Impacts of Bunces Pass Boat Traffic on the Marine Environment

Tiffany Nicholson

University of South Florida St. Petersburg

Table of Contents

Introduction:

Each year nearly 1.4 billion pounds of trash enter the ocean from either a point source or runoff from the land (NOAA 2011). Yet aside from the land pollution that is produced, there is also a large amount of water pollution that takes place each year. This includes the fishing industry, shipping industry, oil spills, and one of the most underrated one is anthropogenic noise pollution. In 2010, NOAA reported that roughly 39% of America's population are living in counties directly on the shoreline with an expected increase of an additional 8% by 2020 (NOAA 2010). With more people moving towards the coastlines, this means a potential increase in the number of boats on the water with an increase in noise polluting the coastal marine habitats.

Source of Noise in Marine Environment:

Sound travels nearly five times faster in water than in the air (Montgomery, John 2011). Sound can be measured by amplitude or intensity; the greater the amplitude, the louder and more intense the sound is. Various properties of the ocean such as density, temperature, and salinity can affect the wavelength in which sound propagates through the water. In the ocean, different types of noises and sounds fill the environment to make it not as silent as one may think. While the oceans are polluted with anthropogenic noise, they are also saturated with natural sounds heard throughout the ocean environment as well.

Natural sources of sound within the ocean are generated by both abiotic and biotic sources. Abiotic sounds such as waves, rainfall, shifting or moving glaciers, wind, plate tectonics, seaquakes, currents, and tides are all various sources of noises

heard in the background. In addition, biotic noises come from various marine organisms such as fish, invertebrates, and marine mammals. These marine organisms produce different sounds in order to communicate, detect prey, avoid predators, mate, or echolocate. Since marine organisms are constantly surrounded by a natural source of noises, it is suspected that many have adapted to the noisy environment.

Although the ocean is naturally not a silent place, due to an increasing amount of the human population and advances in technology, acoustic researchers have found an alarming increase in the noise level in the oceans caused by increases in recreational boating, commercial shipping, and global policing efforts. Noise pollution has increased by an alarming 15dB in just the past fifty years (Firestone & Jarvis, 2007). Not only is anthropogenic noise pollution increasing but they are also becoming more frequent and more common in coastal regions. Since the first propeller driven ship engine was created there has been a rise in the number of boats used in the oceans. More than 80% of global freight transport occurs in the water by shipping (Slabbekoorn & Cate, 2010). The shipping industry has definitely taken a dramatic increase since it helps connect many of the countries through a way of trade and transport. There was an estimated four thousand shipping vessels in 1995, which has now grown to be nearly ten thousand shipping vessels, introducing an increasing amount of noise into the marine environment (Hilderbrand 2009).

The oil exploration industry has also expanded rapidly. Aside from the oil spills that can occur from the oil industry, an immense amount of noise pollution

occurs as drilling is taking place on offshore oilrigs. As the desire for offshore exploration of oil increases, the more noise pollution will increase with high intensity frequencies from drilling into the seafloor (Turl 1982). Other sources of noise pollution come from the military such as their use in sonar or underwater explosives as well as boating in local coastline areas. The military is known to create high intensity frequencies out in deeper ocean due to sonar, which can have long term effects on marine organisms hearing and sensory organs (Turl 1982). The other source of noise pollution being recreational boating takes on lower level frequencies in shallower water. During times of high traffic such as on weekends, the anthropogenic noises are seen to be "continuous instead of episodic," which can have an affect on surrounding marine organisms such as fish or dolphin depending on their level of exposure (Haviland-Howell 2007). While some fish may be able to adapt to a noisy environment and build a tolerance such as those living in the artic where ice is constantly breaking or shifting, others are suffering from negative impacts of the various sounds created.

Effects of Noise Pollution on Marine Life:

Each organism can be affected differently depending on the duration of exposure, age, sex, species, or environmental factors, but each can still be harmed. Sound is able to travel five times faster in the ocean at higher amplitude levels, this allows for long distance communication but also for long distance impacts of harmful and unwanted noises on organisms. Nearly every marine organism has a way of hearing sounds under the water whether it is with their inner ears, lateral lines, or other sensory organs. They use these sounds to help detect and avoid

predators, find prey, communicate, mate, and navigate by having spatial awareness. Many organisms such as trout, perch, and dolphins also have a way of producing their own sounds, which can help in their communication, mating behaviors, or predator and prey interactions. Sound is one of the most important mechanisms a marine organism can have, especially in dark or low sunlight areas of the ocean because you do not have to be in sight to communicate.

A study conducted by Wysocki in 2006 examined ship noise has been shown to induce an increase in the amount of cortisol secretion by various fish species. Cortisol is a hormone that is found within many fish species that is typically secreted when in stress. Since fish only have a certain hearing threshold and range, when sound exceeds their hearing capacity, it can actually cause fish to become stressed. Fish will secrete cortisol into the water, which can then be analyzed and detected with certain compounds. When various fish species were set in an environment filled with various low frequency shipping noises, researches collected a large amount of cortisol in the water from the fish. This also had a relation in the overall duration of exposure to the noises. Since each fish has different hearing thresholds, each fish can only withstand certain noises for so long before it begins causing damage to their sensory organs.

The noises that marine organisms use and hear are important parts in their behaviors and the way they interact with others in the ocean. The added anthropogenic noises from humans cause interferences with the natural biotic and abiotic sounds of the oceans. With loud passing boats overhead, a dolphin loses its ability to communicate or detect their surroundings, which results in a loss of

information due to the loud interference from the boat as shown in a study done by Haviland-Howell in 2007. A study was taken in an intercostal waterway in North Carolina where many dolphins can be found. It was shown that on days of heavy traffic, dolphins would be less prevalent most likely due to the increase frequencies from the boat traffic in the area. They found that since the boat noises were occurring at the same frequencies of the dolphins, that it was most likely interfering with the dolphin's communication and detection of surroundings.

Spotted Sea Trout in Bunces Pass:

Spotted sea trouts, *Cynoscion nebulosus*, are one of many species of fish that use and produce sounds for mating behaviors and communication. In the wild, male spotted sea trouts will produce sounds with the use of a sonic muscle near their swim bladder (Image 1). This sonic muscle will vibrate next to the swim bladder causing a low grunting sound used for and during mating seasons. Spotted Sea trouts are known as "multiple spawners" because they are known to spawn many times throughout an extended season, which typically takes place from mid-March to late-September. The reason for the spawning season to take place during that time is mostly because they prefer a certain temperature and salinity range, which can be met primarily during the warmer parts of the year (Johnson, Darleen and Seaman, William 2009). Since spotted sea trout are broadcast spawners, nearly all their spawning events and aggregations occur at dusk and through the night to help avoid predation in the daylight.

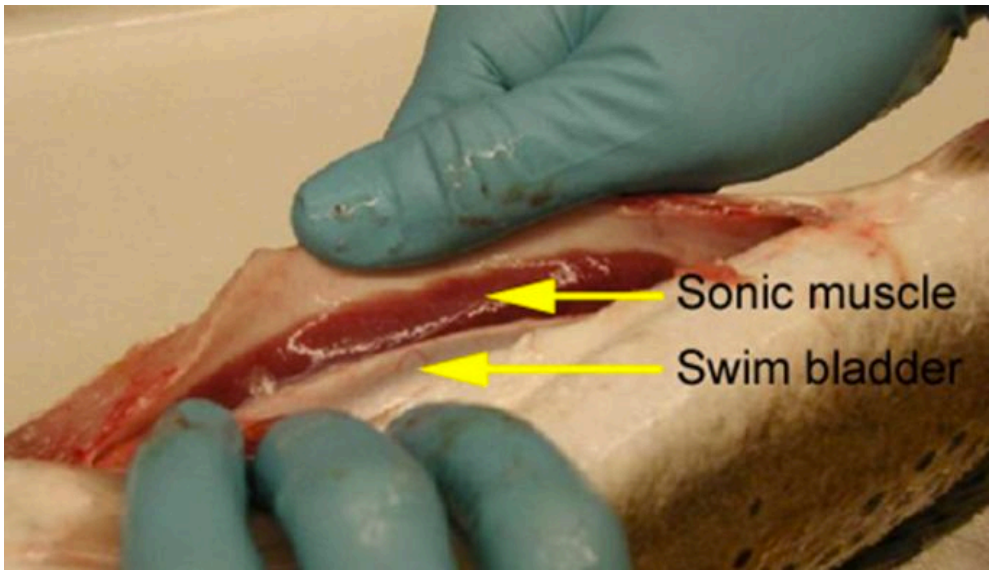

Image 1: Ventral cut of a spotted sea trout to show the sonic muscle and swim bladder, which are used together for sound production in males.

