

2012

Diet and Reproductive Biology of the Blacknose Shark (*Carcharhinus Acronotus*) from the Southwestern Atlantic Ocean

Ryan Michael Ford
University of North Florida

Follow this and additional works at: <https://digitalcommons.unf.edu/etd>

 Part of the [Biology Commons](#)

Suggested Citation

Ford, Ryan Michael, "Diet and Reproductive Biology of the Blacknose Shark (*Carcharhinus Acronotus*) from the Southwestern Atlantic Ocean" (2012). *UNF Graduate Theses and Dissertations*. 347.
<https://digitalcommons.unf.edu/etd/347>

This Master's Thesis is brought to you for free and open access by the Student Scholarship at UNF Digital Commons. It has been accepted for inclusion in UNF Graduate Theses and Dissertations by an authorized administrator of UNF Digital Commons. For more information, please contact [Digital Projects](#).
© 2012 All Rights Reserved

DIET AND REPRODUCTIVE BIOLOGY OF THE BLACKNOSE SHARK
(*CARCHARHINUS ACRONOTUS*) FROM THE SOUTHWESTERN ATLANTIC
OCEAN

By

Ryan Michael Ford

A thesis submitted to the Department of Biology in partial fulfillment for the degree of

Masters of Science in Biology

UNIVERSITY OF NORTH FLORIDA

COLLEGE OF ARTS AND SCIENCES

August, 2012

The thesis of Ryan M. Ford is approved:

Signature Deleted

(Date)

8/7/2012

Dr. Jim Gelsleichter

Signature Deleted

7 August 2012

Dr. Daniel C. Moon

Signature Deleted

7 Aug 2012

Dr. R. Dean Grubbs

Accepted for the Biology Department:

Signature Deleted

7 August 2012

Dr. Daniel C. Moon

Chair

Accepted for the College of Arts and Sciences:

Signature Deleted

Aug 8, 2012

Dr. Barbara Hetrick

Dean

Accepted for the University:

Signature Deleted

8/27/12

Dr. Len Roberson

Dean of the Graduate School

This thesis is dedicated to my mother and father for whom I would not be where I am today without their help and support.

ACKNOWLEDGEMENTS:

I would like thank the NOAA Fisheries Cooperative Research Grant and the University of North Florida for funding and boat time. I also thank Michael McCallister, Brian Fraizer, Dean Grubbs, Andrew Piercy, Brenda Anderson, Matt Kolman, Emily Warchol, Capt. Bruce Stiller and the UNF Shark Biology Program for help with collecting and processing samples.

TABLE OF CONTENTS

| | |
|----------------------|----|
| LIST OF FIGURES..... | v |
| INTRODUCTION..... | 1 |
| REPRODUCTION..... | 3 |
| DIET..... | 12 |
| CONCLUSION..... | 21 |
| APPENDIX..... | 22 |
| WORKS CITED..... | 41 |
| VITA | 43 |

LIST OF FIGURES AND TABLES

Figure 1.

Sample locations along the US southeastern seaboard

Figure2.

Average monthly testis width with October outliers separated. Sample sizes and significance are shown above bars. Significance was determined by post-hoc Bonferroni pairwise contrasts showing a clear monthly trend with May animals having significantly larger testis size. Error bars are standard error. — Presence of seminal fluid was found in the seminal vesicle in all June and July animals (n=24).

Figure 3.

Average percentage of stage VI spermatocytes observed in straight-line counts during histological analysis of testis showing sperm being actively produced in the months of May, June and July. A small portion of testis observed from October and November also showed active sperm production. Sample sizes are above each bar. Error bars are standard error.

Figure 4.

Raw data of the monthly maximum follicle diameter (MFD) showing large mature and small immature follicles in pregnant (P) non-pregnant (NP) Ovulating (OV) and postpartum (PP) females caught between 2003 and 2011 (n=83).

Figure 5.

Raw data of oviducal gland width for pregnant (P) non-pregnant (NP) ovulating (OV) and postpartum (PP) females, showing large and small oviducal glands present in females during the month of ovulation and mating (n=95).

Figure 6.

Percent of mature pregnant and non-pregnant females observed (n= 97) including animals who were scanned with an ultrasound

Figure 7.

Progression of the fetal shark size from month to month (n=50). There were no pregnant sharks caught during the month of June

Figure 8

Pooled cumulative prey curve for all blacknose with prey present (n=39)

Figure 9

Female blacknose cumulative prey curve (n=12)

Figure 10

Male blacknose cumulative prey curve (n=13)

Figure 11

Three-dimensional graphical representations of diet in male *Carcharhinus acronotus* (T= teleosts, C = crustaceans, E = Elasmobranchs, A = Anguilliformes, M = Mollusks, D = Echinoderms)

Figure 12

Three-dimensional graphical representations of diet in male *Carcharhinus acronotus* (T= teleosts, C = crustaceans, E = Elasmobranchs, A = Anguilliformes, M = Molluscs)

Figure 13

Three-dimensional graphical representations of diet in female *Carcharhinus acronotus* (T= teleost, C = crustaceans, M = mollusks, D = echinoderms)

Table 1

One way ANOVA table of testis widths per month with October outliers removed.

Groups = sample month

Table 2

Comparative indices indicating differences in diversity and moderate dietary overlap

Table 3

Diet of *Carcharhinus acronotus* from the southwest Atlantic Ocean expressed as a percent by number (%N) percent by weight (%W), percent by occurrence (%O) and relative importance of lower (%IRI) and higher (%IRI_{Type}) prey categories

Table 4

Female *Carcharhinus acronotus* diet expressed as a percent by number (%N), percent by mass (%M), percent by occurrence (%O) and relative importance of lower (%IRI) and higher (%IRI_{Type}) prey categories

Table 5

Male *Carcharhinus acronotus* diet expressed as a percent by number (%N), percent by mass (%M), percent by occurrence (%O) and relative importance of lower (%IRI) and higher (%IRI_{Type}) prey categories

ABSTRACT

The blacknose shark (*Carcharhinus acronotus*) is a common small coastal shark species found in nearshore waters along the southeast coast of the United States, from North Carolina into the Gulf of Mexico and extending further south into the Bahamas. There has been some debate in recent years over the reproductive periodicity of *C. acronotus* in waters off the U.S. coast. Earlier studies have suggested that Gulf *C. acronotus* reproduce on an annual basis whereas the Atlantic populations of this species may reproduce biennially. Additionally, there have been no known studies on the diet of *C. acronotus*. The goal of the present study was to re-evaluate the reproductive biology of the Atlantic populations of *C. acronotus* with the intent on clarifying discrepancies in reproduction as well as provide information on dietary trends. This was accomplished by examining male and female reproductive tracts and gut contents in animals caught throughout the Atlantic range of *C. acronotus*. Based on these data, spermatogenesis occurs between late May to early July with peak sperm production occurring in June and July. In females, follicular development is complete by late June-early July with ovulation occurring shortly afterwards. Mating occurs between mid-June and early July based on the presence of fresh mating scars on females captured during this time. Current data suggests that gestation begins late July with parturition occurring late May to early June the following year. As observed in earlier studies, reproductive periodicity appears to be largely biennial. However, evidence for concurrent follicular development and pregnancy was observed in several females, suggesting that at least a portion of the Atlantic population may reproduce on an annual basis. Dietary data shows a dominance of teleost prey items

in the diets of *C. acronotus* with scianids making up the majority of the identifiable teleosts.

INTRODUCTION

The blacknose shark (*Carcharhinus acronotus*) is distributed in the western Atlantic Ocean from North Carolina to Brazil and throughout the coastal waters of the Gulf of Mexico (GOM) (Compagno, 1984; Compagno et al. 2005; Castro, 2011). *C. acronotus* ranges in size from approximately 50cm total length (TL) at parturition to a maximum TL of approximately 140cm. Males *C. acronotus* reach maturity between 97 and 106 cm TL whereas females mature at around 103 cm TL (Compagno, 1984, Driggers et al. 2004). Blacknose sharks are commonly caught in both commercial and recreational fisheries in nearshore U.S. waters and composes a large portion of the bycatch in coastal gillnet and shrimp fisheries throughout the species' home range (Thorpe and Frierson, 2009; NMFS, 2007; Trent et. al. 1997). The blacknose shark was managed as part of the small coastal shark (SCS) complex but has recently been separated from the SCS complex and given its own annual quota. This change was in response to the most recent stock assessment in which the population was characterized as overfished with overfishing occurring (NMFS, 2011; 2007).

