with pushing this nutrient-rich water below the warm water could be a factor in causing algal blooms. In 2005, the Monterey Bay Institute found that highly concentrated thin layers of phytoplankton form when upwelling winds relax as a result from the flow of warm, nutrient-poor offshore waters into the bay (Red Tides, 2005). The rise in temperature could also promote the expansion in algae since warm temperatures are beneficial organism growth in general. Because El Niño also brings precipitation, coastal flooding and erosion are common occurrences which could also

mean that an increase in agricultural runoff, meaning more plant-enhancing nitrogen, into the Bay could account for algal blooms as well.

## 5. Results and Discussion

Data from TMMC illustrates spikes in patient admits during each El Niño event: 1976-77, 1977-78, 1982-1983, 1987-88, 1991-92, 1994-95, 1997-98, 2002-03, 2004-05, 2006-07, and 2009-2010 (Figure 1). The first t-Test, calculating the significance of El Niño of all three marine mammal species, was significant with a P-value of 0.029671. This result means that El Niño does significantly impact the three species overall. However, the t-Test done to determine if El Niño impacts sea lions alone, the P-value came to be 0.170669, an insignificant result.

**Figure 1.** Overall numbers of admitted California sea lions (CSL), harbor seals (HS), elephant seals (ES), and total numbers of all three marine mammal species (Totals)*




*Blue vertical lines represent weak El Niños, purple represents moderate El Niños, and green represents strong El Niños. The red line is when the new facility was built in 2009.

Figure 2 compares the ratio of California sea lions that stranded in Monterey and Santa Cruz counties, around Monterey Bay, during the fall season, months September to November, and during the spring season, April to July. It reveals that a considerable number of sea lions come from Monterey Bay quite consistently. Even though the Monterey Coast Guard Jetty is an area where many sea lions congregate, other coastal spots, such as PIER 39 in San Francisco, do not have the significant numbers of sea lions stranding as Monterey Bay does.

Figure 3 compares numbers of sea lion strandings in Monterey Bay during the same two time periods. These months were chosen as the two time periods to compare numbers of strandings, because in 2007, a study done by Goldstein et al. found that in 1998, the first recognized Domoic Acid event, sea lions were found with Domoic Acid Toxicity during those specific months (Figure 4).

**Figure 2.** The ratio of sea lions stranded in Monterey Bay over the total number of sea lions along the California coast in the spring, April to July, and in the fall, September to November from 1982 to 2012.

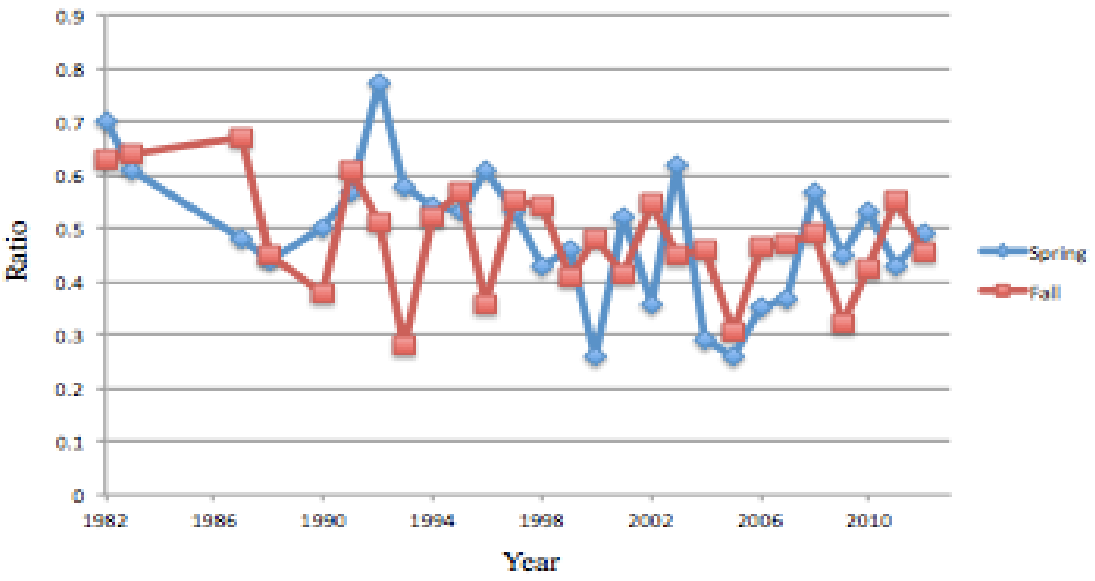



**Figure 3.** Total stranding numbers of sea lions from Monterey Bay in the spring, April to July, and in the fall, September to November from 1982 to 2012.