The Florida Wildlife Research Institute in St. Petersburg discovered that one of the major hotspots for the mating of spotted sea trout occurs in the local area of Bunces Pass in Pinellas County because they are known to be estuarine dependent and prefer sea-grass flats as their primary habitat (Johnson, Darleen and Seaman, William 2009). This study was based primarily on the location and abundance of eggs found in the area, since the average batch fecundity found in the local area was much greater than others. With Tampa Bay being the largest and most industrialized estuary in Florida, this makes for a great habitat due to temperature, salinity, and type of seafloor that are preferred by spotted sea trout. When conducting these studies near the area and across Florida, nearly 96% of the female spotted sea trout caught in the Bunces Pass area had hydrated eggs (Florida Fish and Wildlife 2005). This indicates that the females in this area are ready to spawn. After finding this information, more studies were conducted with the use of a

noninvasive method using passive acoustics. This technique uses a hydrophone, which allows for no disruptions or sacrifices of the species and allows for better knowledge of the species to be observed. It was learned through this technique that spotted sea trout in the Bunces Pass area typically aggregate for roughly 3-12 hours during the night along with many other fish species actively surrounding such as sand sea trout, silver perch, and red drum.

Recreational Boat Usage in Florida/Bunces Pass:

Every day thousands of people take their boats out in the waters of Florida. As Florida is a hotspot for recreational boat usage, many counties within the state have a larger boat population than others. Pinellas County ranks as the top county for most registered boats in the state of Florida as of 2006 (NMMA 2015). Roughly 57,000 boats are registered to the county, indicating a large amount of noise pollution in and around the local area (Pinellas County 2005). Since Pinellas County is its own peninsula and contains roughly 588 miles of coastline, it indicates there are more areas for people to live and go out on the water as compared to other Florida counties. With this being the case, more boats are able to be launched from shore or be accessed by the multiple marinas that surround the area. One main boat ramp that is used in the county is the Fort Desoto county park boat launch. Locals know the boat ramp as the "king of boat ramps" since it contains 32 launching lanes and 196 parking spots for vehicles and trailers, indicating the potential for lots of boat traffic. This ramp sits right at the opening of a passageway known as Bunces Pass, which is known to be a major mating ground for spotted sea trout during the late spring and summer months (Image 2). Bunces Pass is also known by man

fisherman as being a hotspot for Snook and Redfish through the year as well as a typical area to spot dolphin. With summer being one of the major times of the year for boaters to be out, understanding the amount of boat traffic that actually takes place in the area will help realize the affects it could be creating on the marine life below.

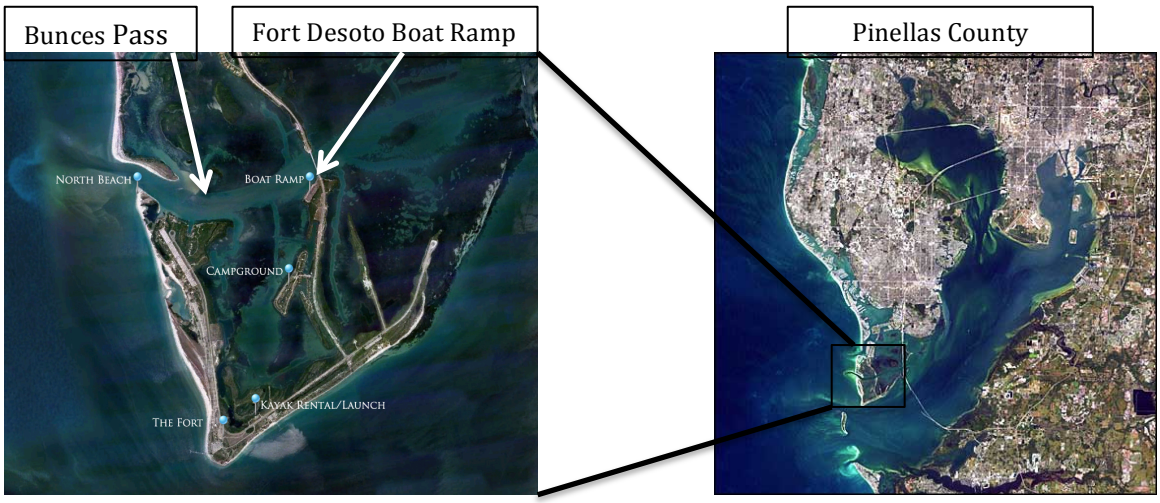

Image 2: A depiction of Pinellas County, Florida and a close up of Fort Desoto Park with the Boat Ramp and Bunces Pass area shown.

With the help of Florida Fish and Wildlife Research Institute (FWRI) in St. Petersburg, the use of underwater hydrophones located in Bunces Pass will be able to assist in gaining the information on how many boats pass through the area and what time of day most occurs in the late spring and summer months. Data from both 2008 and 2013 will give a better understanding of how the amount of boat traffic has changed through the years by seeing a comparison of the amount of the boats in the area. Gaining this understanding of the boat traffic in the area will provide valuable information on the impacts that these boats may be having on the spawning behaviors of spotted sea trout.

Given this information and the methods that will be taken, data on the total amount of boats passing through the area will give an estimation of the boat traffic that takes place in this area over a course of the year and the time of day at which it happens. Data will be taken from the year 2008 and 2013, allowing for a five-year gap to compare if there is a significant difference between data collected in each year. The questions this study seeks to answer are: 1) Will there be a significant difference in the amount of boat traffic between 2008 and 2013? 2) What is the duration of boat noise in the area during the weekends versus the weekdays: versus a month-to-month basis? 3) Will there be a significant overlap in the time of day when boat traffic and large aggregations of spotted sea trout occur?

The expected hypotheses are: 1) data collected from 2008 will have a lower average of boat traffic as compared to 2013; 2) The amount of the boats will be much greater on the weekends than on the weekdays monthly with June and July having the greatest amount of boat traffic; 3) Boat traffic will be greatest during daylight hours while large aggregations of spotted sea trout occurring mostly during dusk and through the night. Having the research and knowledge of the amount of boats that actually go through the area and having more insight on the effects can allow for an understanding of what the potential harm is happening to the fish below in the local Bunces Pass area.

Methods:

Through the technique of passive acoustics with the use of a data logger and hydrophone provided by the members of Dr. Susan Lowerre-Barbieri's reproductive dynamics laboratory at the Florida Fish and Wildlife Research Institute, a total tally

of the amount of boats present and large aggregations of spotted sea trout in the Bunces Pass area were collected and calculated for 2008 and 2013. Hydrophones were placed in March of each year by anchoring them down to the ocean surface, which was at a depth of roughly 7.6 meters in the Bunces Pass inlet (Image 3). A data logger was part of the hydrophone that collected the transmitted data, which would later be used in calculations and data analysis. In 2008 the hydrophone was placed on March 13th and collected back up on September 28th with a total of 200 days of recordings. In 2013 the hydrophone was placed on March 2nd and collected back up on September 28th with a total of 210 days of recordings.