The original goal of the study was to answer the questions concerning reproduction in *C. acronotus*. During sample collection for this study, the opportunity presented itself to do a study on the diet of *C. acronotus*. Previous studies on blacknose shark reproduction have been conflicting (Driggers et. al., 2004; Sulikowski et al., 2007); whereas diet has yet to be formally addressed. The studies presented in this thesis attempt to explain the reproductive biology and the diet of the blacknose shark in the western Atlantic Ocean

Reproductive Biology of the Blacknose Shark (*Carcharhinus acronotus*) in Southeast U.S. Waters

Introduction

The blacknose shark (*Carcharhinus acronotus*) is a small, piscivorous, carcharhinid species-distributed in the western Atlantic from Virginia to Brazil and throughout the coastal waters of the Gulf of Mexico (GOM) (Compagno, 1984; Compagno et. al. 2005; Castro, 2011). *C. acronotus* ranges in size from approximately 45 cm total length (TL) at parturition to a maximum TL of approximately 140cm. Males reach maturity between 97 and 106 cm TL whereas females mature at around 103 cm TL (Compagno, 1984, Driggers et al. 2004, and Sulikowski et al. 2007). The species is commonly caught in both commercial and recreational fisheries in nearshore U.S. waters and composes a majority of the bycatch in coastal gillnet fisheries throughout its home range (Thorpe and Frierson, 2009; NMFS, 2007; Trent et. al. 1997).

In 1993 a fisheries management plan (FMP) was established to manage shark populations in US Atlantic waters. To account for differences in life history, species were grouped into three groups: Pelagic Sharks, Large Coastal Sharks (LCS), and Small Coastal Sharks (SCS), each of which consisted of species with similar life history characteristics. Species included in the SCS management group include the bonnethead (*Sphyrna tiburo*), blacknose (*Carcharhinus acronotus*), Atlantic sharpnose (*Rhizoprionodon terraenovae*) and finetooth (*Carcharhinus isodon*) (NMFS, 1993).

During the summer of 2010 there was a 64 percent reduction in total allowable catch (TAC) for the blacknose sharks relative to 2004-2008 in preparation for the implementation of Amendment 3 of the FMP in 2011 (NMFS, 2011). Amendment 3 establishes a separate quota for blacknose sharks which will require more species specific information, including a detailed understanding of blacknose life history strategies (NMFS, 2011). This change was in response to the most recent stock assessment of *C. acronotus* which characterized the population as overfished with overfishing occurring (NMFS, 2011; 2007).

With the current population status categorized as overfished with overfishing occurring there is a need for more data on the life history of *C. acronotus*. Recent studies have indicated the possibility of regional differences in reproduction of Atlantic *C. acronotus* and Gulf of Mexico (GOM) *C. acronotus*. Driggers et. al. (2004) suggested that *C. acronotus* off the coast of South Carolina exhibit biennial reproduction, whereas Sulikowski et. al. (2007) suggested that GOM animals exhibit annual reproduction. This conflicting information makes it difficult for fishery managers to make accurate decisions when setting total allowable catch (TAC) quotas. To further complicate matters Hazin (2002) suggested an annual mode of reproduction for *C. acronotus* in coastal waters off of Brazil.

The objective of this project was to characterize the reproductive cycle of *C. acronotus* along the U.S. Atlantic seaboard. To accomplish this, a rigorous sampling methodology was used to capture individuals across the sampling range and throughout all stages of reproduction. Gonads and other biological data were collected and used to determine the stage of reproduction.

Methods

Animal collection

Sharks were captured using both bottom longlines and gillnets throughout the US Atlantic seaboard from North Carolina to the Florida Keys via both fishery-dependent and fishery-independent sources (Figure 1). Bottom longlines consisted of a high test mainline, either monofilament or solid braided nylon depending on the survey in question, which included 50 - 100 gageons with baited 15/0, 16/0 or 18/0 circle hooks. Each hook was baited with 0.5 – 1 kg of *Scomber scombrus* and allowed to soak for between 30 and 120 minutes before retrieval to reduce mortality of non-targeted species. Fishery independent gillnets were 213 m. long, 5 ft tall, with 5-inch stretch monofilament mesh. Each net was allowed to soak for approximately 30 min to reduce mortality of non-targeted species. Once captured, animals were euthanized via anesthesia without revival via immersion in 1 g/L tricane methanesulfonate (MS-222) and severing the spinal cord and a field dissection was performed to collect samples.

The following external morphometric measurements were taken for each animal captured. Pre-caudal length (PCL), measured from the tip of the rostrum to the caudal peduncle; fork length (FL), measured from the tip of the rostrum to the fork in the sharks heterocercal caudal fin; total length (TL) the length of the animal from the rostrum to the tip of the upper lobe of the caudal fin in an upright position, and stretched total length (STL), measured from the tip of the rostrum to the tip of the upper lobe of the caudal fin stretched to its maximum length, were taken to the nearest 0.5 centimeter.

Measurements of reproductive activity

Males

Clasper (myxopterygia) lengths were measured from the cloacal opening to the tip of the rhipidion and state of maturity was established via the level of calcification of claspers and whether they possessed a freely opening rhipidion. The presence of sperm was determined by either puncturing the seminal vesicle of dissected specimens or massaging the urogenital papillae of non-euthanized animals to force any sperm present out the apophyle and was used only as an indicator for when viable sperm was present. Both testes were separated from the epigonal organ and width, length and mass were measured for both testis to the nearest mm or 0.1 g respectively. The largest testis was sectioned and fixed in 10% formalin for 48 h then rinsed and stored in 70% ethanol until used for histological analysis of cellular architecture.

Histology

A further analysis of male reproductive seasonality was carried out through histological observations of testicular structure. Five micrometer sections of testis were prepared using routine paraffin histology and stained using Harris Hematoxylin and Eosin. Observations of spermatogenesis were conducted by counting each stage of spermatogenesis along a bisecting line crossing from the germinal zone to the outer edge of the testis, in a method known as straight line counts (Maruska et. al. 1996).

The testes of *C. acronotus* are radial and the stages of spermatogenesis were determined based on Maruska et. al. (1996) and are as follows:

Stage I, also called the germinal zone, consists of loosely organized germ cells and lacks a true germinal epithelium. Stage II consists of a fully formed spermatocyst

containing both spermatogonia and the associated Sertoli cells. In stage III, the spermatogonia complete mitosis to become primary spermatocytes and will then undergo the first meiotic division producing secondary spermatocytes. In stage IV, the secondary spermatocytes complete the second meiotic division producing spermatids. Stage V includes immature sperm which consist of spermatids which have undergone spermatogenesis but have yet to organize in packets. Stage VI is composed of mature sperm in tightly organized packets arranged heads-out in a spiral around the spermatocyst. Unlike the results shown in Maruska (1996) stage VII was located after stage six and did not include ruptured spermatocysts but rather empty and flattened spermatocysts characterized by a high rate of immune cell infiltration.

Females

The active ovary was excised and the largest follicular diameter was measured and it was noted if the follicles were non-vitellogenic, vitellogenic or regressed. Maximum widths of the oviducal gland and uterus were measured for both gravid and non-gravid females. In gravid females the total number of developing embryos was recorded as well as each embryo's sex and STL. Some mature females were observed non-lethally via ultrasound to determine the number and size of pups present in the reproductive tract.

Results

Males

A total of 73 males were examined in the present study. The monthly average testis width (\pm SE) ranged from 6.9 ± 1.67 mm in September (n=10) to 32.7 ± 1.37 mm in

May (n= 3). A seasonal pattern of testis function was observed by the rapid growth seen in early spring and subsequent regression of the testes in early summer (ANOVA: $d f= 9$, $p<0.001$; Table 1). There were two males caught in October who had unusually large testis size. As these males were obvious outliers to the general trends of male reproduction, they were removed from further analysis.

Histological analysis of testicular structure was examined in 38 *C. acronotus*. Late stage spermatogenesis was observed in sharks collected in the months of: May (n= 2), June (n = 6) and July (n = 5). Stage VI spermatocysts made up ~3.3% of the total spermatocysts counted in sharks collected in May, ~ 17.4% in June sharks and ~8.2% in July sharks. The animals in October had ~1.4% of the total spermatocysts counted as Stage VI while the lone November animal had ~1% of its spermatocysts as Stage VI.

Two of the males caught in October exhibited both abnormally large testis size as well as late stage spermatogenesis. A single November animal also exhibited late stage spermatogenesis however, did not have unusually large testes. The testis size of the two October animals were similar to the average testis size for June animals (Figure 3).

