Fall 12-15-2014

A Survey of Shark Population in Winyah Bay, SC: A Comparison of Data from 2002-2006 and from 2012-2014

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2014

BY

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Marine Science

Submitted in Partial Fulfillment of the
Requirements for the Degree of Bachelor of Science
In the Honors Program at
Coastal Carolina University

December 2014

Acknowledgements

First, I would like to thank Dr. Dan Abel for helping me through this thesis, and for being so patient with me. I would also like to thank Sam Gary, Christian Pankow, and Bryan Keller for providing me with the data and for taking me out longlining in Winyah Bay. In addition, I want to thank all of the students and volunteers who have helped with the longline trips from 2002 to 2014. The Coastal Carolina University shark program would not be possible if people did not want to go out and be involved in the research.

Abstract

As a result of a long-term longline study conducted by Coastal Carolina University, data on the population structure of sharks in Winyah Bay, SC have been recorded since 2002. The data are collected from late spring to fall each year. Two separate data sets, from 2002 to 2006 and from 2012 to 2014, were analyzed for catch per unit effort (CPUE), catch composition, sex ratios, and average precaudal lengths (PCL) for males and females. The average CPUE for the 2002-2006 data set was 2.68 with a standard deviation of 0.73 while the average for the most recent data set was 3.20 with a standard deviation of 2.45. The sandbar shark *Carcharhinus plumbeus* was found to be the most common species in both sets, and the Atlantic sharpnose shark *Rhizoprionodon terraenovae* was the only other species to be in the top four most frequently caught species for both 2002 to 2006 and 2012 to 2014. In these species, sex ratios and average PCLs were similar between the two sets of data. Gear selectivity and bait play a role in affecting all of these factors. While these can be standardized, understanding the environmental factors that affect the population structure is more difficult. However, doing both of these is important to successfully managing the elasmobranch populations both in the Atlantic and around the globe. The definite extent of their global decline is unknown, but there will be consequences in the ecosystem if their populations are allowed to continue to plummet. Surveys, like the ones conducted by Coastal Carolina University, can help assess the health of elasmobranch populations which will ultimately lead to better conservation.

Introduction

Sharks in coastal South Carolina waters occupy high trophic levels from mesopredators to apex predators. However, these predators are experiencing a decline not only in the Carolinas, but also throughout the Atlantic and around the globe (Baum *et al.* 2003, Baum and Myers 2004, Burgess *et al.* 2005). The most extreme models show that some coastal and oceanic species have declined by more than 75% in the past 15 years (Baum *et al.* 2003). The variability of the decline of many species was confirmed by an Ecological Risk Assessment (ERA) of pelagic sharks conducted by Cortes *et al.* (2010). The ERA measures how vulnerable a specific stock is to overfishing. It looks at the biological productivity of a species and its susceptibility to being exploited in a fishery. Biological productivity is defined as the intrinsic rate of population increase and was determined through age-structured models and life tables. Several conditions affect the susceptibility of a species. The availability, or the probability that the stock and fishing fleet will interact, the encounterability, or the likeliness that a stock will be encountered with one unit of fishing effort, the selectivity, or the probability that a shark is actually caught on the fishing gear, and the post-capture mortality, or the probability that the shark will die after capture, are these four conditions (Cortes *et al.* 2010). Different species exhibited different levels of productivity and susceptibility as determined by the ERA. However, all of the sharks were found to be at risk and in decline (Cortes *et al.* 2010).

It has been predicted that losing apex predators, like large sharks, will have a negative impact on the ecosystem. As the number of large sharks has decreased, the number of smaller sharks and rays is increasing (Myers *et al.* 2007). Removing predatory sharks increases predation from lower trophic levels which changes the structure of the ecosystem (Myers *et al.* 2007). This decline and its potential consequences have brought more awareness to the conservation of elasmobranchs. The observed decline has also led to increased longline surveys by programs such as the Apex Predators Program that is run by the National Oceanic and Atmospheric Administration (NOAA). They are meant to assess the health of local shark populations.