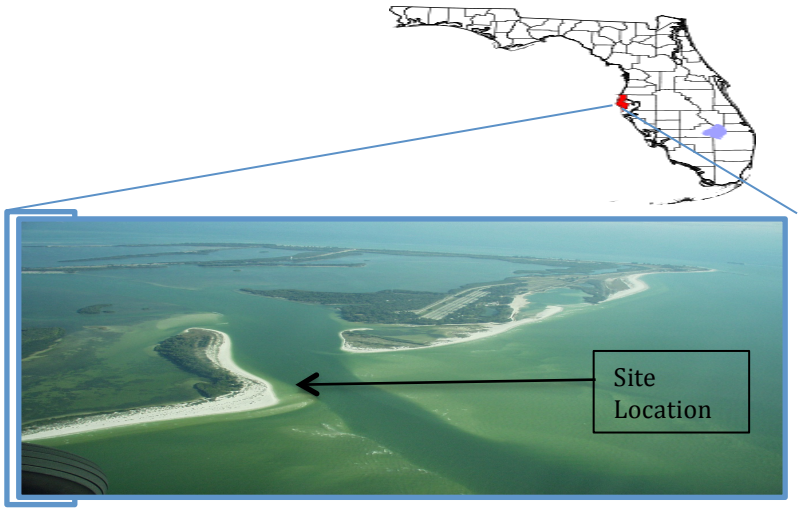

Image 3: Bunces Pass inlet located in Pinellas County, Florida with the site location of the hydrophone and data logger used in the experiment.

Each data logger for each year contained a ten second recording every ten minutes of each 24hr day for the entire time period it was in the water. This was equivalent to a total of 144, 10-second recordings each day. While it does not allow for data collection of the entire 24 hour time period, it allows for an average percentage of boats and large aggregations of spotted sea trout that were present in

the area during those times. Once the data loggers were back in the Florida Fish and Wild life lab, the data was transferred into software known as Cool-Edit allowing the data to be audible and measurable (Cool-Edit 2000).

An Excel spreadsheet was created that had the 144 ten-minute intervals of each day and year recorded as well as a column for whether a boat or large aggregation of spotted sea trout was present in the area during the 10-second period. Once each spreadsheet was finished from each of the two years, data and graphs were created to help gain a better understanding and visual of the amount and time the boats and large aggregations passed through the area during the time frames of the two years researched.

Results:

The percent of recordings in which boats were present increased significantly by year (Fig. 1; t-test: t-ratio = 3.77; p = 0.0002). On average, nearly 17% of the 144 recordings taken each day had boats present in all 200 days of 2008 versus 25% for the 210 days of 2013. In 2008, 4,953 recordings had boats present and in 2013, 6,944 recordings had boats present.

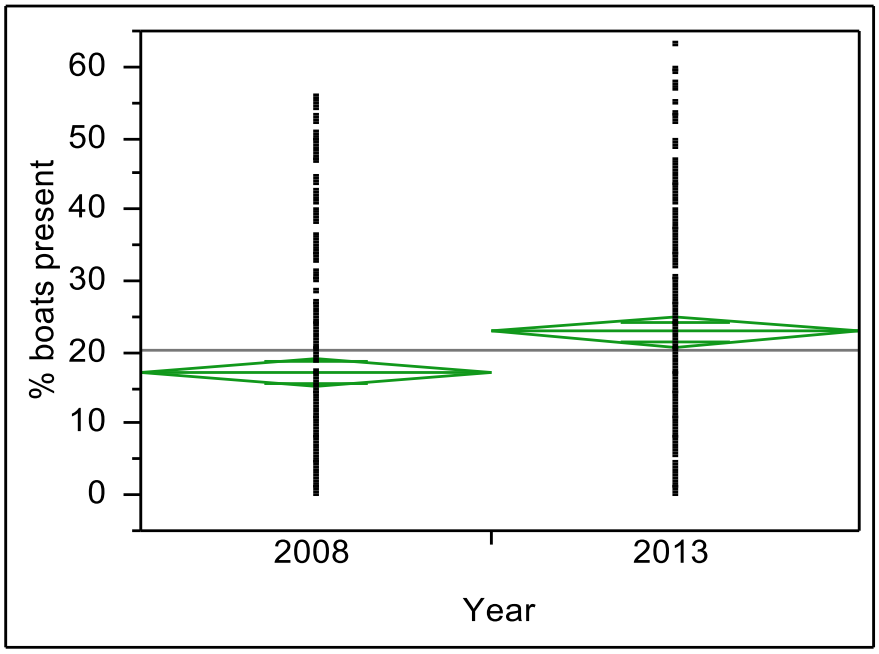

Figure 1: Percent of recordings in which boats were present by year (n = 410)

The percent of recordings in which boats were present increased significantly by month for both 2008 and 2013 combined (Fig. 2a; ANOVA: F = 4.66; p = 0.0001). For the year 2008, the percent of recordings in which boats were present increased significantly by month (Fig. 2b; ANOVA: F = 3.61; p = 0.002). For the year 2013, the percent of recordings in which boats were present increased significantly by month (Fig. 2c; ANOVA: F = 4.30; p = 0.0004).

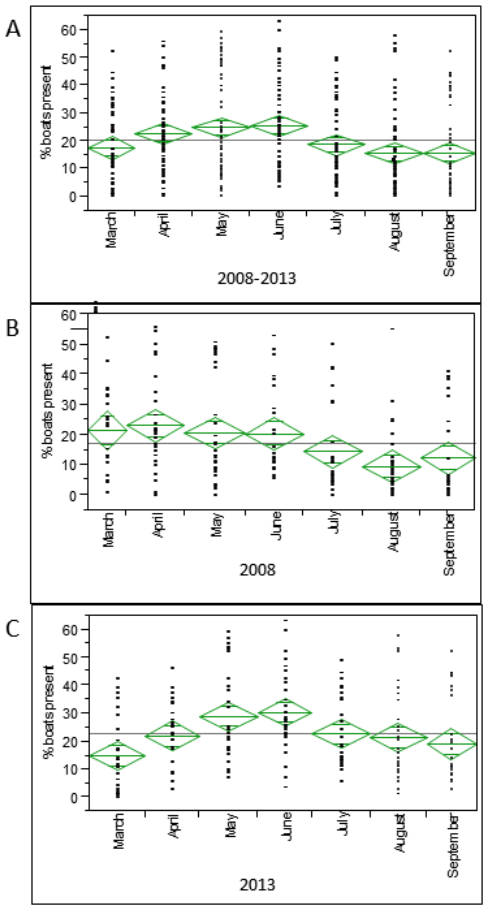

Figure 2: Percent of recordings in which boats were present. (a) by month for 2008 and 2013 (n = 410); (b) by month for 2008 (n = 200); (c) by month for 2013 (n = 210).

The percent of recordings in which boats were present increased significantly by day of the week for both 2008 and 2013 combined (Fig. 3a; ANOVA: F = 46.09; p = 0.0001). Overall the percent of recordings in which boats were present by day was about 5% lower in 2008 compared to 2013, however the pattern of activity was identical, with Saturday and Sunday being the days with most boat activity. For the year 2008, the percent of recordings in which boats were present increased significantly by day of the week (Fig. 3b; ANOVA: F = 27.05; p = 0.0001).

For the year 2013, the percent of recordings in which boats were present increased significantly by day of the week (Fig. 3c; ANOVA: F = 22.63; p = 0.0001).