Spermatozoa was present in the seminal vesicles of all mature males sampled in June (n= 14) and July (n= 10). The presence of mature spermatozoa was also observed in the October males that possessed enlarged testis and exhibited histological evidence of late stage spermatogenesis. However, the November male which had late stage spermatogenesis present in histological observations, did not have spermatozoa in its seminal vesicle.

Females

Reproductive tracts from a total of 71 females were examined. Of these 71 females, 65 were mature and used for the subsequent analysis. Of those, 21 were not pregnant, 3 were in the process of ovulating and 40 were pregnant or postpartum.

Folliculogenesis began in late January as indicated by a yellowing of the follicles within the ovaries and terminated with ovulation in June, as indicated by large yellow follicles in the ovary and ovulated ova within the reproductive tract. Both pregnant and non-pregnant animals were observed with large vitellogenic follicles during the month of June. Similarly there were pregnant, and non-pregnant females who had recently underwent parturition in the month of June with small, non-vitellogenic follicles. The maximum follicular diameter (MFD) was observed in July (25.5mm) in a pregnant animal (138.5 cm STL). The largest MFD observed in a non-pregnant female (112.8 cm STL) was 23mm during the month of June. All MFD values were reported as raw data rather than means because there were too many categories of female reproductive status (i.e., vitellogenic non-pregnant, vitellogenic pregnant, non-vitellogenic non-pregnant) and the sample size of each individual category was too low (Figure 4).

Maximum oviducal gland width showed a similar pattern with some of both pregnant and non-pregnant animals exhibiting large oviducal gland widths during the month of June. Along with animals with large oviducal gland width, there were also some pregnant and non-pregnant females with lower oviducal widths (Figure 5). The largest oviducal gland width observed was 36.2 mm in a pregnant June female (138.5 cm STL) whereas the largest width observed in a non-pregnant female was 35.3 mm (133.4 STL).

Mating wounds were observed on the flanks of females caught during the month of June. These June females also contained large vitellogenic and or ovulated ova. This observation suggests that mating occurs concurrently with ovulation during mid to late June.

Approximately 64% of the 97 mature females observed via dissection or ultrasound were pregnant or ovulating (Figure 6). After an 11 month gestation period, parturition occurs in mid to late May (Figure 7). Pups were born at approximately 470 mm STL. The largest observed near term pup was 466 mm STL. The average litter size observed was 4.3 with the many females having at least 5 pups present at the time of examination.

Discussion

The results of this study demonstrate that Atlantic blacknose shark reproduce on a seasonal basis. Folliculogenesis begins in late January/early February in reproductively active female blacknose sharks and terminates in ovulation between June and July. Male blacknose sharks produce sperm annually between May and June and mate with females during the same time females are undergoing ovulation. Once fertilization occurs, females carry the embryos to term in approximately 11 months. Interestingly blacknose sharks in US Atlantic waters appear to be biologically capable of reproducing both annually and biennially. A number of late-stage pregnant females were found to be undergoing Vitellogenesis and presumably mate with males shortly following parturition. However, approximately 30% of the mature female blacknose sharks examined in this study that were not gravid during the time of normal pregnancy. This, observation

coupled with the small female reproductive glands in some near-term pregnant animals lead to the conclusion that these individuals are at least reproducing biennially.

Based on data from the current study, male blacknose sharks in U.S. Atlantic waters maximize their production of sperm in the month of June. This is similar to what Sulikowski et. al. (2007) saw with male peak sperm production in May, June, and July for animals caught in the Gulf of Mexico. The large testis sizes observed during the month of May did not coincide with presence of seminal fluid within the seminal vesicle or the largest proportion of Stage VI spermatogenesis. Sperm production peaks in June with a peak in the percentage that Stage VI spermatocysts make-up of the testis. Seminal fluid was present in the seminal vesicle only during June and July indicating that males are capable of reproducing annually, which agrees with what Drigger et. al. (2007) and Sulikowski et. al. (2004) observed in their respective studies.

Previous studies on blacknose shark reproduction have indicated that the reproductive periodicity depends on the location where the animal is captured. Sulikowski et. al. (2007) found that blacknose reproduce in a well-defined annual cycle in the Gulf of Mexico. In contrast to this, Driggers et. al. (2004) proposed that blacknose sharks reproduce biennially in the Atlantic waters off the South Carolina coast. The current study has shown that female Atlantic blacknose sharks may be biologically capable of reproducing both annually and biennially. This is similar to what has recently been observed in another shark of the genus *Carcharhinus*, the finetooth shark (*Carcharhinus isodon*), i.e., a few animals were observed to exhibit biennial reproductive periodicity when the majority of the animals observed exhibited annual reproduction (Driggers and Hoffmayer, 2009). Unlike the aforementioned study however, this study

found a larger proportion of animals exhibiting both annual and biennial reproduction, suggesting that it is not a rare occurrence.

This discrepancy in reproductive periodicity was indicated by the presence of a large number of mature, non-gravid females during the normal 11 month gestation period, as well as the presence of large vitellogenic follicles and small, non-vitellogenic follicles in females caught during the month of June, the time of mating and ovulation. Geographical location does not appear to be a factor in the periodicity of blacknose reproduction within U.S. Atlantic waters as animals caught off of the Florida Keys as well as those caught off the coast of South Carolina showed similar trends in annual and biennial reproduction.

At any given time the US Atlantic population of blacknose sharks may have only 50% of its mature female population actively reproducing. This can have important consequences for management of the species. Previous management practices had included the blacknose shark with the SCS management complex and used a reproductive periodicity of 1.5 years to account for the conflicting conclusions in previous studies (NMFS, 2007). Current management (Amendment 3) separates the Atlantic blacknose allowable biologic catch (ABC) from the rest of the SCS complex ABC (NMFS, 2011). If not already being done the reproductive periodicity should be managed as though the entire population of Atlantic blacknose were biennially reproducing as only 50% of the population is actively reproducing in a given year. Though both annual and biennial reproductive methods may be being used, it is yet unclear as to what mechanisms account for this variability and further research is needed to clarify these mechanisms.

The Diet of the Atlantic Blacknose Shark, (*Carcharhinus acronotus*) in US Atlantic Waters

Introduction

Understanding the feeding habits and the diversity of prey species is essential when characterizing the effects an animal has on its ecosystem (Wetherbee and Cortés, 2004). Sharks represent an important part of the marine fauna in the western Atlantic Ocean and Caribbean Sea and are generally known to be higher level trophic predators within their habitat range. As such, information on what sharks prey upon is important when making management decisions as these decisions are often based solely upon the population dynamics of the species in question, but may, at times, fail to consider the ecological effects of the removal of higher level predators, such as top-down effects. One method to determine these potential effects is by determining what the animal's dietary habits are as well as any variations found in these habits.

The blacknose shark (*Carcharhinus acronotus*) is distributed in the western Atlantic from Virginia to Brazil and throughout the coastal waters of the GOM (Compagno, 1984; Compagno et. al. 2005; Castro, 2011). *C. acronotus* ranges in size from approximately 50cm total length (TL) at parturition to a maximum TL of approximately 140cm. Males reach maturity between 97 and 106 cm TL whereas females mature at around 103 cm TL (Driggers et. al., 2004; Compagno et. al., 2005; Sulikowski et. al., 2007 and Castro, 2011). The species is commonly caught in both

commercial and recreational fisheries in nearshore U.S. waters and composes a majority of the bycatch in coastal gillnet fisheries throughout its home range (Trent et. al. 1997; NMFS, 2007; Thorpe and Frierson, 2009). *C. acronotus* was managed as part of the small coastal shark (SCS) complex but has recently been separated from the SCS complex and given its own annual quota. This change was in response to the most recent stock assessment of *C. acronotus* characterized the population as overfished with overfishing occurring (NMFS, 2011; 2007).

The blacknose shark has become a species of concern for managers for reasons not covered in this paper. As such it is important that the effects that this species of shark has on its ecosystem be better understood. To accomplish this, a gut content analysis was conducted for the species as a whole, between sexes and within pregnant and non-pregnant females.