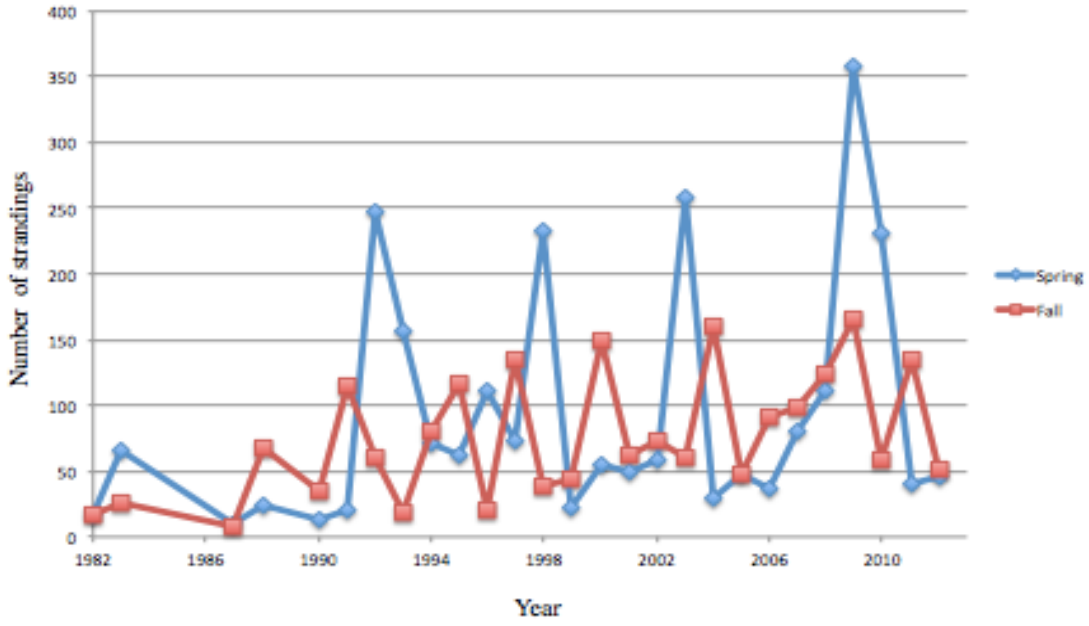
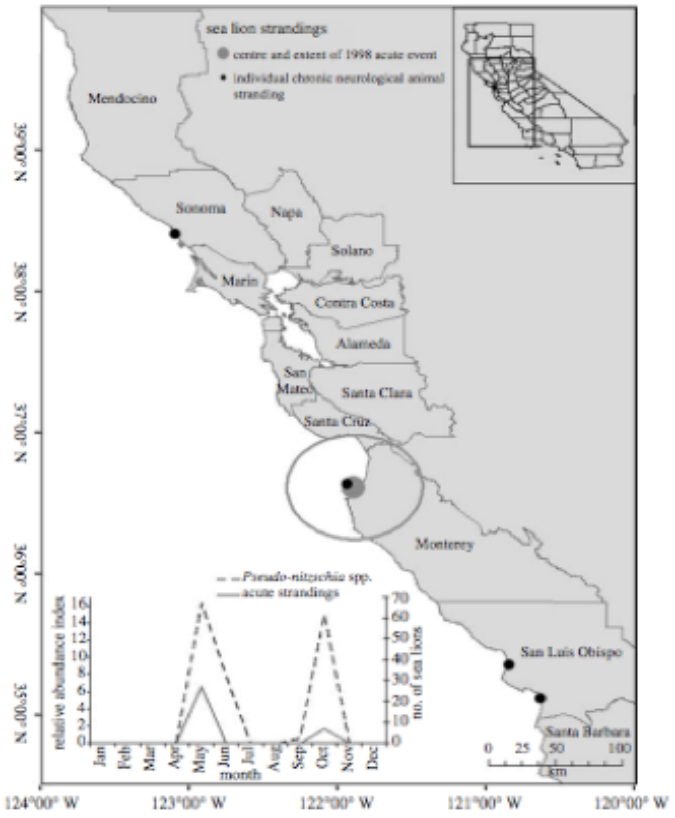


**Figure 4.** Pseudo-nitzschia spp. sampled from Santa Cruz Pier in 1998. The circled area represents area of acute domoic acid stranding event and location of chronic neurological animal stranding within 1 year after the acute event. Inset graphs show monthly comparisons of estimates of Pseudo-nitzschia spp. abundance and number of sea lions stranding with acute toxicity. Source: Goldstein et al. 2007




I first calculated the P-values for the ratio and the admit numbers during the spring and fall during El Niño's main year, since the warm waters do not always arrive before Christmas time (NOAA, 2014) (Tables 1A and 1B). I also calculated different P-values for each classification of El Niños to determine if there was a pattern between the impact among the sea lions and an increase in strength of El Niño. During the spring, the P-values for the ratios did not show a trend, but for the moderate and strong El Niños, there was a significant impact on Monterey Bay (Table 1A). For the admit numbers, the first two numbers are significant which does indicate that El Niño does impact sea lions in general (Table 1A). The last row, "strong," is most likely not

significant, because two of the strong El Niños occurred before the Marine Mammal Center had construction to increase their carrying capacity. Therefore, the patient numbers during that time were much smaller which could distort the results. These significant values suggest that El Niño does affect Monterey Bay in the spring, especially the number of sea lions.