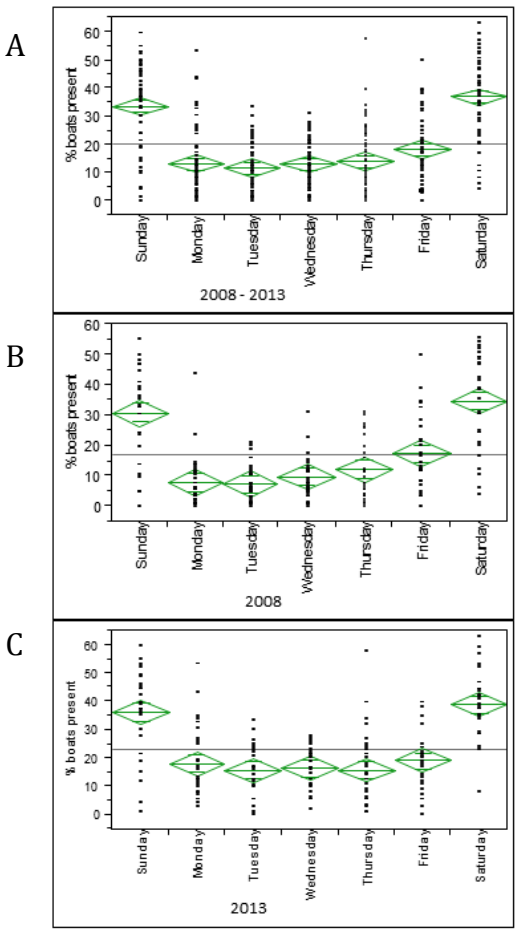

Figure 3: Percent of recordings in which boats were present by day of the week. (a) by day of week for 2008 and 2013 (n = 410); (b) by day of week for 2008 (n = 200); (c) by day of week for 2013 (n = 210).

To summarize, day of the week accounted for the vast majority (79.8%) of the boat activity; month accounted for 13.2% and year accounted for 7.0% (Fit model: F = 31.51; p < 0.0001). Showing that day of the week had the most significant change of boat activity by day than by month or year.

The percent of boats and large aggregations of spotted sea trout in an average day of 2008 showed to have a significant difference in the timing that each occurred most. Of all 200 recorded days in 2008, boat activity occurred mostly in the late morning to mid afternoon while the large aggregations of spotted sea trout occurred mostly late afternoon until early mornings with a slight crossover during sunset times. The average percent of large aggregations of spotted sea trout was significantly more increased than the average percent of boats per day (Figure 4).

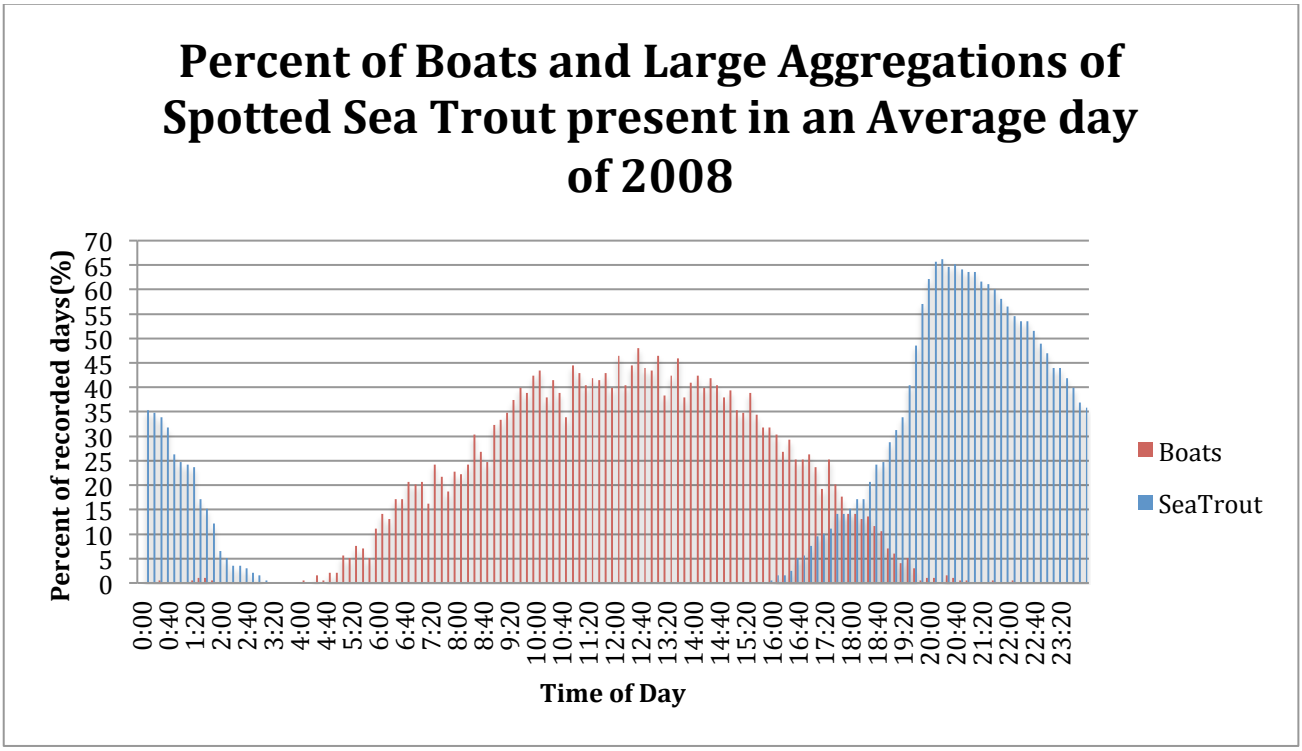

Figure 4: Percent of boats and large aggregations of spotted sea trout present in an average day of 2008 (n = 144).

The percent of boats and large aggregations of spotted sea trout in an average day of 2013 showed to have a significant difference in the timing that each occurred most. Of all 210 recorded days in 2013, boat activity occurred mostly in the late morning to mid afternoon while the large aggregations of spotted sea trout

occurred mostly late afternoon until early mornings with a slight crossover during sunset times. The average percent of large aggregations of spotted sea trout was significantly more decreased than the average percent of boats per day (Figure 5).