Surveys have been conducted all along the Southeast coast of the United States, but few have been conducted in Winyah Bay, SC. In 2002, Coastal Carolina University started its own longline study on the shark population in Winyah Bay and its surrounding waters. Abel *et al.* (2007) produced result for the first two years of the long-term study, and found that Winyah Bay is a possible nursery ground for the local sharks. The paper also identified 12 species of sharks in the bay and described abundance and distribution in the bay as a result of salinity (Abel *et al.* 2007). From 2002 to 2006, the most commonly caught species were the sandbar shark *Carcharhinus plumbeus*, the Atlantic sharpnose shark *Rhizoprionodon terraenovae,* the blacktip shark *Carcharhinus limbatus,* and the finetooth shark *Carcharhinus isodon.* In the most recent data set that was collected from 2012 to 2014, the most common species were *C. plumbeus*, the southern stingray *Dasyatis americana*, the spinner shark *Carcharhinus brevipinna,* and *R. terraenovae*. Two of the most commonly caught sharks through both data sets in Winyah Bay are the sandbar shark and the Atlantic sharpnose shark. Understanding life histories and feeding habits of local species is important to any study. This can determine how they fit in the exchange of energy between the upper trophic levels in the marine ecosystem (Gelsleichter *et al.* 1999). Understanding the how sharks fit into the trophic levels of the marine ecosystem is important to developing accurate ecosystem models (Drymon *et al.* 2012).

Sandbar sharks can be found from southern New England down to the Gulf of Mexico and make seasonal migrations between feeding and nursery grounds (Ellis and Musick 2007). Stomach content analysis showed that sandbars feed on teleosts, crustaceans, molluscs, and other elasmobranchs. Like other species, sandbars also exhibit ontogenetic changes in diet. As the shark grows, cephalopods and elasmobranchs become more common prey items and crustaceans become less important (Ellis and Musick 2007, McElroy *et al.* 2006). The stomach contents revealed a large number of fish families that were preyed upon by the sandbar sharks. This can be related directly to the diversity of the fish in the Chesapeake Bay where Ellis and Musick (2007) collected their data. A high diversity of prey was also found by McElroy *et al.* (2006) in Hawaiian waters. The diversity of fish in these sharks is an indicator of their opportunistic feeding habits which make them a versatile top predator.

Atlantic sharpnose sharks are the most common small coastal sharks on the southeastern coast of the United States and in the Gulf of Mexico (Loefer and Sedberry 2002). Sharpnose sharks are also common on the northwestern coast of the United States (Gelsleichter *et al.* 199). They are commonly caught on many forms of gear, which includes bottom longlines. They can be found in a variety of habitats, and some of these may be nursery sites (Bethea *et al.* 2006). The sharks move into coastal waters in April and the neonates arrive in June (Bethea *et al.* 2006). By the end of June, all life stages of sharpnose are present in the coastal waters and then move offshore in the fall (Bethea *et al.* 2006). Since it is such a wide-ranging species, the sharpnose shark is especially important to constructing ecosystem models (Drymon *et al.* 2012). Gelsleichter *et al.* (1999) found that teleost prey was the most dominant food item found in the stomachs of sharpnose sharks. They also feed on crustaceans, molluscs, and other elasmobranchs. Like the sandbars, sharpnose sharks also appear to be opportunistic feeders that feed on a variety of prey items. Also similar to the sandbar sharks, sharpnose sharks exhibited an ontogenetic shift in prey type (Bethea *et al.* 2006, Drymon *et al.* 2012). Young of the year sharpnose fed mostly on demersal teleost fish, arthropods, and molluscs and adults fed almost exclusively on teleost fish (Bethea *et al.* 2006).

The main objective of this study was to compare the data set from 2002 to 2006 with the most recent data from 2012 to 2014. Gary *et al.* (2009) analyzed the first data set and produced a survey of the shark population structure. Comparisons were done on catch composition, sex ratios, and size. Observable differences between the two sets of data were recorded because understanding how the population is changing can be important for future studies and management plans.

Materials and Methods

The study site was Winyah Bay, South Carolina and its nearby waters. Winyah Bay (Figure 1) is a coastal plain estuary located just 70 km northeast of Charleston, SC. The bay measures 22 km long and has an area of 65 km^2. Five rivers join to form the bay: the Black, Pee Dee, Sampit, and Waccamaw Rivers. The flow rates from these rivers range from 0.03 to over 2830 m^2/s (Johnson 1972 and Kjefve *et al.* 1982). Winyah Bay is classified as a partially mixed estuary in both low and moderate flows, and the upper and middle sections of the bay are classified as a salt wedge estuary in high flow (Bloomer 1973).