Methods

Animal collection

Sharks were captured using both bottom longlines and gillnets throughout the US Atlantic seaboard from North Carolina to the Florida Keys via both fishery-dependent and fishery-independent sources (Figure 1). Bottom longlines consisted of a high test mainline, either monofilament or solid braided nylon depending on the survey in question, which included 50 - 100 gangs with baited 15/0 circle hooks. Each hook was baited with between 0.5 – 1 kg of *Scomber scombrus* (half or whole) and allowed to soak for between 30 and 120 minutes before retrieval to reduce mortality of non-targeted species. Fishery independent gillnets were 700 ft. long, 5 ft tall, with 5 inch stretch

monofilament netting. Each net was allowed to soak for approximately 30 min to reduce mortality of non-targeted species. Once captured animals were euthanized via anesthesia without revival via immersion in 1 g/L tricane methanesulfonate (MS-222) and severing the spinal cord and a field dissection was performed to collect stomachs. Stomachs were taken back to the lab and either preserved in 10% buffered formalin or frozen until gut content could be analyzed.

Stomachs

Stomachs were dissected and large prey items were removed. Following removal of all large items the stomach was then rinsed over a 2mm seine to collect any small items such as otoliths or carapaces. Once removed all items were rinsed before identification to lowest possible taxonomic group. Identified items were then quantified and wet weights were taken to the nearest 0.1 g for each individual prey item.

Data analysis

Cumulative prey curves were constructed for both *C. acronotus* as a whole and male and female samples to determine if sample size was suitable for dietary analysis. To construct these curves the order in which stomachs are analyzed were randomized ten times, with the mean number of new prey items being plotted against the total number of stomachs examined for each of the three sample groups (Ferry et. al. 1996).

The Index of Relative Importance (IRI), which facilitates comparisons of diets across species and studies, was calculated for the prey items of each group using the equation modified from Pinkas et. al. (1971) where volumetric percentage (%V) is replaced by the gravimetric percentage (%W) resulting in the equation:

$$IRI = (\%N + \%W) / (\%O)$$

In the above equation %N is the relative abundance of a particular prey item expressed as a percentage, % W is the total wet-weight of a particular prey item divided by the wet weight of all prey items and multiplied by 100, and %O is the frequency of occurrence of a given prey item expressed as a percentage.

Dietary composition was analyzed based on the suggestions of Cortés (1997) utilizing the calculated IRI expressed as a percentage (%IRI), where IRI_i is the index of relative importance for prey item i using the following equation:

$$\%IRI_i = 100 \frac{IRI_i}{\sum_{i=1}^n IRI_i}$$

For each dietary analysis a three dimensional graph was constructed based on the suggestion of Cortés et. al. (1997) and similar to the graph used by Gelsleichter et. al. (1999) with % W on the x-axis, % O on the y-axis and % N on the z-axis. The resulting graphs allow for a visual representation of predatory behaviors based upon where the data fall within the three-dimensional Cartesian graph.

Shannon-Weiner index was calculated to compare the diversity of diet within the population and between the sexes of *C. acronotus* using the equation:

$$H = - \sum (p_i \log[p_i])$$

Where p_i is the proportion of prey item i in the diet of either the population or each sex.

To compare the diet across the sexes the Morisita (C_H) index was used to determine dietary overlap and to facilitate comparisons between studies. The equation is as follows:

$$C_H = 2 \frac{(\sum p_{ij}p_{ik})}{(\sum p_{ij}^2 + \sum p_{ik}^2)}$$

Where p_{ij} is the proportion of prey item i in the diet of males and p_{ik} is the proportion of prey item i found in females.

Results

A total of 90 sharks had their gut contents examined during the course of this study. Of those, 52 (57.8%) were empty. The stomachs from 37 females and 23 males were examined independently of one another. Empty guts were observed in 26 (70.3%) of the female stomachs and 10 (43.5%) of the male stomachs.

Despite the limited sample size and large numbers of empty guts cumulative prey curves for the total data set reached a defined asymptotic limits indicating that the sample size was large enough to accurately describe the diet. This however was not the case with the individual male or female diets (Figures 8-11). Though the male and female samples provide only a portion of the total dietary breadth of the sexes the dietary indices were reported for each sex nonetheless.

Combined sexes

Teleosts were the most important prey category of *C. acronotus* on a numerical (74.5%) gravimetric (85.1%) and occurrence (64.0%) basis. The %IRI indicated that

teleosts made up 63.4% of the diet (Table 1). Within the teleosts, sciaenids made up the largest portion of the diet having its own %IRI of 40.2%. By far the most abundant prey item was *Leiostomus xanthurus* found in 24% of the stomachs observed and was the most important overall lower taxon (%IRI = 12.1%). After teleosts Crustacea and Mollusca made up 22.7% and 11.4% of the diet respectively. The rest of the prey categories made up only a small fraction of the remaining diet.

Female

The most important prey category for females was teleosts on a numerical (77.1%) gravitative (92.3%) and occurrence (65.2%) basis and making up 75.2% of the diet as indicated by %IRI (Table 2). Sciaenids were the most important teleost group comprising of 48.3% of the diet. After teleosts, Anguilliformes composed 11.1% of the diet with the remaining fraction being composed of crustaceans, mollusks and echinoderms respectively.

Males

Male diets consisted mainly of teleosts as this category was once again the most important prey category on a numerical (78.4%) gravitative (75.6%) and occurrence (66.7%) and making up 60% of the male diet. A common Atlantic octopus *Octopus vulgaris* was found in the stomach of one male shark, however after calculations ended up an important part of the dietary breadth 14.2%. A small *Rhizoprionodon terraenovae* found in a single stomach made up another 10.2% of the male diet followed by crustaceans and Anguilliformes respectively (Table 3).

Comparison of male and female diets

The blacknose shark has a highly homogeneous diet composed mainly of teleosts. When viewed separately, females appear to be more homogeneous than the males with teleosts composing almost 10% more of their overall diet. Males in contrast had a more heterogeneous diet (Figure 12 – 14). This higher heterogeneity in male diet is supported by Shannon-Weiner index values of 2.06 for males and 1.89 for females. Furthermore there is a weak, but significant overlap between the sexes for prey items as indicated by the Morisitas overlap index (0.68; Table 4).

Discussion

The diet of *C. acronotus* was dominated by demersal teleosts in the family Sciaenidae. The large numbers of empty stomachs can most likely be attributed to the method by which animals were caught, via baited hooks on a bottom longline. The use of baited hooks has been shown to be bias in catching sharks with empty stomachs as it is usually hungry sharks that bite. Males and females of *C. acronotus* have similar dietary habits as the animals are not sexually segregated and thus feed in the same niche. However, current data suggests that males may be less selective of what they will prey upon than females. It is as yet unclear to the mechanisms that cause this discrepancy, or if it statistically exists.

The most abundant prey items found in the guts of *C. acronotus* were sciaenids, of which the spot croaker *Leiostomus xanthurus* dominated. As such sciaenids, such as *L. xanthurus*, appear to play an important role in the diets of *C. acronotus*. Sciaenids are a common prey item for many predatory fishes including bluefish, striped bass and summer

flounder and make up an important component of estuarine foodwebs (Govoni et. al. 1986).

This study was the first of its kind on *C. acronotus* and the first in which diet was segregated by sex. Though the accuracy of males was limited due to low sample size, they nonetheless had the most variability in their diet, which included the elasmobranch *Rhizoprionodon terraenovae* and an entire *Octopus vulgaris*. In contrast females fed almost exclusively on teleosts. This slight discrepancy between the male and female dietary breadths may be significant if sample size is increased. It is possible that the higher homogeneity seen in females, if shown to be significant, could be due to a difference in home ranges leading to differences in prey availability. The difference is unlikely to be due to seasonal changes as sharks were caught throughout the year. It is however possible that the larger females are more inclined to feed on prey items which have a higher caloric content to increase the energy stores needed for reproduction (Reck et. al. 2007).

This study suggests that, *C. acronotus* prefers teleosts to other prey items. This would mean that the higher bycatch of blacknose in shrimp trawls may be due to the animals feeding on demersal fishes in the shrimping grounds. The blacknose shark may not prey on the shrimp caught in the net as much as the fish that are excluded by the fish exclusion device (FED). However, these same FEDs will also prevent the removal of *C. acronotus* as bycatch thus reducing the cost to fishermen as well as the environmental costs (Schick et al, 1999).

The removal of *C. acronotus* from the ecosystem could lead to an increase in the population of smaller foraging sciaenids which could in turn decrease the populations of polychaetes as well as bivalves in the area through the predation of these foragers (Zapfe et al. 2008). With managers beginning to look at more of a community-based management, predator prey interactions and the possible consequences of a community losing an important predator, such as a shark, should be taken into account when making decisions (NOAA 2011).