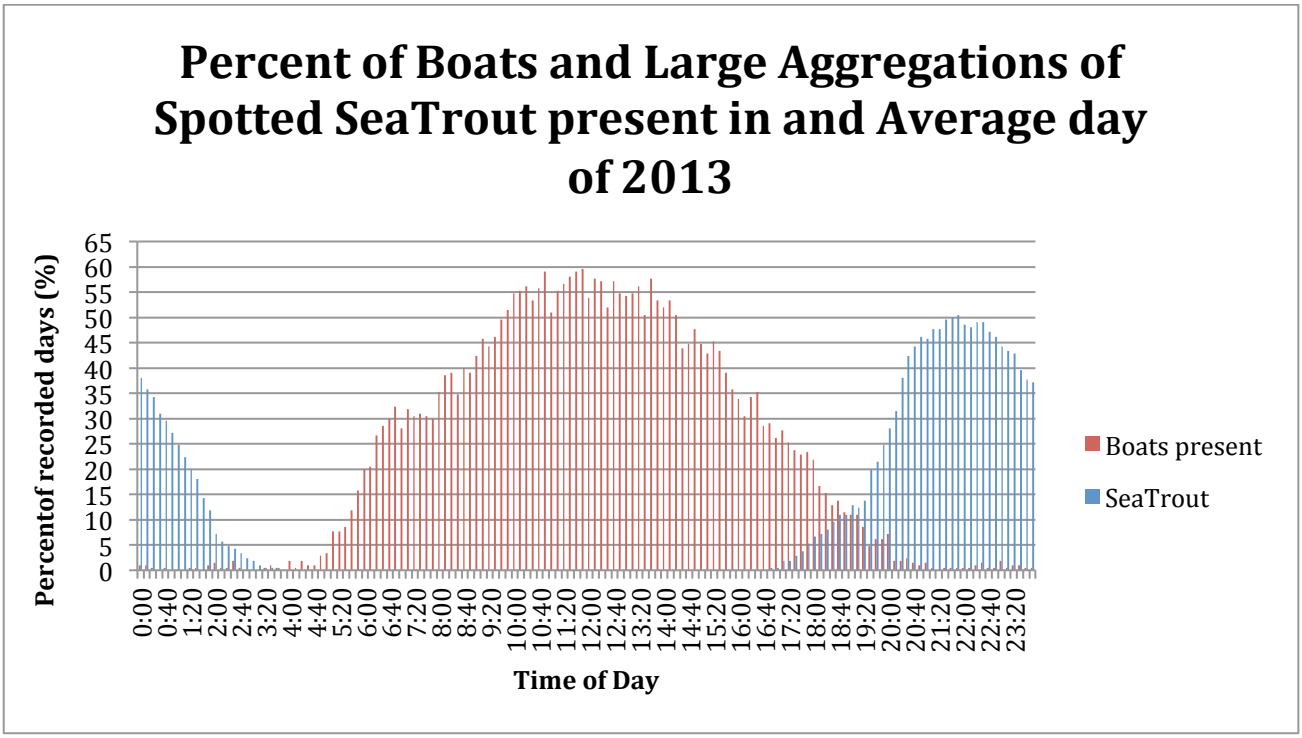

Figure 5: Percent of boats and large aggregations of spotted seatrout present in an average day of 2013 (n = 144).

Data Analysis

When comparing the difference between 2008 and 2013, Figure 1 depicts how boat activity significantly increased over the 5 years. Of all 200 days of data in 2008, roughly 17% of the recordings each day had boats present. In 2013, nearly 25% of the recordings each day had boats present, giving an 8% increase in the amount of boats present each day in 2013 compared to 2008. Overall the total number of recordings that had boats present in 2008 was 4,953 and in 2013 the total was 6,944. This is roughly a 40.2% increase from the year 2008 to 2013 in total

number of recordings with boats present. Over the 5 years, it can be seen that the amount of boat activity has significantly increased in the Bunces Pass area, which could be due to a population increase within the area, causing more boats to be present. Just in Florida alone, the total population of people in 2008 was roughly 18.6 million and in 2013 the population increased to nearly 19.3 million, giving a 3.76% increase of people in just 5 years (United States Census Bureau 2008/2013). In Pinellas County the total population of people in 2008 was nearly 910 thousand people and in 2013 there was a 2.1% increase in the population to reach roughly 929 thousand people (United States Census Bureau 2008/2013). With nearly 588 miles of coastline in the Pinellas County, it is a very popular county for lots of people to come and visit or populate, which could also cause the increase in amount of boat activity in the area.

From a year-to-year comparison, there is a 7% difference in the amount of boat activity occurring, yet in a month-to-month comparison there is a 13.2% difference in boat activity. This shows that there is a greater variance in boat activity by month than just by year alone. In both 2008 and 2013 combined, April, May, and June are the months with the most boat activity, with June being the greatest (Figure 2a). In June roughly 26% of recordings had boats present each day as compared to only 15% average in the month of September. The reason for this could be due to various natural abiotic factors including precipitation, temperature, daylight hours, or wind. Data taken form Albert Whitted Airport in St. Petersburg, Florida (in Pinellas County) shows the various average annual abiotic factors that could be affecting boat activity in some months than others over the year (Diebel, James

1993-2012). Records from 1993 to 2012 show that the average hottest time of the year in the area is in mid-late July, with the warmest time of the year being from early May to late September (Figure 6). This could explain why the most popular time of boat activity for 2008 and 2013 occurred during April-June because it is typically a warm temperature outside in the area. When it comes time for July, the temperature is typically at its max, means that it is going to be very hot days out, possibly not attracting as many people to be out on the boats.

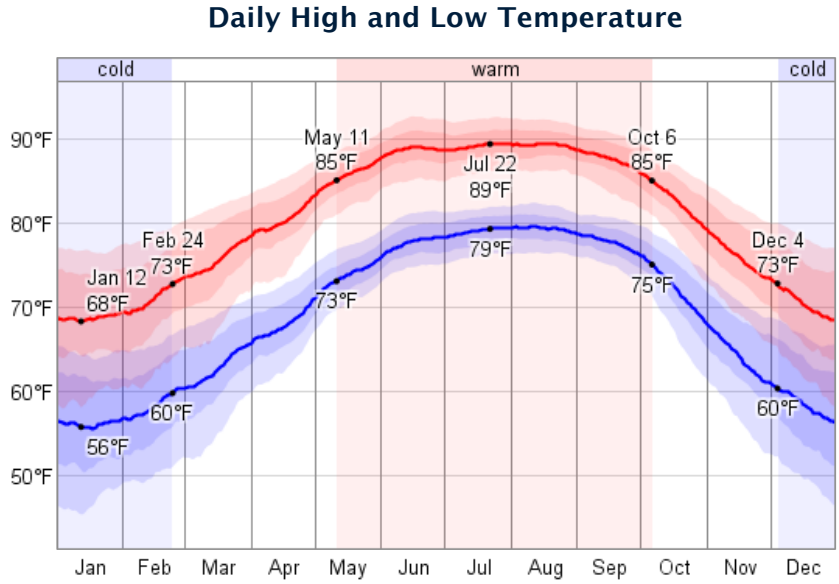

Figure 6: The daily average low (blue) and high (red) temperature with percentile bands (inner band from 25th to 75th percentile, outer band from 10th to 90th percentile).

On average daylight and twilight throughout the course of the year varies. This data shows that June is on average the month with the most daily hours of sunlight, which then continues to decrease until December, which has the least amount of daily hours of daylight (Figure 7). This could help explain why more recordings had boats present in the month of June because not only is the temperature typically warm, it is also the month with the most amount of daylight hours per day. Since most boat activity was found during daylight times (Figure

3&4), this could better explain the reason for more boat activity during the month of June as compared to September.

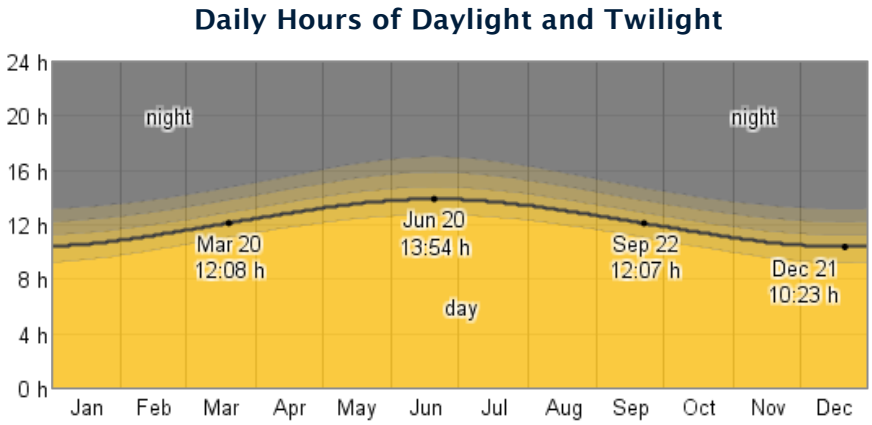

Figure 7: The number of hours during which the Sun is visible (black line), with various degrees of daylight, twilight, and night, indicated by the color bands.