The ratio during the fall season did not have significant P-values, but the numbers decreased closer to a significant value, which could imply that there is a weak correlation between El Niño and its effect on Monterey Bay during the fall season (Table 1B). The admit numbers reflect the same situation of not containing significant values, but the decrease in value indicates a small correlation as well that El Niños affect sea lions during the fall.

Tables 2A and 2B were calculated using the same method but included values before El Niño arrived. Because El Niño sometimes arrives in December, I wanted to determine if there could be an effect on the environment on the spring and fall seasons before El Niño arrived. During the spring season, there were no significant values for either the ratios or the admit numbers (Table 2A). On the other hand, Table 2B demonstrates a strong correlation with the ratios. The numbers increase in significance as the strength of El Niño increases which indicates that the first fall season, sometimes before and sometimes as the very beginning, has a strong impact on the sea lions in Monterey Bay. This result means that El Niño is a factor in sea lion strandings in the fall season.

**Table 1A.** P-values calculated using values during the spring season of El Niño's official year.

| El Niño Strength | Ratio | Admit Numbers |
|---|---|---|

| | | |
|---|---|---|
| All | 0.4723755 | 0.035905 |
| Moderate and Strong | 0.051989 | 0.0270635 |
| Strong | 0.4646145 | 0.4646405 |

**Table 1B.** P-values calculated using values during the fall season of El Niño's official year.

| El Niño Strength | Ratio | Admit Numbers |
|---|---|---|
| All | 0.40224 | 0.2359585 |
| Moderate and Strong | 0.1962885 | 0.2244065 |
| Strong | 0.1418915 | 0.1508895 |

**Table 2A.** P-values calculated using values for two spring seasons: before El Niño arrived and during El Niño's official fall season.

| El Niño Strength | Ratio | Admit Numbers |
|---|---|---|
| All | 0.4960505 | 0.1518815 |
| Moderate and Strong | 0.1505925 | 0.092579 |
| Strong | 0.2391695 | 0.468728 |

**Table 2B.** P-values calculated using values for two fall seasons: just before El Niño arrived and during El Niño's official fall season.

| El Niño Strength | Ratio | Admit Numbers |
|---|---|---|
| All | 0.033015 | 0.342649 |
| Moderate and Strong | 0.005995 | 0.4606465 |
| Strong | 0.001497 | 0.20004 |

Consequently, the results indicated that the fall in the beginning of El Niño affects Monterey Bay and the spring during El Niño affects the number of sea lions, with weak correlations indicating an effect on Monterey Bay and the number of sea lions during the second season of fall. However, this data does not represent the number of Domoic Acid patients received (this data could not be obtained); therefore, the numbers could be different than the ones here which include every sea lion admitted by TMMC.

Even though my hypothesis, the combined effect of El Niño and agricultural runoff account for the increase of marine mammal strandings and die-offs through sea

lion strandings, is partially supported by the data by the fact that El Niño is a factor in sea lion strandings in the fall at the beginning of El Niño and in the spring during El Niño, agricultural runoff could be having a greater impact on marine mammal health by influencing harmful algal blooms in Monterey Bay.

## 6. The Effect of Nitrogen and its Increased Use in California

Nitrogen is the main ingredient in fertilizer that promotes plant growth and increases crop yield in the agriculture industry, because it is a limiting nutrient (Tajul et al. 2012). Nitrogen in general is bought specifically for agricultural purposes.