Data were collected from May to October from 2002 to 2006. Another data set was collected during the same months from 2012 to 2014. For the data from 2002 to 2006 and from 2012 to 2013, sharks were caught following the methods used by Abel *et al.* (2006). Approximately ten trips were taken each month. On each trip, two bottom longlines were deployed three separate times. Each longline had a buoy and an anchor on each end. Twenty-five gangions were evenly spaced on each longline. The gangions were 0.3 m long and were made of 200-lb monofilament with either a 12-ought (12/0) or 16-ought (16/0) circle hook attached at the end. The gangions were attached to the longline using a tuna clip. After both lines were deployed, they were allowed to soak for 30 minutes. The hooks were checked after 30 minutes to help reduce mortalities. Sharks were worked up after they caught. This included identifying the species, sexing, and measuring. The total length (TL), fork length (FL), and precaudal length (PCL) were be measured in cm. Once it was determined that the shark was healthy, it was released. Depending on its size and species, it was tagged before it was released. This process was repeated three times for a total of six longlines per trip.

Due to a shortage of Atlantic mackerel *Scomber scombrus* in the area, whole sardines (Family Clupeidae) became the main bait type in the middle of the 2013 season. In 2014, the fishing procedures were changed. Instead of twenty-five gangions on each line, twenty-four were used. 16/0 hooks and 5/0 hooks were alternated on these longlines with bait that was sized appropriately for the size of the hook. Green poodle noodles were cut into rings and were attached to the gangion using zip ties. The purpose of these floats was to try and cut down on bycatch and lost bait by keeping the hooks off the bottom. Cut Atlantic mackerel and sardines will be used as bait. *S. scombrus* and sardines were alternated daily. The longlines were deployed in the same manner as previous studies and the same measurements were taken from the sharks.

The catch per unit effort (CPUE) was measured for each year for the days that sharks were caught. CPUE is defined as the number of sharks caught $\times$ 100 hooks^{-1} $\times$ hours^{-1}.

Results

The highest CPUE occurred in 2013 and the lowest in 2014 (Table 1). The average CPUE for the 2002-2006 data set was 2.68 with a standard deviation of 0.73 while the average for the most recent data set was 3.20 with a standard deviation of 2.45. Of the Sphyrnidae Family, there were more individuals caught from 2012 to 2014 (Table 2). A total of 11 scalloped hammerhead sharks *Sphyrna lewini* and 33 bonnethead sharks *Sphyrna tiburo* were caught in these years, while five *S. lewini* and three *S. tiburo* were caught from 2002 to 2006.

From 2002 to 2006, a total of ten elasmobranch species were caught (Figure 2). The most commonly caught species was *C. plumbeus*, which made up approximately 51% of the catch composition (Figure 2). In the 2012-2014 data set, there were twelve species of elasmobranch caught (Figure 3). Approximately 24% of the sharks caught in this set were also *C. plumbeus*, making them the most commonly caught species (Figure 3). Eight different species were recorded in both data sets, and out of those seven were sharks and one was a ray.

The most common elasmobranch in both sets was the sandbar shark. A total of 224 sandbars were caught from 2002 to 2006 and 80 were caught from 2012 to 2014. The percentages of females and males were 63% and 37% for the first set, and 59% and 41% for the most recent data. The average precaudal lengths (PCL) was greater for both females and males in the 2002-2006 data set than the 2012-2014 set (Figure 4 and Figure 5).

The second most common species from 2002 to 2006 was *R. terraenovae*. This species was the fourth most common in the 2012-2014 set. For the Atlantic sharpnose shark, the PCL was greater in the earlier data set for both females and males (Figure 4 and 5). In 2012 to 2014, *D. americana* was the second most abundant species caught and was not in the top four species caught in 2002 to 2006, with only 13 individuals. Only one of these southern stingrays was a male. Out of 61 rays caught in 2012 to 2014, 49 were female (80%) and 16% of these gave birth on board the boat.