Another important natural abiotic factor to consider that could affect boat activity is the amount of precipitation that occurs each month. In the same records from 1993-2012, the data shows that the most amount of rainfall occurs during the month of July, typically because of thunderstorms (Figure 8). With more precipitation, this means that the dew point also increases during that time, causing the air to seem muggy and harder for perspiration on a persons skin to evaporate and cool the body. From April- June, rainfall on average occurs due to thunderstorms yet because these months are also considered to be warmer months and contain more daily hours of sunlight, this continues to support why most boat activity would occur during these three months of the year that was recorded in 2008 and 2013. In each of the graphs of Figure 3, there is a significant decrease in the amount of recordings with boats present from the month of June to the month of July, which it most likely due to the average temperature increase, daily hours of

sunlight, and increase in amount of precipitation due to thunderstorms just between the two months.

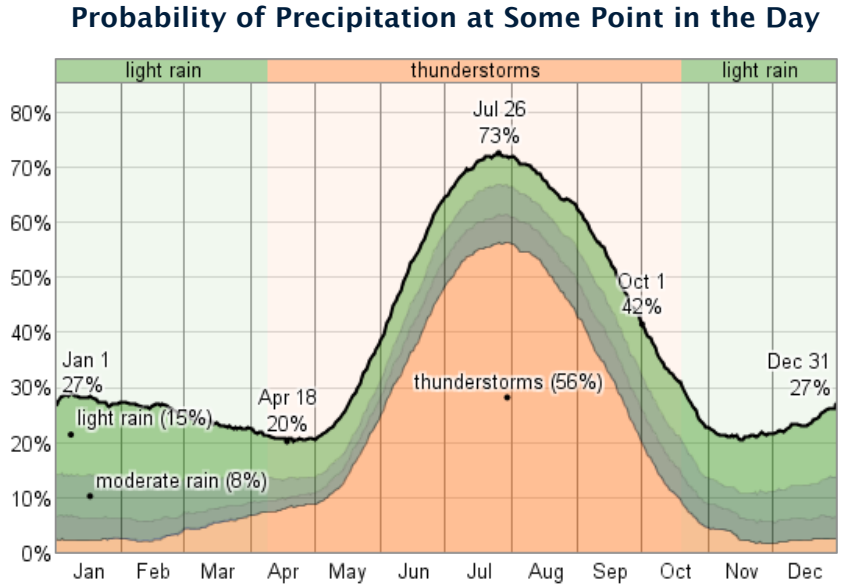

Figure8: The fraction of days in which various types of precipitation are observed. If more than one type of precipitation is reported in a given day, the more severe precipitation is counted.

In 2008, March, April, May, and June were the months with the most boat activity and August being the least active. This could have been due to Tropical Storm Fay that hit the state of Florida in mid August 2008. Tropical Storm Fay hit southern Florida on August 18th and made its track north through the state of Florida until is later dissipated near Georgia on August 23rd. During this time period, there was a four-day gap when no recordings had boats present at the time from August 19th – August 22nd. This could have been due to the increase wind and precipitation brought from the tropical storm.

While the tropical Storm Fay caused the month of August to be the least active in boat noise, in the year 2013 only one main tropical storm hit near the Pinellas County in June. For 2013, June was recorded as having the highest

percentage of recordings with boats present, regardless of Tropical Storm Andrea hitting close by the area. On average the month of June in 2013 had boats present in about 33% of the recordings each day. While the lowest percentage of boats present in recordings (~10%) occurred during the time of the Tropical Storm Andrea, June 5th -June 8th, all other days had such high percentages that it still caused the month of June to be the most active month.

After comparing a month-to-month analysis, data was further broken down into a day of the week comparison to see if specific days of the week had a greater affect on boat activity rather than just by months. The day of the week comparison showed a 79.8% significant difference as compared to only a 13.2% significant difference from a month-to- month comparison (Figure 3). This indicates that specific days of the week have a more significant impact on the presence of boats than based on months or even years. For the both years combined, the most amount of boat activity occurred during the weekend. On both Saturday and Sunday, the average percentage of recordings with boats present was roughly 35% as compared to an average of only 15% for all other days of the week in both 2008 and 2013. This is most likely due to the fact that people typically work or go to school during the week days of Monday-Friday with a weekend break of both Saturday and Sunday. Due to this typical schedule, people are more likely to be out on the water or populating a beach on a Saturday or Sunday rather than a weekday. When listening to the data during the weekends, there was a clear difference in not only boat presence/duration but also boat noise. Typically on the weekends, boats would be present in nearly all recordings during the daylight times, with very little gaps of no

boats heard meaning fish were exposed to loud noises for a longer duration of time as compared to on weekdays. Boat noise was also significantly increased during these days as compared to a weekday, most likely due to just a general increase in the amount of boats present in that area during those times. Visually looking at the data on the Cool-Edit software one could easily depict what type of day it was just based on the layout of the noise frequencies because it was significantly more colorful and more spikes, meaning more noise. Image 4 below depicts a typical weekend day, with many peaks throughout the middle of the day, which indicate that boats are present due to high intense frequencies of noise coming from the engines. The bright yellow and orange colors that can be seen at either end of the recording indicate large aggregations of fish sounds since they are at a lower frequency. On a typical weekday, there would be a significantly less amount of loud peaks through the middle of the day and the duration of them would also significantly decrease.

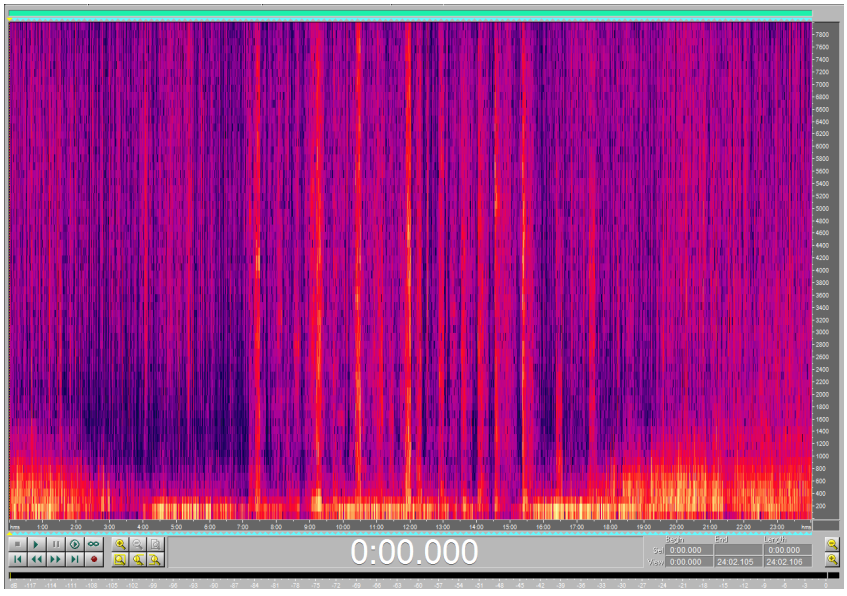

Image 4: A full day of recordings for a weekend day in the Cool-Edit software.

When comparing 2008 and 2013 separately by month, it can be seen that the most active months in each year were slightly different yet when doing a day of the week comparison separately by year, Saturday and Sunday are still the most active days of the week regardless the year. So even with a 5-year difference, the day of the week comparison does not change or affect the percentage of recordings with boats present.

In Figure 4, it can be seen that the range of time for boats in 2008 to be present is roughly 0500 to 1910 (~14hrs) with the greatest percentage of boats heard at 1240 (47.98%). This graph depicts how the majority of boats heard during the recordings were found during daylight hours most likely because it is best for boaters to have the greatest amount of visibility while operating a boat. Even when one is outside during the day, it can visually be seen that the majority of boats are typically operating during the day rather than the night. Typically the main reasons a boater would even be operating a boat at night or early morning is for fishing reasons or research. When comparing the time and greatest percentage of boats present during the day with large aggregations of spotted sea trout, it can be seen that not only are the time frames different but the percentage of spotted sea trout is much grater than that of boats. In 2008 the total range that a spotted sea trout was heard occurred from 1610 – 0300 (~12hrs) with the greatest percentage of sea trout heard at 2010 (65.66%). While the total range of spotted sea trout is slightly lower than that of the boats, the greatest percentage of spotted sea trout is significantly higher than that of boats by nearly 19%. Regardless of the time, this

indicates that more large aggregations of spotted sea trout were heard overall compared to boats.