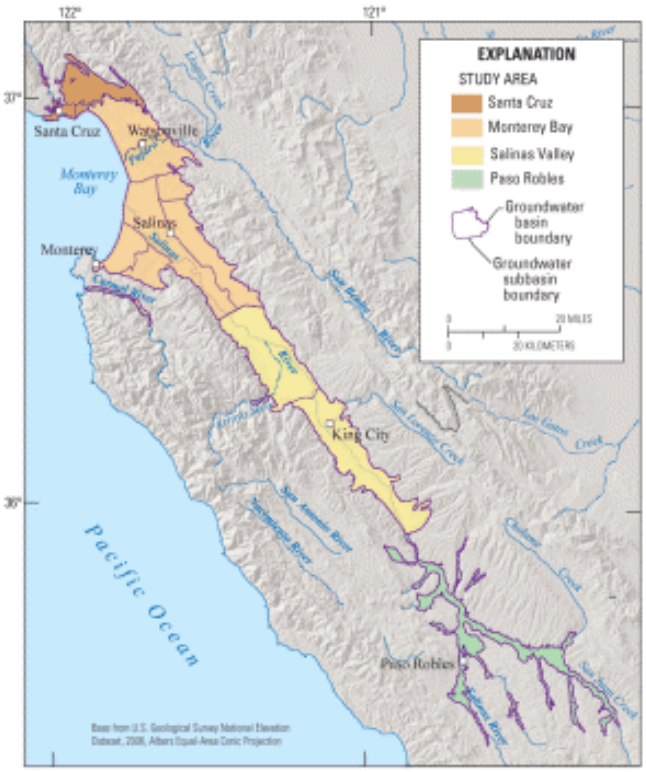
Because nitrogen promotes plant growth on land, nitrogen is expected to enhance plant growth in the water. In 2005, researchers at Stanford found that agricultural runoff does lead to phytoplankton blooms in the ocean (Beman et al 2005). Furthermore, their study was conducted in the Gulf of California where 80% of cases stimulated blooms within days of fertilization and irrigation of agricultural fields. Their finds strongly support that nitrogen-rich agricultural run-off leads to algal blooms.

Both fertilizer use and the amount of nitrogen bought for farms have increased within the last seventy years from about 20,000 tons sold in 1943 to over 600,000 tons statewide in 2010 (Rosenstock et al. 2013). Due to its long-term use, there could have been a steady build-up that would be currently affecting the ocean environment (Los Huertos et al. 2001).

## 7. Nitrogen Pollution in Monterey Bay through Agricultural Runoff and Submarine Groundwater Discharge

Monterey Bay receives drainwater from three main watersheds, the Salinas Valley, Pajaro River, and Elkhorn Slough, all of which comprise an agricultural region that produces 11% or $2.5 billion worth of total produce in the state (Los Huertos et al. 2001) (Figure 5). An aquifer assessment in 2011, done by the U.S. Geological Survey (USGS) in cooperation with the California State Water Resources Board (CSWRD), found that of the factors affecting groundwater quality, nitrate is the component most frequently existing at high concentrations in the primary aquifer system used for public supply (Kulongoski and Belitz, 2011). The area assessed is highlighted in Figure 5. The other component of the report identified natural and human factors that affect the groundwater quality and found that most wells that contained nitrate were classified as being below agricultural-use areas. Therefore, this finding means that nitrogen from agricultural use is having a direct impact on contamination of groundwater aquifers. In the Pajaro River Valley, high nitrate concentrations were also found in three agricultural drainage ditches, and in increasing amounts further downstream, in the northern section of the Monterey Bay area shown in Figure 5 (Los Huertos et al. 2001). Because the Pajaro River is one of three main watersheds that drain into Monterey Bay, there is a high possibility that this high amount of nitrogen is flowing into directly into it (Los Huertos et al. 2001).

**Figure 5.** USGS and CSWRD Study Area. Source: Kulongoski and Belitz, 2011




The Salinas River is the largest of the three rivers that drains into Monterey Bay and is the main waterway that winds through the Salinas agricultural region, meaning it carries the agricultural drain water into the Bay (Anderson et al. 2003). Furthermore, California's Pinto Lake near Watsonville has the nation's most toxic algae, and in 2010, sea otters in Monterey Bay were poisoned by the algae found in the lake (Resource Media and National Wildlife Federation, 2013). Therefore, because agricultural drain water feeds into Monterey Bay, nitrate contamination from agricultural fertilizer through agricultural runoff is a highly probable factor toward explaining why Monterey Bay frequently has algal bloom. Because the groundwater in Monterey County has also had increased amounts of nitrogen contamination (Rubin, 2013), submarine groundwater is most likely adding nitrogen into the Bay waters, as well.

Coastal environments, in general, receive nitrogen from submarine groundwater discharge (SGD) from unconfined aquifers and is being increasingly recognized as an important source of nutrients (Santoro et al. 2006). In 2011, Lecher et al. studied if SGD and nitrogen additions contribute to Monterey Bay's algal hotspot status and found that SGD around the bay is enriched in nitrogen compared to bay

waters. This finding suggests that the nitrogen found in SDG is an important aspect in maintaining incubator-like conditions for algal blooms to thrive. In the Pajaro River watershed, Nitrate-N concentrations exceeded U.S. drinking water standards (Los Huertos et al. 2001), which could impact groundwater quality and therefore groundwater discharge into Monterey Bay.