From 2002 to 2006, the third most frequently caught elasmobranch was *C. limbatus*. This shark was not one of the top four species caught in 2012 to 2014. Female blacktip sharks made up 93% and 73% of the catch in the first and second data set, respectively. The average PCL for female sharks was greater in the 2012-2014 data set (Figure 4). However, the average PCL for males was less in the most recent data set (Figure 5). *C. brevipinna* was the third most commonly caught shark in the 2012-2014 data set, however only a single spinner shark was caught in the earlier data set. The female spinner sharks caught from 2002 to 2006 had greater average PCLs than those caught in the second data set (Figure 4). No males were caught from 2002 to 2006.

Finally, *C. isodon* was the fourth most common species in the first data set. The finetooth shark catch composition was 79% female from 2002 to 2006. A total of four finetooth sharks were caught from 2012 to 2014 and 100% of them were female. The average PCL for females was greater in the first data set than it was in the second (Figure 4). No male spinner sharks were caught from 2012 to 2014.

Discussion

In the two data sets, there were distinct differences between CPUEs, catch composition, sex ratios, and average precaudal lengths. CPUE stayed fairly constant from 2002 to 2006. From 2012 to 2014, the CPUE varied greatly, as shown by the large standard deviation. The year with the lowest CPUE was 2014. This could be a result of the change in gear setup and bait. The bait was cut into smaller pieces in 2014 than it has been in previous years. Sharks might have also been deterred from the hooks by the green floats. The floats were also supposed to keep the hooks off the bottom. This would have reduced the number of demersal species caught, like skates and rays. The low CPUE could have also been a result of any one environmental factor, or a combination of several.

The top four most commonly caught elasmobranch species were different for both data sets, with the exception of *C. plumbeus*. In both cases this shark was the most frequently caught. Just over fifty percent of the sandbar sharks caught in both sets were female, making this species the most consistent through the records. The difference in their PCLs could be due to gear selectivity. There could also be an environmental factor that is affecting the size of *C. plumbeus* in the area. Sandbar sharks are known to migrate along the East Coast between their feeding and nursery grounds (Ellis and Musick 2007). Winyah Bay is likely along their migration route, which would make them a reliable catch in coastal South Carolina waters. *R. terraenovae* was found in the top four of both sets. According to Loefer and Sedberry (2002), the Atlantic sharpnose is the most common small coastal shark species caught along the southeastern coastal of the United States and in the Gulf of Mexico. Winyah Bay acts as a protected nursery areas for some marine species in this region. Atlantic sharpnose sharks may be using Winyah Bay as a nursery, since they can be found in a wide variety of habitats, as suggested by Bethea *et al.* (2006). The data from this longline study shows that *R. terraenovae* are present in the bay throughout the study period, from May to October. This agrees with the paper by Bethea *et al.* (2006) which found that the sharks arrive in coastal waters in mid-spring and stay until fall. Again, the sex ratios of *R. terraenovae* were similar between the two data sets. The average PCL for both males and females were also similar between the data sets.

The remaining most common species were caught frequently in one data set, but were far less frequent in the other set. *C. isodon C. limbatus, D. americana, and C. brevipinna* were all examples of this. The influx of *D. americana* could have been due to the change in bait; either in bait type or size of bait. The gear could have also had an influence. For the other shark species, it is difficult to pinpoint the exact reason behind the change. At this time, there is not enough complete environmental data to come to a conclusion. Another aspect of the catch composition that varied greatly between the two data sets was the presence of members from the Sphyrnidae family in the most recent set. *S. tiburo and S. lewini* were both caught more frequently in the most recent data set than in 2002 to 2006. The bonnethead sharks were exclusively female, and the scalloped hammerheads had approximately a 1:1 sex ratio. In Florida, it was found that the average size at maturity for bonnethead sharks was 72.1 cm TL for males and 82.1 cm TL for female (Lombardi-Carlson 2007). All of the bonnethead sharks caught in both studies were over this median size, which suggests they do not use Winyah Bay as a nursery for neonates. In the northwestern Gulf of Mexico, it was found that male scalloped hammerhead sharks mature at 180 cm TL and the females mature at 250 cm TL (Branstetter 1987). The scalloped hammerhead sharks in this study were all well under this size, for both data sets, suggesting that only the neonates are found in the coastal waters off South Carolina. They may be using the bay for protection or for a reliable source of food.