Figure 4 also depicts a crossover between boats and large aggregations of spotted sea trout from 1610 – 1940, nearly 3.5hrs, with the greatest amount of interaction time being at 1750 (15.15%). During this time it can be expected that boat traffic could have been affecting the mating sounds produced by male sea trouts. Since the total percentage of sea trout increased significantly after this spike in interaction, it can be predicted that with less boat traffic, more male sea trouts were able to aggregate and be heard. While it is believed that spotted sea trout spawn at night to avoid predation, it can also be expected for this particular area that it be because there is also a significantly less amount of boat traffic and noise.

To compare this data 2008 data to 2013 in Figure 5, it can clearly be seen that the average percentage of boat traffic increased significantly more than in 2008, which may have also caused that decline in the average amount of large aggregations of spotted sea trout seen in 2013. The total range in which boats could have been heard in 2013 was from 0440 to 2010 (~16.5hrs) with the greatest percentage of day with boats present being at 1140 (59.12%). The greatest percentage of days with boats present in 2008 was only about 48% and now in 2013 the percentage has increase to roughly 59% for an 11% increase for the days in which boats were heard at those times. For the large aggregations of spotted sea trout, the total range in which they could have been heard was from 1710 to 0300 (~10hrs) with the greatest percentage being at 2150 (50.48%). In 2008 the greatest percentage of days with large aggregations present was 65.66% and with a five-year

gap this percentage decrease by nearly 15%. The greatest interaction period between boats and spotted sea trouts occurred around 1840 (10.95%). In both years, the greatest point of interaction occurred around the time of dusk or sunset, which is typically when boaters will come in due to daylight disappearing and when spotted sea trout prefer to spawn due to limited daylight.

When comparing the two years of data between Figures 4 and 5, it is suspected that with the increased amount of boat traffic that was seen from the five years, it impacted the total percentage of spotted sea trout that was once heard. Even though not every day had the total range of boat traffic or large aggregations present, the average span of boats present during the 24-hour day was more prevalent than that of the spotted sea trout. Another observation made between the two figures is that the overall trend of each boats and spotted sea trout stayed roughly the same, yet the average percentages for each changed from 2008 to 2013. This indicates that, the overall percentage of each facto heard had more of a significant effect than did the timing of the day. With increased amount of boats from 2008 to 2013, it can be seen that the percentage of large aggregations of spotted sea trout decreased which would be a cause from the increase in boat noise. Since male spotted sea trouts only make noise during spawning events, it is important for them to be heard and communicate to others surrounding them in the area, with more boats, this sound could be interrupted for disturbed, causing a loss of information. While spotted sea trouts are broadcast spawners and don't have to rely on direct fertilization of the eggs, it is still important for the communication to

be heard so that it increases the optimal chance for the eggs to become fertilized in that area.

Discussion:

With the U.S. population heading for the coastlines, this indicates an incredible increase in the amount of anthropogenic influences and impacts that humans are causing on the aquatic environment. With an estimation of over 17 million small boat owners in the United States, the impact that the United States alone is creating in the waters and along the coasts are immense (Lydecker 1999). Of those 17 million registered U.S. boats, roughly 950,000 to 1 million boats are registered to Florida according to the National Marine Manufactures Association (NMMA 2015). In another study done by the NMMA, it was shown that 1 out of every 10 households in America owns a boat. When considering the number of households that live along the coastlines of fresh or salt water, this highlights how many people are truly using the ocean just for recreational purposes. While the impacts of recreational uses of boats along the coasts may only be seen as a local issue and impact, it can provide an understanding of how it could be negatively affect fish in other areas as well.

All the added noises that humans have created in the ocean have caused much harm to the marine organisms that rely heavily on their hearing sensory organs whether it is physical harm on organ or disruption to behavior. A study that was done in 2009 by Codarin and other researchers experimented whether a cabin cruiser passing nearby a marine protected area had affects on the hearing and communication of three different species of fish. The results in their study showed

significant affects to the acoustic communication of the fish by interfering and decreasing the range in which they can detect intraspecific sounds (Codarin 2009). Not only does the anthropogenic or "unwanted" noises cause stress on organisms it also affects their growth and reproduction, predator and prey detection, as well as communication. With loud noises around, their communication range is decreased causing information loss, which leads to not being able to detect prey resulting in a lack of food source or foraging and decreased metabolism (Kight, Caitlin R., and John P. Swaddle 2011).

With an estimated 800 marine species from 109 families being able to produce sounds such as crustaceans and cetaceans, noise is an important factor within the marine habitat amongst many diverse marine organisms. Many of the fish that produce the sounds also rely on hearing those sounds for mating and for predator and prey interactions. In a study done by Hans Slabbekoorn in 2010, the Atlantic cod and cichlids are just two of many species that rely on sounds for mating purposes. During mating, these fish are able to sense and detect certain mating cues that will determine whether or not to mate with certain fish. In the case of boat traffic or other anthropogenic noises occurring nearby, this would cause a disruption in the hearing ability for those specific mating cues.

It was shown that when the fish were introduced to outside noises, it caused the fish to not mate as actively without the added noise in the background, mostly likely causing the decrease. It was stated that these added noises are capable of reducing the detection distances by up to 100 times. While each fish is affected differently, many fish only have a short hearing range so when anthropogenic noises

are in the surrounding area, this could cause fish with the short hearing ranges to lose valuable information and communication. With the knowledge that Bunces Pass is a popular breeding ground for spotted sea trout, the amount of boat traffic taking place can disrupt the sounds that are produced by the males during mating. Even though mating takes place at night, where this is less boat traffic, the boats that do pass over are causing a potential for harm and stress of the fish during these important mating times.

In the same study, predator prey interactions were disrupted by the same anthropogenic noises. Many fish rely on being able to detect a fish struggling for their source of prey (Slabbekoorn 2010). Typically when a fish is in distress, it emits pulsed broadband sounds that are detectable by many other fishes in the surrounding area. Another important detection method is used by many benthic species that are able to detect if fish are beneath sediment. Even prey is able to detect certain cues such as infrasound from predators, which can help avoid them. Each of these detection methods are altered or interfered when anthropogenic noises such as passing boats are in the surrounding areas. So when viewing the data that was collected from the results, it can be seen that with the amount of boat traffic that was taking place in the time period, there could have been many cases of lost information or communication between fish and marine organisms. While there may not be any known knowledge of other fish species or marine organisms being negatively affected in the exact Bunces Pass area, knowing that anthropogenic noises such as boats have these types of effects on fish can give that better understanding of what is taking place to the marine life in the area.

Aside from the large aggregations of spawning spotted sea trout observed in this study, there are also many other species of fish present in the Bunces Pass area such as silver perch, red drum, black drum, and the marine mammal, dolphins. Many of these species are also known to aggregate during the day, especially the dolphin in the area. While it may not be directly known, the increased amount of boat traffic throughout the middle of the day could be affecting those other species in the environment.