## 8. Political Conflict on the Use of Nitrogen

The solution to halting further contamination of nitrogen is not as easy as proposing a policy recommendation of stopping or significantly reducing the amount of nitrogen. An agricultural waiver to mandate water-quality monitoring and farmer education only took effect in 2004 (Rubin, 2014). As water conditions have worsened since then, environmentalists have wanted tougher regulations while farmers state that more regulation fails to take into account many of the difficulties they struggle with, such as crop failure (Rubin, 2014). The most recent agricultural waiver, passed in 2012, took three years for the Central Coast Regional Water Quality Control Board to vote unananimously and to pass the waiver into law (Rubin, 2014). Still, though, environmentalists state the waiver is too lenient and farmers state it is impossible to comply with the standards (Rubin, 2014). Farmers recognize the issue of contaminated water from their use of nitrogen but accept the issue as being too large for them to address and resolve (Rubin, 2014). As far as holding farmers accountable for the amount of nitrogen applied, many studies have tried to track nitrogen back to specific farms, but those studies failed since nitrogen is too soluble and spreads throughout the soil (Los Huertos). Although this most recent agricultural waiver does introduce a reduction of nitrogen use, by only allowing the amount that a plant can absorb to be

applied, other solutions need to be explored where farmers do not feel threatened and the environment can stop being polluted by excessive nitrgoen use. Before presenting alternative solutions, reviewing legislation regarding marine mammal protection, coastal management, and water in general is important to establish which material can be used to invoke protection of the environment and identify gaps in legislation.

## 9. Legislation Relating to This Issue

The California Coastal Act (CCA) 2014 demonstrates the prominence of human activities over environmental protection. Only one section directs attention to biological preservation of the environment including water quality: Section 20231. It consists of a list of ways to protect biological productivity, human health, and water quality but provides no details or methodology for how to ensure or monitor the environment (CCA 2014). Controlling runoff and "minimizing waste water discharges" are included in the list, but without further regulation, the terms can be interpreted very openly. Furthermore, with only one section devoted to the biological aspect of coastal management, the conflict between human use and environmental protection is shown to already emphasize human interests. The sections regarding agricultural activities do not address their possible pollution in the environment, but instead, address the conflict between conserving agricultural land against urban sprawl (CCA 2014). Three sections' titles are "Prime agricultural land; maintenance in agricultural production," "Agricultural land; determination of viability of uses; economic feasibility evaluation," and "Lands suitable for agricultural use; conversion" (CCA 2014). Therefore, the state's interests align with agricultural needs, and requesting for assistance from this angle would not prove worthwhile.

While agriculture is highly valued, the coastal act also acknowledges the presence of algal blooms. They are addressed in a different section, which also highlights the lack of acknowledgement of a possible connection between agricultural use and algal blooms by the State. Though, the act states the responsibility to "identify additional research, development, and demonstration to monitoring, prevention, control, and mitigation" which seems promising in that a case can be made for state funding to sponsor a study in Monterey Bay.

While the CCA would not be of assistance when asking for action by the state, the The Marine Mammal Protection Act (MMPA) could be in violation calling for action by the federal government. The MMPA came into effect October 21, 1972, and two of the main policies include protection for "marine mammal species or stocks that may be in danger of extinction or depletion as a result of human activities" and that these species cannot fall below their "optimum sustainable population level" (Marine Mammal Protection Act, 2014). The director of veterinary science at the Marine Mammal Center, Dr. Shawn Johnson, stated that algal blooms are getting more frequent and larger every year, the animals are not responding to treatment like in the past, and most importantly, if there are a few hundred or even a thousand sea lions affected by domoic acid, there's a few thousand pups most likely dying as well (Quirin, 2014). If these issues repeatedly happen, Domoic Acid Toxicity could negativly impact the sea lion population as a whole in the near future. With adults dying and leaving their pups to fend for themselves, who usually stay with their mothers for a year, it is unlikely that these populations will stay at an "optimum sustainable population level." Furthermore, if sufficient evidence can prove that human activities are putting the California sea lion species in danger of falling below

that sustainable population level, then two of the MMPA's policies can be pointed out to call for federal assistance.

The Clean Water Act (CWA) is also vital to consider as it regulates both direct and indirect discharges into waters (CWA, 2014). In the section regarding agriculture, the act places responsibility on states to "assist and encourage producers to use best management practices to reduce or prevent instances of nonpoint source pollutants" that drain into waters (CWA, 2014). The act further states that Total Daily Maximum Loads should be established along with identification of needed load reductions within a watershed from agricultural producers (CWA, 2014). The only issue is that nitogen is extremely soluble, therefore the difficulty lies in holding farmers accountable for the amount of nitrogen placed on their crops (Los Huertos). However, due to this difficulty and clear issue of nitrogen contamination established in the sections 7 and 8, I argue that the state should put more resources toward finding those best management practices in the agriculture sector in accordance with this act.

Because Monterey Bay is an algal hot spot along the California coast, further investigation between nitrogen levels and toxic algal blooms need to be conducted. If a causative relationship is found, a strong case can be given for federal help, particularly NOAA, to address the nitrogen contamination. Even though this does not help a case against drinking water, attacking the issue from multiple angles ensures a better chance of action and change in the region, as a whole.