Although studies like these are important in successfully managing species, there are numerous factors that could affect these results. In order to get a more complete picture of what is going on in Winyah Bay, the environmental parameters need to be included in the study. This includes rainfall, salinity, temperature, amount of light throughout the day, and even the amount of pollution that enters the bay from the five rivers. Gary *et al.* (2009) found that the amount of daylight affects the presence of sharks in Winyah Bay. Abel *et al.* (2007) found that CPUE mirrored salinity trends in the data. It is likely that not one environmental factor affects CPUE or catch composition, but that a combination of several factors work together. Another possible reason for the differences between the data sets is changing gear and bait. Gear and bait standardization is important in surveys so that there are fewer variables affecting the sharks. The longline protocol did stay the same until 2014, however the gear was changed drastically at that point. The green floats could have easily deterred some sharks from taking the bait. By switching half of the hooks to 5/0 ones, the selectivity of the gear changed and larger sharks might have been discouraged from biting those hooks. The size of the bait, the type of bait, and the condition of the bait (i.e. frozen, thawed, whole, or broken) could also affect the results of a survey. A future comprehensive study on the bait preference of sharks will help determine if any of these factors do in fact affect CPUE or catch composition.

In conclusion, it is obvious that a variety of factors affect marine species. Understanding these help managers create more accurate plans. Understanding how the sharks are using certain habitats and how the population is structured is also important to the management of these species. These top predators are in decline around the world (Baum *et al.* 2003, Baum and Myers 2004, Burgess *et al.* 2005). Surveys, like this one, are crucial to properly assessing the health of shark populations both locally and globally.

References

Abel DC, Young RF, Garwood JA, Travaline M, and Yednock BK (2007) Observations on the importance of salinity structure to shark populations and nurseries in two South Carolina estuaries. Pages 109-124 in McCandless CT, Kohler NE, and Pratt, Jr. HL editors. Shark Nursery Grounds of the Gulf of Mexico and the East Coast Waters of the United States. American Fisheries Society, Symposium 50, Bethesda, MD.

Baum JK, *et al.* (2003) Collapse and conservation of shark populations in the Northwest Atlantic. Science 299:389-392.

Baum JK, Myers RA (2004) Shifting baselines and the decline of pelagic sharks in the Gulf of Mexico. Eco Letters 7:135-145.

Bethea DM, Carlson JK, Buckel JA, and Satterwhite M (2006) Ontogenetic and site-related trends in the diet of the Atlantic sharpnose shark *Rhizoprionodon terraenovae* from the northeast Gulf of Mexico. Bull Mar Science 78(2):287-307.

Branstetter S (1987) Age, growth, and reproductive biology of the silky shark, *Carcharhinus falciformis,* and the scalloped hammerhead, *Sphyrna lewini*, from the northwestern Gulf of Mexico. Environ Biol Fish 19(3): 161-173.

Burgess GH, *et al.* (2005) Is the collapse of shark populations in the Northwest Atlantic Ocean and Gulf of Mexico real? Fisheries 30(10):19-26.

Cortes E, *et al.* (2010) Ecological risk assessment of pelagic sharks caught in the Atlantic pelagic longline fisheries. Aquatic Living Resources 23:25-34.

Drymon MJ, Powers SP, and Carmichael RH (2012) Trophic plasticity in the Atlantic sharpnose shark (*Rhizoprionodon terraenovae*) from the north central Gulf of Mexico. Environ Biol Fish 95:21-35.

Ellis JK, Musik JA (2007) Ontogenetic changes in the diet of the sandbar shark, *Carcharhinus plumbeus,* in the lower Chesapeake Bay and Virginia (USA) coastal waters. Environ Biol Fish 80:51-67.

Gary SJ, Abel DC, and Howington EB (2009) Shark Population Structure in Winyah Bay, SC: Results of a Five Year Study. *Master's Thesis, Coastal Carolina University.*

Gelsleichter J, Musick JA, and Nichols S (1999) Food habits of the smooth dogfish, *Mustelus canis*, dusky shark, *Carcharhinus obscurus*, Atlantic sharpnose shark, *Rhizoprionodon terraenovae*, and the sand tiger, *Carcharias taurus*, from the northwest Atlantic Ocean. Environ Biol Fishes 54:205-217.

Loefer JK, Sedberry GR (2003) Life history of the Atlantic sharpnose shark (*Rhizoprionodon terraenovae*) (Richardson, 1836) off the southeastern United States. Fish Bull 101:75-88.