In recent studies conducted by Haviland-Howell in 2007, boat traffic in the North Carolina Intercostal Waterway was shown to have effects on the communication of bottlenose dolphins. With the use of hydrophones and cameras located in various regions of the waterway, they were able to find the average amount of boats that passed through the area along with when dolphins were sighted or heard underwater. They were able to calculate that the majority of boat traffic took place in the middle of the day or early afternoon with the most boats passing through on the weekends or on holidays, such as in this current experiment for Bunces Pass. The total number of dolphins observed each day was calculated and dolphins in the area during high boat traffic hours showed a much harder time in communicating than when there were less anthropogenic noises in the surrounding area. It also showed that dolphins would be less prevalent in the intercostal waterway during times of increased boat traffic, most likely to avoid the noise produced by the boats. Since Bunces Pass is also known as being a popular place to spot dolphins as well as a popular inlet for boats, knowing the amount of boats that pass through the area gave a better understanding of how this could be affecting the

local dolphin population in the area. Anytime dolphins were heard during the day when analyzing the data, it was typically during times of low boat traffic. This suggests that dolphins would most likely flee the area during times of high boat traffic such as on the weekends or holidays. Knowing the effects it has on dolphins communication can also suggest that this type of noise pollution has the same type of effects on the marine mammals such as dolphins or manatees that inhabit the Bunces Pass area. With this information, similar studies can be conducted on various fish species to see if they have the same type of reactions and negative impacts even though their sensory organs slightly differ from marine mammals.

The silver perch, *Bairdiella chrysoura,* produce sounds with the use of a sonic muscle and swim bladder during courtship, similar to the spotted sea trout. Typically the spawning season takes place during the same time range as the spotted sea trout and could definitely be heard during the recordings taken from each day, roughly occurring at the same times of day. Unlike the low drumming or grunting sounds that spotted sea trout make, the silver perch is known for making a much higher frequency "knocking" sound, which is said to help attract mates. Knowing that silver perch are spawning during the same time as spotted sea trout, it could be expected that they are experiencing the same damages and disturbances by the surrounding boats in the area.

As the population of people in the area only continues to rise, it can only be expected that the amount of boat traffic in the area would also be increasing. With the populations of spotted sea trout having a slight decrease in presence over the five-year gap in this study, the numbers could be continuing to decrease with this

increasing population rate. While the direct physical damages can't be tested or known from this study, it can at least be seen that as the boat traffic increased over the year, the amount of large aggregations of spotted sea trout decreased.

Conclusion

With an average of 361 days of sunshine in Pinellas County (Diebel, James 1993-2012), it is expected that hundreds if not thousands of people are out and around on the water every week. With the Fort Desoto boat ramp being the biggest one in the county, the amount of boat traffic that goes on in the Bunces Pass inlet is certainly making its impact on the marine environment. With the relationship between boats and sea trout changing through the years, it can easily be seen that there is some type of impact taking place in the area. Whether it is happening mostly in the month of June or on the weekends, the level of exposure that fish and other marine organisms are facing in the marine environment could continue to cause a decrease in the species that live in or surround the area. Through this information it would be important to know more about the regulations that are set towards noise pollution in general and setting those regulations towards the Bunces Pas area.

Since the ocean doesn't truly have any boundaries, it is more difficult to regulate noise pollution. Due to the fact that sound can travel faster at higher frequencies under water, it is important to take this action at a more global scale of regulations. Yet in order to do this, people must be educated about the issue that is constantly occurring everyday in the waters around us. With Bunces Pass being such a popular area for boat traffic, it is probable that very few people are aware that it is home to a spawning hotspot for various Florida fish species. Educating the

public on these topics or making them more aware of the issues they could be causing on their behaviors would assist in setting future regulations. Since noise pollution is such a complex problem, it is better to understand the issue that is occurring, set and enforce certain regulations, and then improve on the solutions.

With further research, knowing the actual frequencies of boats could help understand the true level of exposure that fish species such as spotted sea trout endure in the area. Also learning more about the type of frequencies spotted sea trout produce can help determine at what level boat noise is interfering with the mating behaviors. With further continuation of this study, additional years could be reviewed to see if the amount of boat traffic is continuing to increase with the years and if it is still causing an impact or decrease on the large aggregations of spotted sea trout in the area.

This study could also be expanded in multiple ways such as listening and recording for more species of fish in the area as well as dolphins. This would allow for a variety of new data on different species of marine organisms and help gain a better understanding on the impacts that boat traffic is potentially causing on different types of organisms in the same area. Expanding the time span on the study to allow for a full year of research would allow for a better understanding of what boat traffic and spotted sea trout activities are like during the winter months. Adding more hydrophones throughout the Bunces Pass inlet to see if certain areas are worse than others would allow for a much larger range of data rather than one particular spot. Even getting the exact frequencies that boat engines are emitting into the water surrounding the hydrophone provide valuable information on the

true level of exposure marine organisms are experiencing in the area. These type of data will help better understand the type of improvements the area could be implementing to help the issue of noise pollution. This suggests that with further expansion of data recordings, a greater amount of results could be seen along with possible variations in the duration of boat traffic and fish sounds. While this study allowed for a five-year comparison and posed various research questions that showed significant data, continuing to expand on this study could eventually help educate the people who live in the area. With these significant results, along with a better understanding of boat traffic on a small scale, the effects of noise pollution by recreational boats can further be researched in the hopes of improving the issue and creating solutions to help keep a healthy marine environment.

Bibliography

"Basic Facts of Recreational Vessel Population and Recreational Boating Demographics: Making Waves NMMA Policy Brief" *National Marine Manufactures Association. 2015*

Buckstaff, Kara C. "Effects of watercraft noise on the acoustic behavior of bottlenose dolphins, Tursiops truncatus, in Sarasota Bay, Florida." *Marine mammal science* 20.4 (2004): 709-725.

Codarin, Antonio, et al. "Effects of ambient and boat noise on hearing and communication in three fish species living in a marine protected area (Miramare, Italy)." *Marine pollution bulletin* 58.12 (2009): 1880-1887.

Cool Edit. Syntrillium Software Corporation. 1992. Version 2.0

Diebel, James. "Weather Spark: Average Temperature in St. Petersburg." *Cedar Lake Ventures, Inc.* 1993-2012.

Firestone, Jermey and Jarvis, Christina. "Response and Responsibility: Regulating Noise Pollution in the Marine Environment." *Journal of International Wildlife Law and Policy*, 10:109–152, 2007.

Francis, Clinton D., and Jesse R. Barber. "A framework for understanding noise impacts on wildlife: an urgent conservation priority." *Frontiers in Ecology and the Environment* 11.6 (2013): 305-313.

Haviland-Howell, Genevieve, et al. "Recreational boating traffic: a chronic source of anthropogenic noise in the Wilmington, North Carolina Intracoastal Waterway." *The Journal of the Acoustical Society of America* 122.1 (2007): 151-160.

Hildebrand, John A. "Anthropogenic and natural sources of ambient noise in the ocean." *Marine Ecology Progress Series* 395 (2009): 5-20.

Johnson, Darleen and Seaman, William. "Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (South Florida): Spotted Seatrout." *US Fish and Wildlife Service* (2009).

Kight, Caitlin R., and John P. Swaddle. "How and why environmental noise impacts animals: an integrative, mechanistic review." *Ecology letters* 14.10 (2011): 1052-1061.

Lydecker, Ryck, and Margaret Podlich. "A profile of recreational boating in the United States." *Trends and Future Challenges for US National Ocean and Coastal Policy* (1999): 81.

Simmonds, M. P., Dolman, S. J., Jasny, M., Parsons, E. C. M., Weilgart, L., Wright, A. J., & Leaper, R. (2014). Marine noise pollution--increasing recognition but need f or more practical action. Journal of Ocean Technology, 9(1), 71-90.

Slabbekoorn, Hans, et al. "A noisy spring: the impact of globally rising underwater sound levels on fish." *Trends in Ecology & Evolution* 25.7 (2010): 419-427.

Weilgart, L.S. "The impacts of anthropogenic ocean noise on cetaceans and implications for management." *Department of Biology, Dalhousie University, Halifax*, 2007.

Wysocki, Lidia Eva, John P. Dittami, and Friedrich Ladich. "Ship noise and cortisol secretion in European freshwater fishes." *Biological conservation*128.4 (2006): 501-508.