## 10. Recommended Solutions for This Political Issue

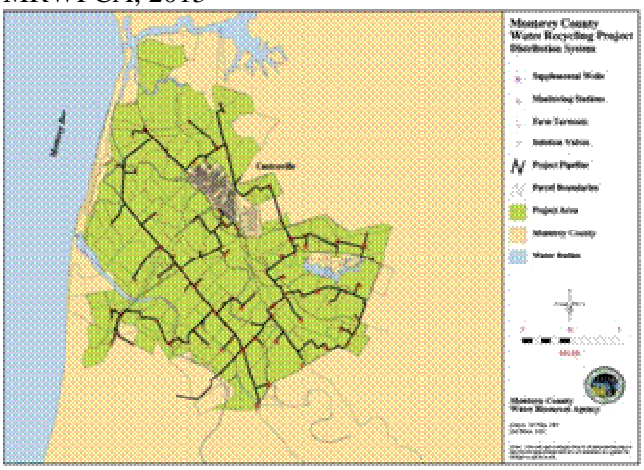
Even though nitrogen is inexpensive to buy, imposing a nitrogen tax is not something farmers would agree upon. They claim that their revenues only just cover their costs, and because they are private businesses, the truth to their statement is impossible to know (Los Huertos). A cap and trade system would be imposed for a short period of time as it would limit total amount of nitrogen being used. Not all crops can uptake the same amount of nitrogen (Los Huertos); therefore, farmers can sell and trade permits to buy nitrogen according to the produce that they grow. Although, due to the large amount of nitrogen contamination that already exists, more drastic action needs to be taken.

The first action would be to create a water recycling plant. Because nitrogen is extremely soluble, a water containment system could be built below and around farm fields to then transport it to the treatment center. Because farmers have vertical pipes built into the ground(Los Huertos), the containment pipes would be built underneath them to catch the nitrogen-contaminated water. At the treatment center, three processes, approved by the Center for Disease Control for nitrogen clean-up, can be performed: ion exchange, distillation, and reverse osmosis. The water can then be returned to the farmers and released into the ocean as clean water. This clears two problems: farmers from using too much groundwater and contaminated water from reaching the ocean. Furthermore, because a water recycling center has already been built in Monterey County and proven successful, farmers are more likely to agree and the city is more likely to fund the project.

This water treatment center was established in 1992, when the Monterey Regional Water Pollution Control Agency and the Monterey County Water Resources

Agency created the Monterey County Reclamation Projects to recycle water for irrigation in Northern Salinas Valley (Monterey Regional Water Pollution Control Agency [MRWPCA], 2013). Currently, this is the largest sewage treatment center in the world (MRWPCA, 2013). The latest report on this recycled water was in 1998 which showed that there were no viable microbes of public health concern (MRWPCA, 2013). However, this recycled water is only distributed in Northern Monterey County across 12,000 acres through the Castroville Seawater Intrusion Project (MRWPCA, 2013). While this project is a great step toward decontaminating irrigated water, which could lower nitrate pollution in SGD, the project covers only a small portion of farmland in comparison to all the coastal farms surrounding Monterey Bay (Figure 6).

**Figure 6.** Lines showing distribution of recycled water through pipelines. Source: MRWPCA, 2013




**Castroville Seawater Intrusion Project (CSIP) distribution system located on 12,000 acres of farmland in Northern Salinas Valley.**

The second major action would be to sell an eco-certification that sells crops at a higher price from not growing them with nitrogen. These crops would be monitored to ensure that they would not mix with those that were grown with high amounts of nitrogen. This would allow for farmers to have a choice between selling two types of the same crops or continuing to

use nitrogen for all of them. The price would be higher on the consumer end for the farmer to make up the money lost.

The state of California has already adopted a protocol of creating a sustainable seafood certificate and marketing promotion program for California fisheries, as required by Assembly Bill 1217 (California Sustainable Seafood Initiative, 2014). It is meant to encourage California fisheries to seek certification to practice sustainable practices and to encourage California consumers to purchase certified sustainable California seafood (California Sustainable Seafood Initiative, 2014). The implementation has not yet begun; therefore, relating its success to the success of this certification for farmers cannot be estimated. However, it does demonstrate the state's willingness to help wildlife and the environment through farmers and consumers.

On the consumer side, there is empirical literature that demonstrates a consumer inclination to change purchasing behavior in favor of eco-labels (Loureiro, 2003) (Blamey et al. 2000). The Rainforest Alliance and Fair Trade USA are examples of successful campaigns linking agriculture, farming, and wildlife through eco-certification. A sales analysis on Rainforest Alliance's certification on Pennsylvania timber, which has been in place since 1998, demonstrates that buyers earned Pennsylvania a total of $7.7 million more than if it had sold its timber to noncertified buyers (Rainforest Alliance, 2014). Relating this certification to environmental concerns, a study done in 2011 found that the Rainforest Alliance certification in forestry helped to protect nearby UNESCO World Heritage Sites (Rainforest Alliance, 2014). If farmers in the agricultural region surrounding Monterey Bay were to develop sustainable farming practices, using less nitrogen to

gain the certificate, similar conditions could result with an improvement in watershed quality and consequently, less events of marine mammal strandings and die-offs.