Lombardi-Carlson LA (2007) Life history traits of bonnethead sharks, *Sphyrna tiburo*, from the eastern Gulf of Mexico. SEDAR 13-DW-24-V3.

McElroy WD, *et al.* (2006) Food habits and ontogenetic changes in the diet of the sandbar shark, *Carcharhinus plumbeus*, in Hawaii. Environ Biol Fish 76:81-92.

Myers RA, Baum JK, Shepherd TD, Powers SP, and Peterson CH (2007) Cascading effects of the loss of apex predatory sharks from a coastal ocean. Science 315:1846-1850.

Table 1. The catch per unit effort (CPUE) for each year in the study. CPUE is defined as the number of sharks caught × 100 hooks^{-1} × hours^{-1}.

Year	*CPUE*
2002	3.96
2003	2.33
2004	2.53
2005	2.15
2006	2.43
2012	1.98
2013	6.02
2014	1.60

Table 2. The number of females caught versus the number of males caught for the scalloped hammerhead *Sphyrna lewini* and the bonnethead shark *Sphyrna tiburo* for each data set.

Year	*Species*	*Female*	*Male*
2002-2006	S. lewini	5	0
2012-2014	S. lewini	5	6
2002-2006	S. tiburo	3	0
2012-2014	S. tiburo	33	0

Figure 1. Winyah Bay, South Carolina is fed by five rivers and is a protected estuary that is used by many marine fishes, like elasmobranchs.

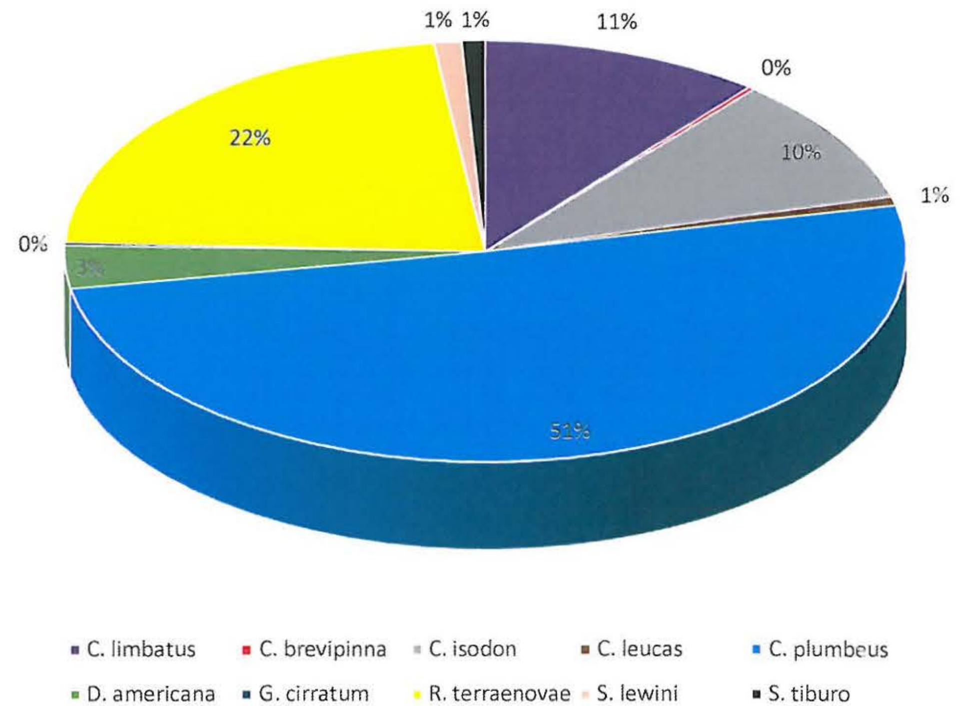

Figure 2. From 2002 to 2006, ten species of elasmobranchs were caught in Winyah Bay, SC, with *Carcharhinus plumbeus* making up over 50% of the catch.

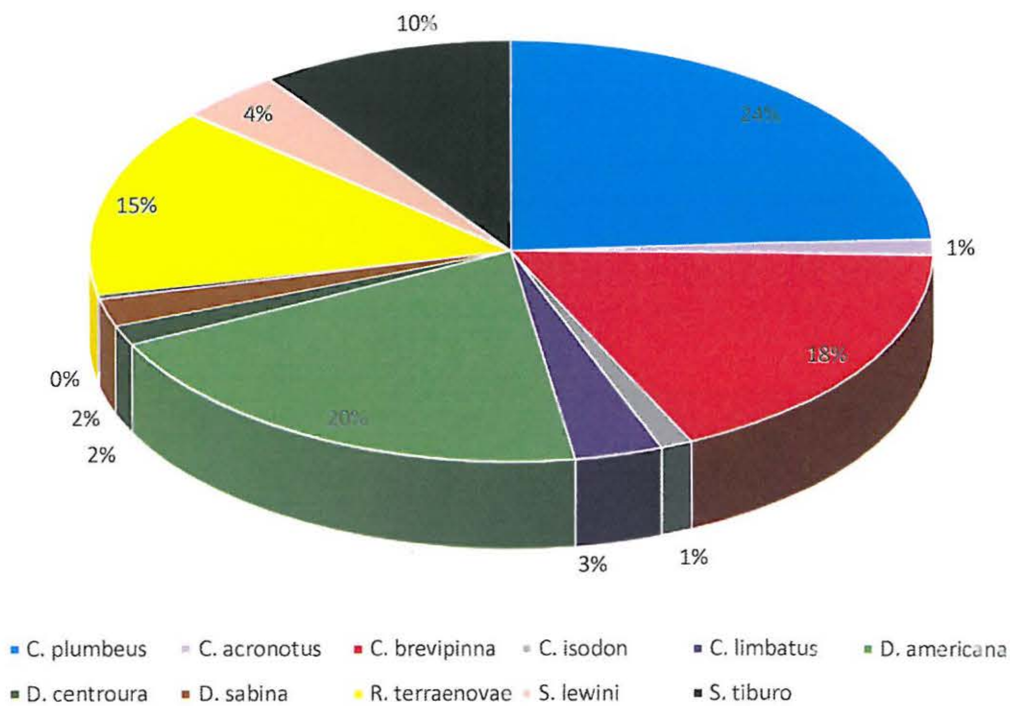

Figure 3. From 2012 to 2014, 12 species of elasmobranch were caught in Winyah Bay, SC, with 24% of the catch being *Carcharhinus plumbeus.*