A result relating more specifically to agriculture is shown through the Fair Trade USA organization. In 2013, the biggest year for Fair Trade Certified produce, Fair Trade produce volumes sold in the US grew 37% over 2012, and the farmers and workers earned $4.2 million to invest in their communities' needs (Fair Trade USA, 2014).

Consequently, these examples and successes from certification programs, aided by the literature of increased purchasing behavior toward eco-labels, demonstrates a strong chance of success for farmers and the environment if their own eco-certificate were to be created. In order to initate demand and awareness for the certification, a marketing campaign would be implemented, especially to gain demand at shopping stores and farmers markets. A symbol would be designed on the packaging notifying the consumer that the extra price is for a good cause, and as California has a huge following for sustainability and environmental protection, as determined by my own experiences living in California and as shown by being the first state to pass a ban on plastic bags and its pioneering role in creating Assembly Bill 32, there is a strong possibility that people would respond strongly and positively. This campaign would create a conversation toward paying a higher price in order for people to have clean drinking water and to harm less marine life, particularly the marine mammals. This marketing campaign would be across social media and through online and print newspapers.

## 11. Conclusion

This thesis explores the reasons why the frequency of marine mammal strandings and die-offs are increasing. Because they are top predators, they indicate changes in the ocean environments which tells us that we are missing information about the events happening in, and near, the ocean. Research behind these changes needs to be continued to not only protect the marine life, but to also protect human health.

Although the data presented does support my hypothesis that El Niño impacts Monterey Bay and that other scientific studies prove a strong presence of nitrogen around Monterey Bay, the primary causes for the algal blooms are still not concretely known.

Looking further into this issue will help to protect the future of these animals before their die-off events become too extreme to handle. The data collected in the research lead me to hypothesize that with more research, marine mammal strandings may be recognized as a strong indicator of the status of oceanic health.

## 12. Acknowledgements

I would like to thank my readers, Professors Thomas Kim and Branwen Williams, for their immense assistance throughout the semester. I also want to thank Professor Marc Los Huertos for his help on the nitrogen and agricultural conflict and

Lauren Rust and David Krucik from the Marine Mammal Center for sharing their knoweldge and permitting me to use their data.

## Bibliography

Anderson, Brian S., John W. Hunt, Bryn M. Phillips, Patricia A. Nicely, Kristine D. Gilbert, Victor de Vlaming, Valerie Connor, Nancy Richard, and Ronald S. Tjeerdema. "Ecotoxicologic Impacts of Agricultural Drain Water in the Salinas River, California, USA." *Environmental Toxicology and Chemistry / SETAC* 22, no. 10 (October 2003): 2375–84.

Bargu S., Silver M., Goldstein T., Roberts K., and F Gulland. (2010). Complexity of domoic acid-related sea lion strandings in Monterey Bay, California: foraging

patterns, climate events, and toxic blooms. Marine Ecology-Progress Series 418, 213-222.

Beman, Michael J., Arrigo, Kevin R., and Pamela A. Matson. Agricultural Runoff Fuels Large Phytoplankton Blooms in Vulnerable Areas of the Ocean. *Nature* 434, no. 7030 (March 10, 2005): 211–14. doi:10.1038/nature03370.

Blamey, R.K., Bennett, J.W., Louviere, J.J., Morrison, M.D,. and J. Rolfe. (2000). A test of policy labels in environmental choice modeling studies. *Ecological Economics*, 32(2), 269-286.

*California Coastal Act (CCA).* United States of America. California Coastal Commission. Sacramento: 2014. Web. 4 Nov. 2014.

*California Sustainable Seafood Initiative*. State of California, 2014. Web. 2 Dec. 2014.

*Clean Water Act (CWA)*. United States of America. Environmental Protection Agency. 2014. Web. 12 Nov. 2014.

*Fairtrade USA 2013 Annual Report*. Fairtrade USA, 2014. Web. 22 Nov. 2014. <http://fairtradeusa.org/sites/default/files/2013-FairTradeUSA-Annual_Report.pdf>.

Gaines, Steve and Satie Airame. "Upwelling." National Oceanic and Atmospheric Administration. 27 December 2012. Web. 15 Sept. 2014

Goldstein, T, J.A.K Mazet, T.S Zabka, G Langlois, K.M Colegrove, M Silver, S Bargu, et al. "Novel Symptomatology and Changing Epidemiology of Domoic Acid Toxicosis in California Sea Lions (Zalophus Californianus): An Increasing Risk to Marine Mammal Health." *Proceedings of the Royal Society B: Biological Sciences* 275, no. 1632 (February 7, 2008): 267–76. doi:10.1098/rspb.2007.1221.