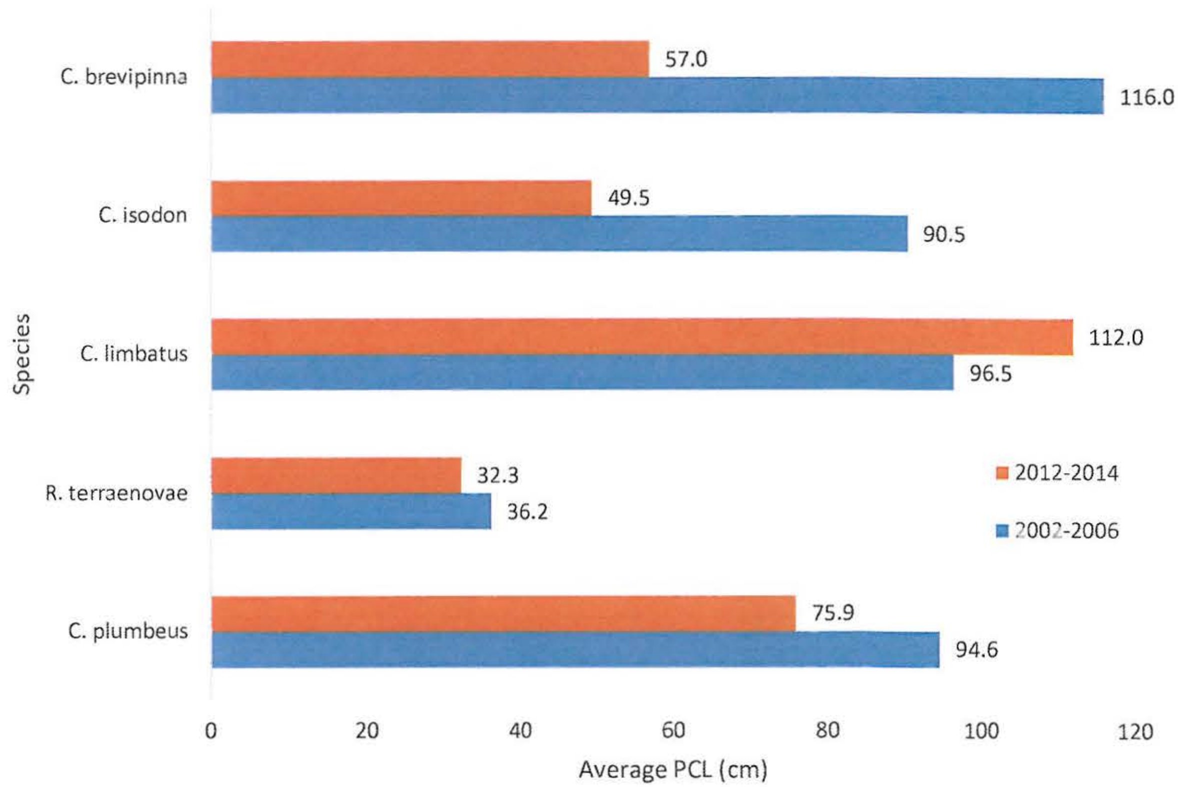

Figure 4. The average precaudal length (PCL) measured in cm of female sharks in both data sets. The most commonly caught species were included in the data.

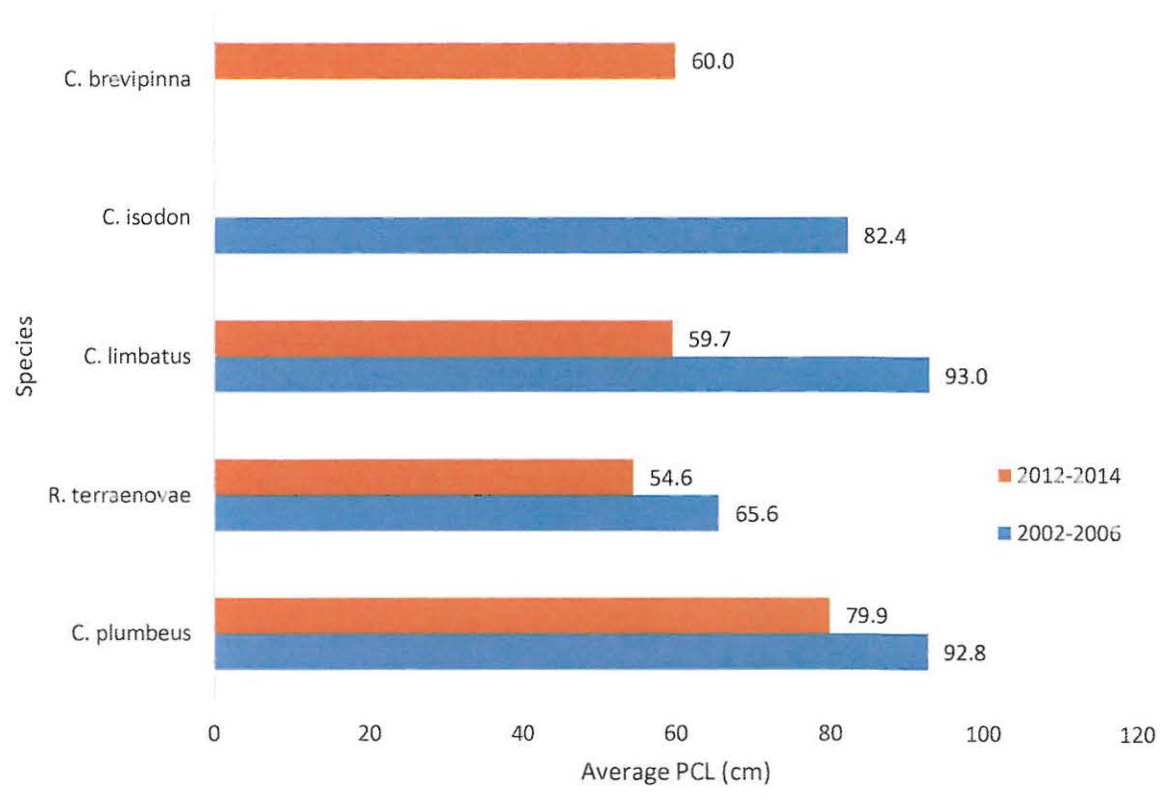

Figure 5. The average precaudal length (PCL) measured in cm for male sharks caught in both data sets. The most frequently caught species were included in the data.