Gulland, Frances M.D., and Ailsa J. Hall. (2007). Is marine mammal health deteriorating? Trends in the global reporting of marine mammal disease. *EcoHealth* 4(2). 135-150.

Kulongoski, J.T., and Belitz, Kenneth, 2011, Status and understanding of groundwater quality in the Monterey Bay and Salinas Valley Basins, 2005—California GAMA Priority Basin Project: U.S. Geological Survey Scientific Investigations Report 2011–5058, 84 p.

Latif, M., and N. S. Keenlyside. "El Niño/Southern Oscillation Response to Global Warming." *Proceedings of the National Academy of Sciences* 106, no. 49 (December 8, 2009): 20578–83. doi:10.1073/pnas.0710860105.

Lecher, A., K. A. Null, K. R. Mackey, N. T. Dimova, A. Paytan, C. M. Schmidt, P. W. Swarzenski, and J. P. Ryan. "Evaluation of Submarine Groundwater Discharge as a

Source of Nutrients, Carbon , and Metals to the Monterey Bay Extreme Bloom Incubator." *AGU Fall Meeting Abstracts* 31 (December 1, 2011): 1254.

Lelong, Aurélie, Hélène Hégaret, Philippe Soudant, and Stephen S Bates. "Pseudo-Nitzschia (Bacillariophyceae) Species, Domoic Acid and Amnesic Shellfish Poisoning: Revisiting Previous Paradigms." *Phycologia* 51, no. 2 (March 1, 2012): 168–216. doi:10.2216/11-37.1.

Los Huertos, Marc. Personal Interview. 21 November 2014.

Los Huertos, M., Gentry, L. E., and C. Shennan. (2001) Land use and stream nitrogen concentrations in agricultural water-sheds along the Central Coast of California. *The Scientific World Journal* (1). 615–622.

Loureiro, M.L. (2003). Rethinking new wines: Implications of local and environmentally friendly labels. *Food Policy*, 28(5-6), 547-560.

*Marine Mammal Protection Act (MMPA)*. United States of America. National Oceanic and Atmospheric Administration, 2014. Web. 4 Nov. 2014.

"Measuring Our Impact." Rainforest Alliance, 2014. Web. 4 Dec. 2014.

Quirin, Courtney. "On Calif. Coast, Biotoxins Cause Deadly Sea Lion Seizures, Seafood Scare." *Al Jazeera America*. 26 August 2014. Web. 16 Sept. 2014.

"Recycled Water." *About MRWPCA : Water Recycling*. Monterey Regional Water Pollution Control Agency, 2013. Web. 12 Nov. 2014.

*Red Tides*. The Monterey Bay Aquarium Research Institute, 2005. Web. 2 Oct. 2014.

Resource Media and National Wildlife Federation, Sept. 2013. *Toxic Algae: Coming Soon to a Lake near You?* Web. 2 Oct. 2014.

Rosenstock, Todd S., Liptzin, Daniel, Six, Johan, Tomich, Thomas P. (2013). Nitrogen fertilizer use in California: Assessing the data, trends and a way forward. *California Agriculture* 67(1), 68-79.

Rubin, Sara. "After Three Years of Indecision, a New Ag Runoff Rule Takes Effect. Both Enviros and Farmers Say It's Not Good Enough." *Monterey County Weekly*. 21 June 2012. Web. 15 Sept. 2014.

Rubin, Sara. "Lawmakers Scramble to Make Drinking Water a Right; Meanwhile, Contamination in Monterey County Is Getting Worse." *Monterey County Weekly*. 13 June 2013. Web. 15 Sept. 2014.

Santoro, Alyson E., Alexandria B. Boehm, and Christopher A. Francis. "Denitrifier Community Composition Along a Nitrate and Salinity Gradient in a Coastal Aquifer." *Applied and Environmental Microbiology* 72.3 (2006): 2102–2109. *PMC*. Web. 12 Dec. 2014.

Tajul M. I., Alam M.M., Hossain S. M. M., Naher K., Rafii M. Y., and M. A. Latif. (2013). Hindawi Publishing Corporation, The Scientific World Journal Volume 2013, Article ID 193018, 9 pages http://dx.doi.org/10.1155/2013/193018.

"What Is an El Niño?" National Oceanic and Atmospheric Administration, 2014. Web. 4 Oct. 2014.

"Why Do Harmful Algal Blooms Occur?" *National Ocean Service*. National Oceanic and Atmospheric Administration, 10 Oct. 2014. Web. 12 Nov. 2014.

"20th Anniversary: Marine Mammal Health and Stranding Response Program (MMHSRP)." National Oceanic and Atmospheric Administration, 2012. Web. 14 Oct. 2014.