. Further research should include a possible tracking study to determine home ranges and possible differences of these home ranges between the sexes, as well as looking at possible ontogenetic shifts in diet. A monitoring of the prey species, *L. xanthurus* should also be considered to determine if *C. acronotus* is following its prey or if it is selectively preying upon any small sciaenid that it comes across.

CONCLUSION

The studies presented here suggest that the blacknose shark is biologically capable of reproducing both annually and biennially which may lead to some possible changes in management of the species. Likewise the diet study has shown that the blacknose is a highly piscivorous marine predator specializing in demersal fishes, in particular the sciaenids. Future management decisions should account for both of these new data when developing new or evaluating current management of the blacknose shark.

Future studies on the blacknose shark should concentrate on their movements and habitat usage with an emphasis on comparing home ranges to their prey movements. If the blacknose is following their favored prey items into and out of estuarine environments it may lead to a predictive factor of when the blacknose occurs in a certain area giving rise to better or more efficient management regimes. Along with movement, reproduction should be further evaluated to determine what the mechanism is, if any, for changing between annual and biennial reproductive periods as this knowledge would also contribute heavily to management decisions in either a temporal or regional way.

APENDEX

Figure 1

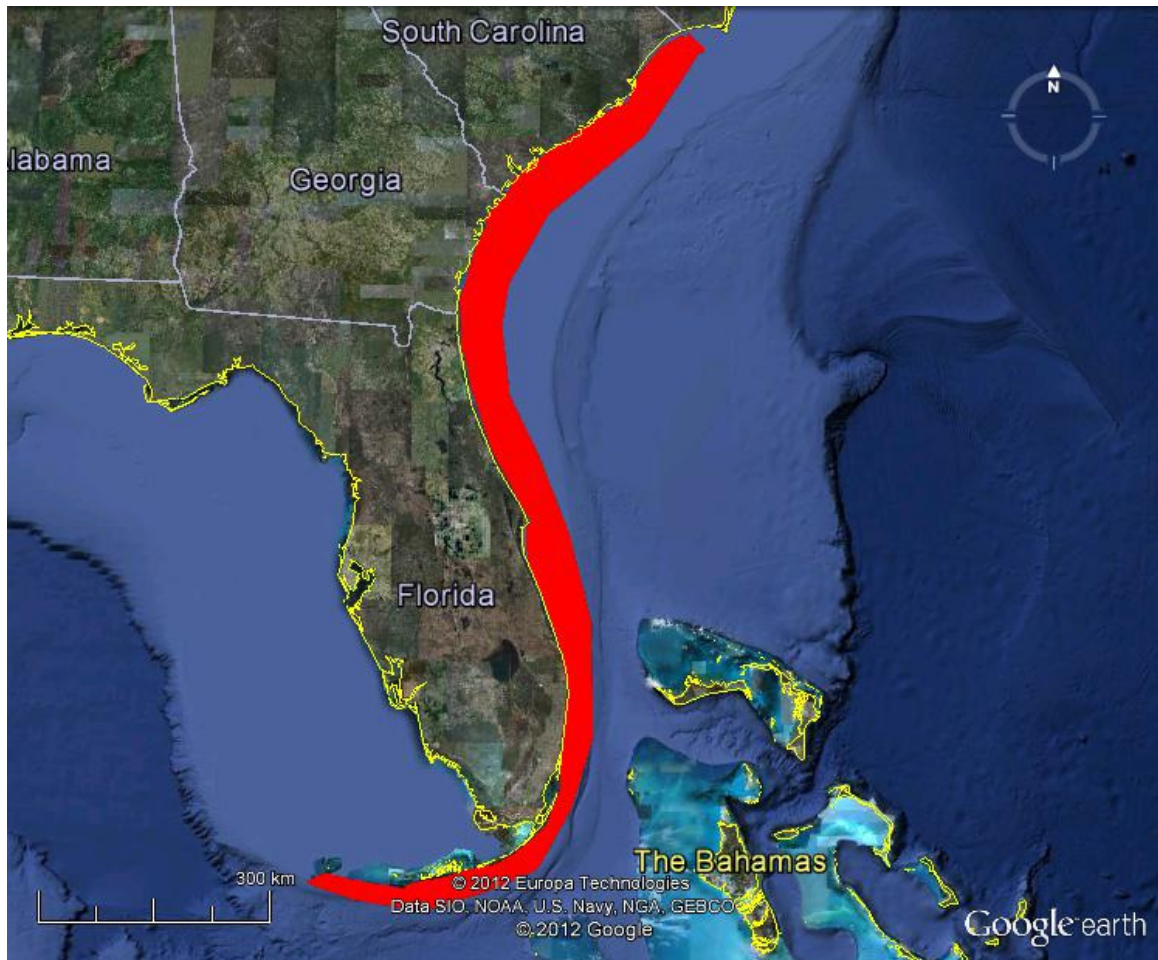


Figure 2

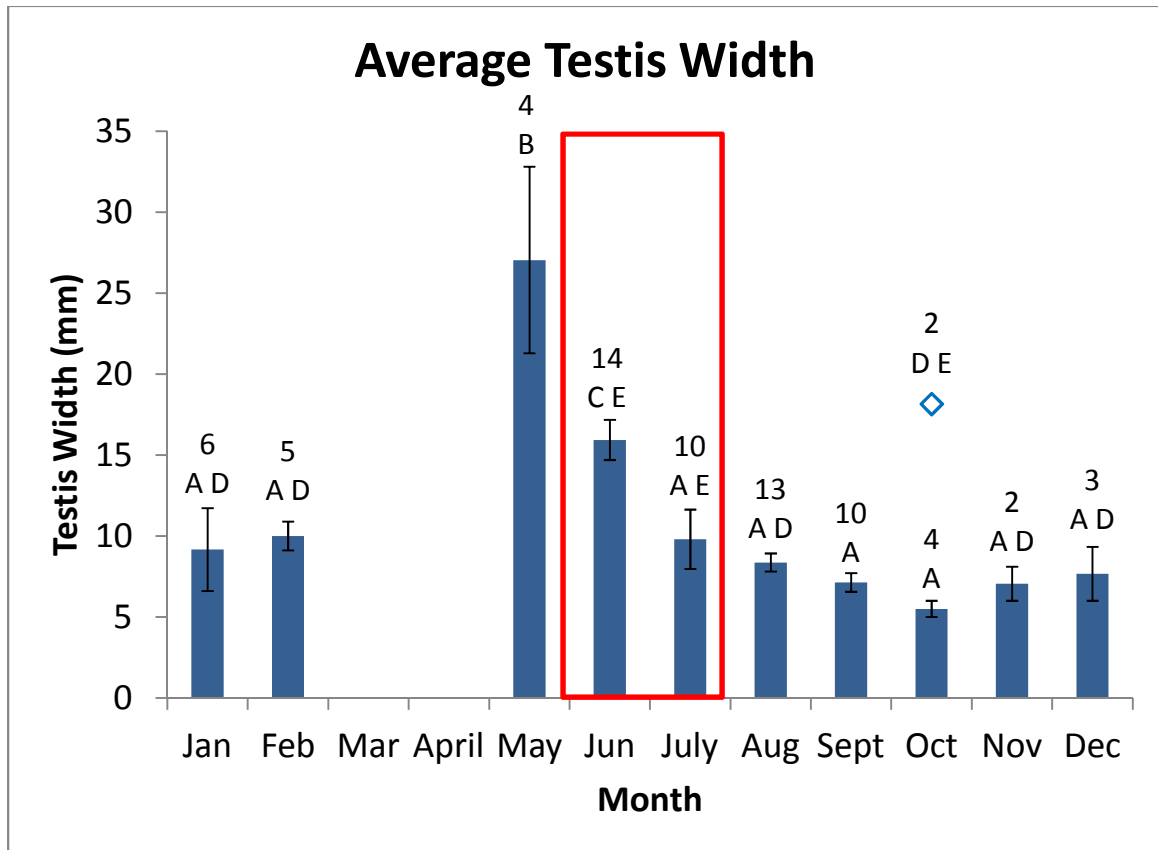


Figure 3

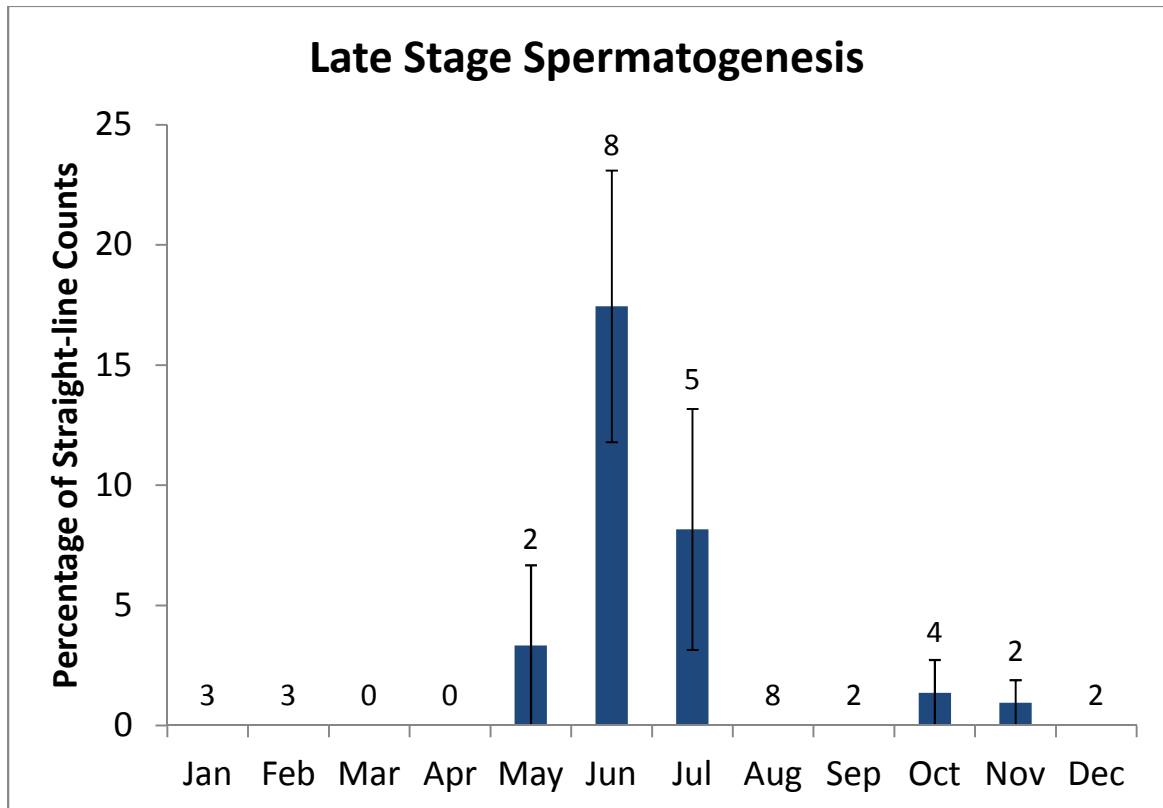


Figure 4

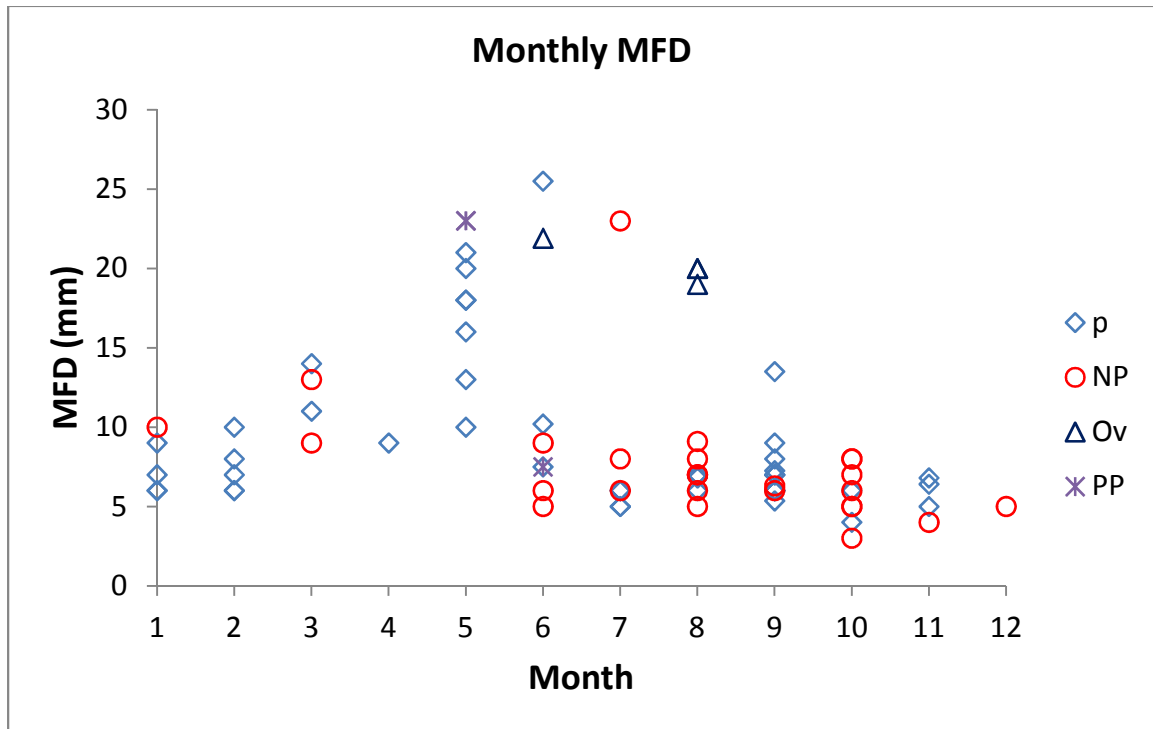


Figure 5

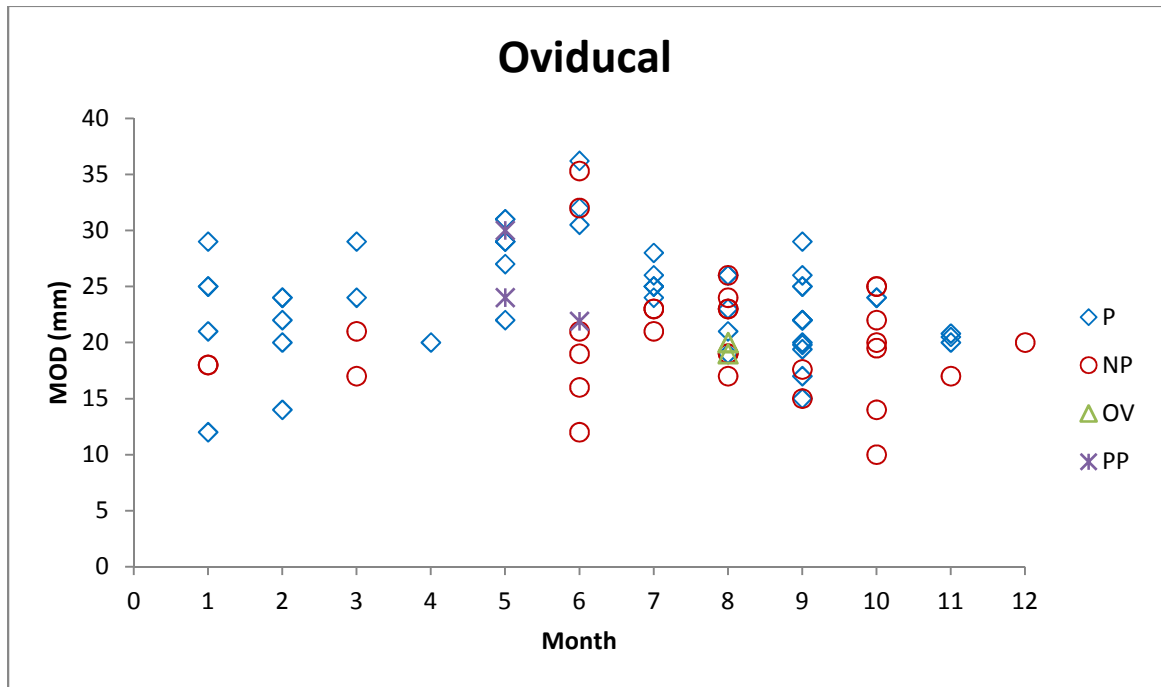


Figure 6

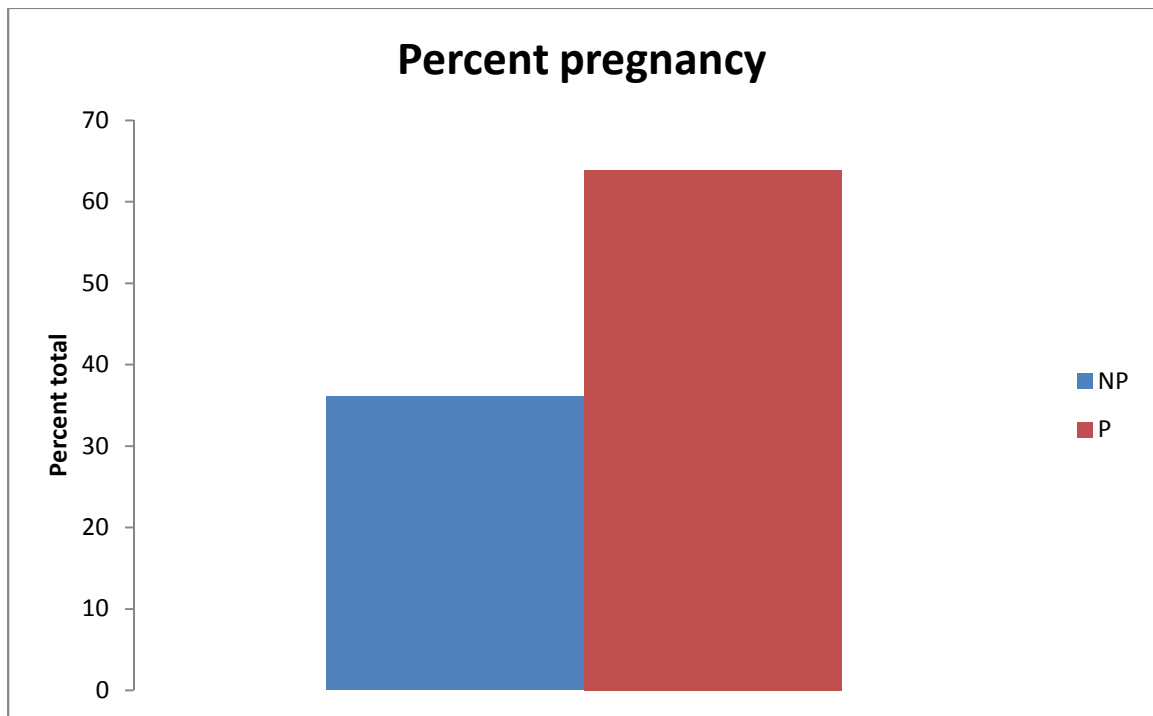


Figure 7

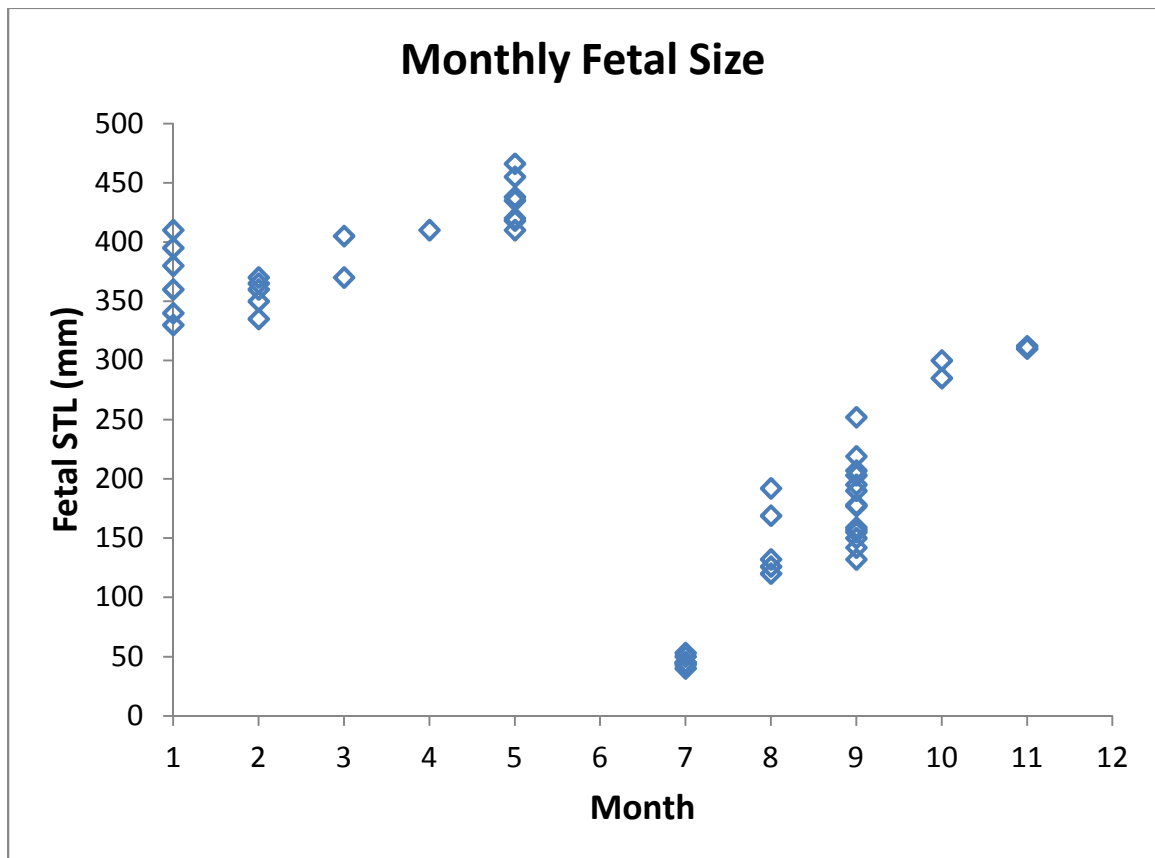


Figure 8

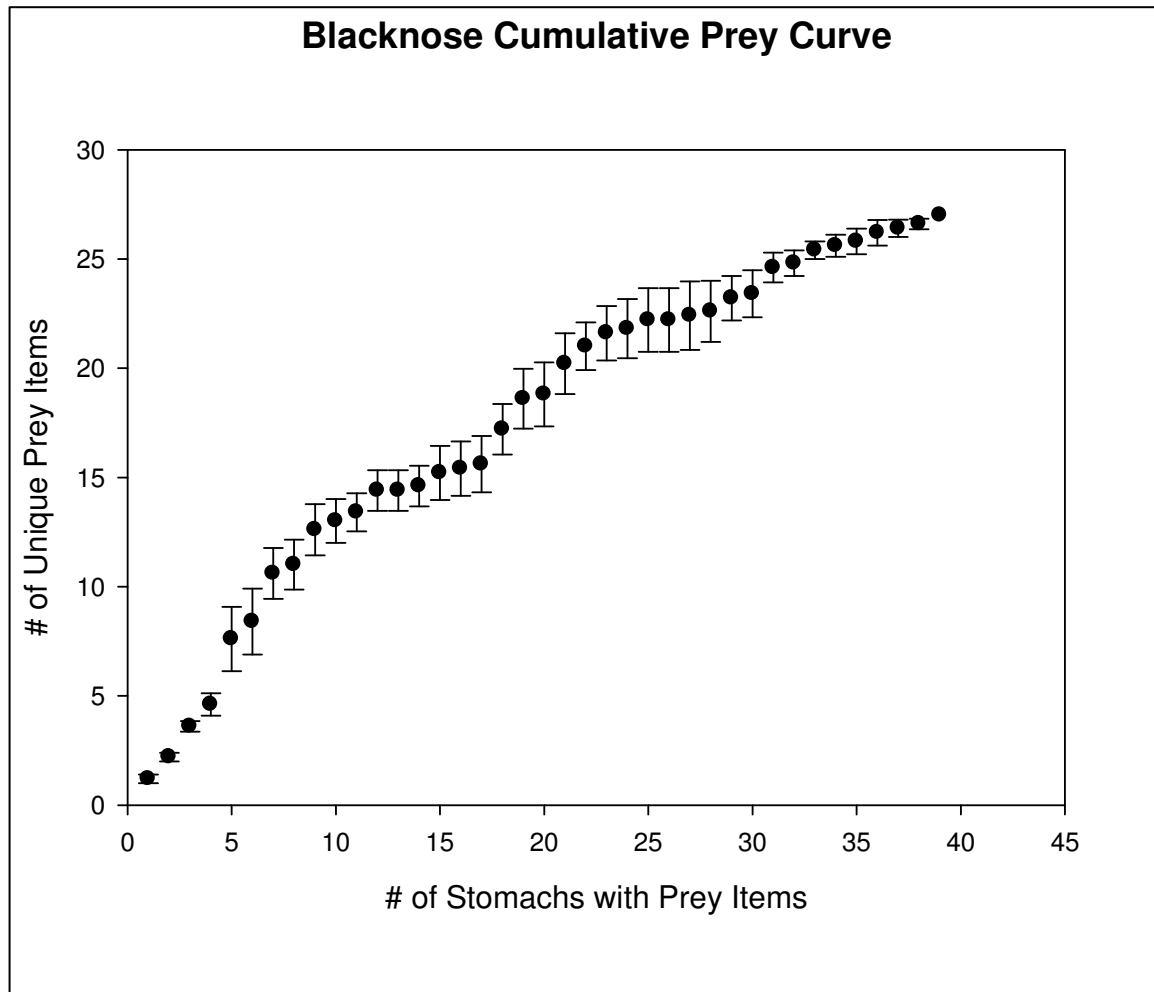


Figure 9

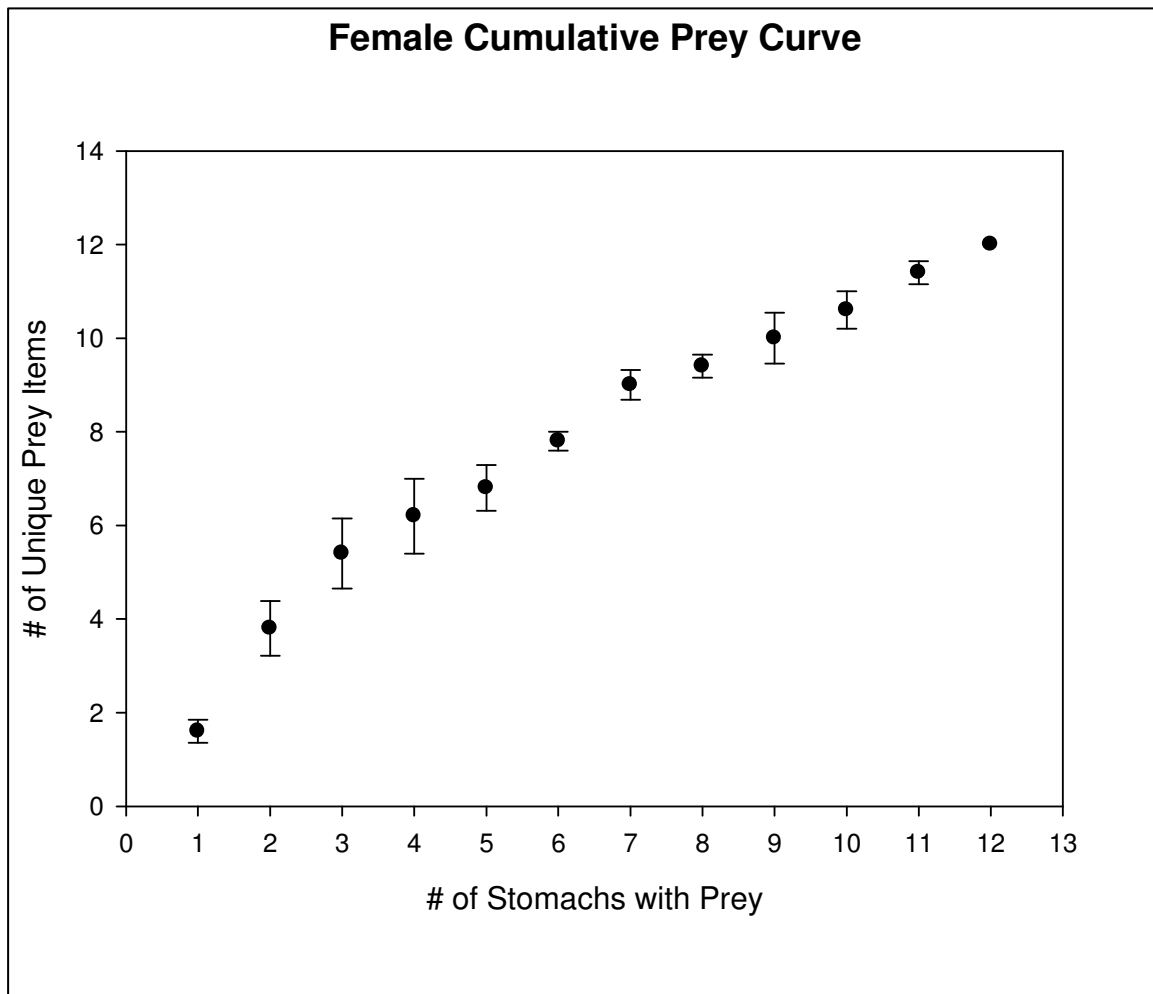


Figure 10

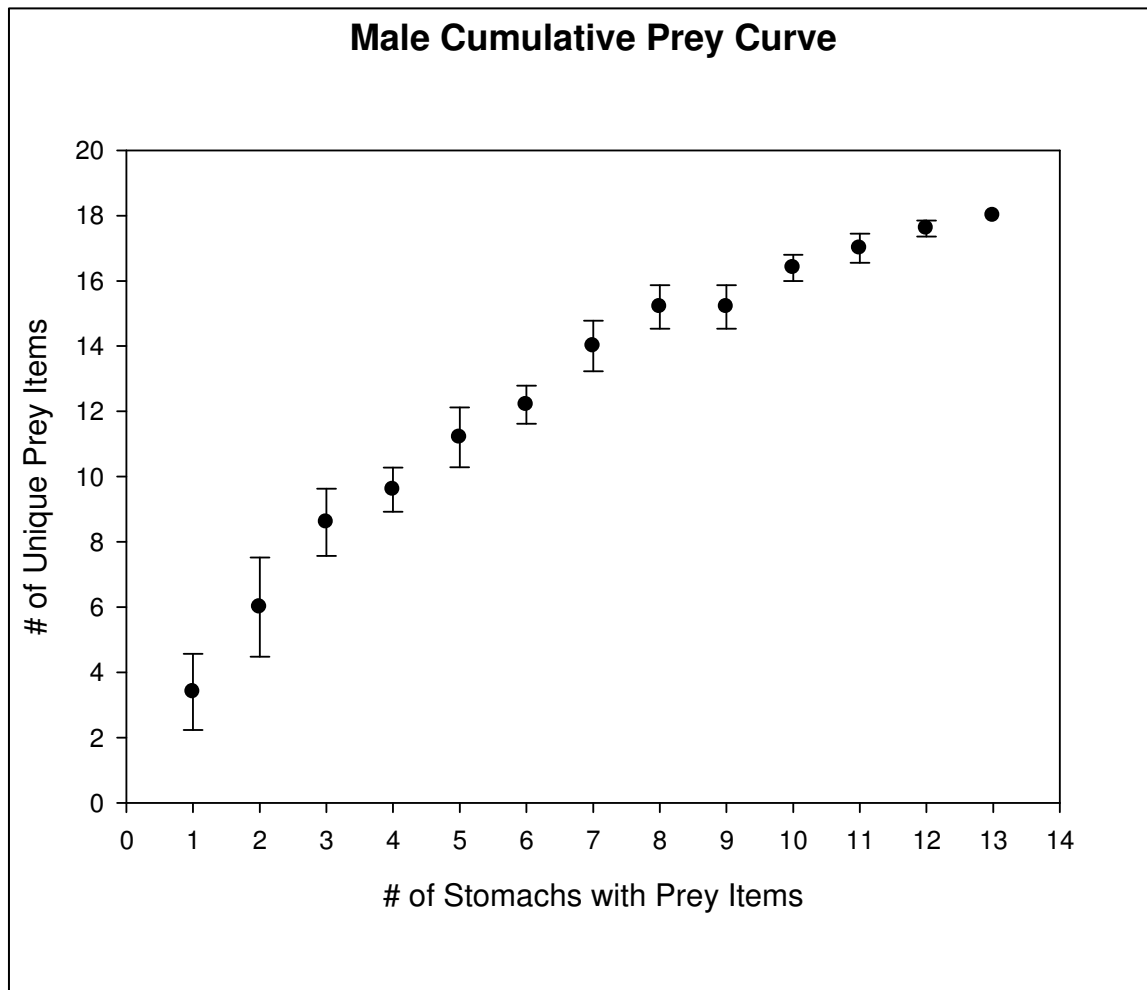


Figure 11

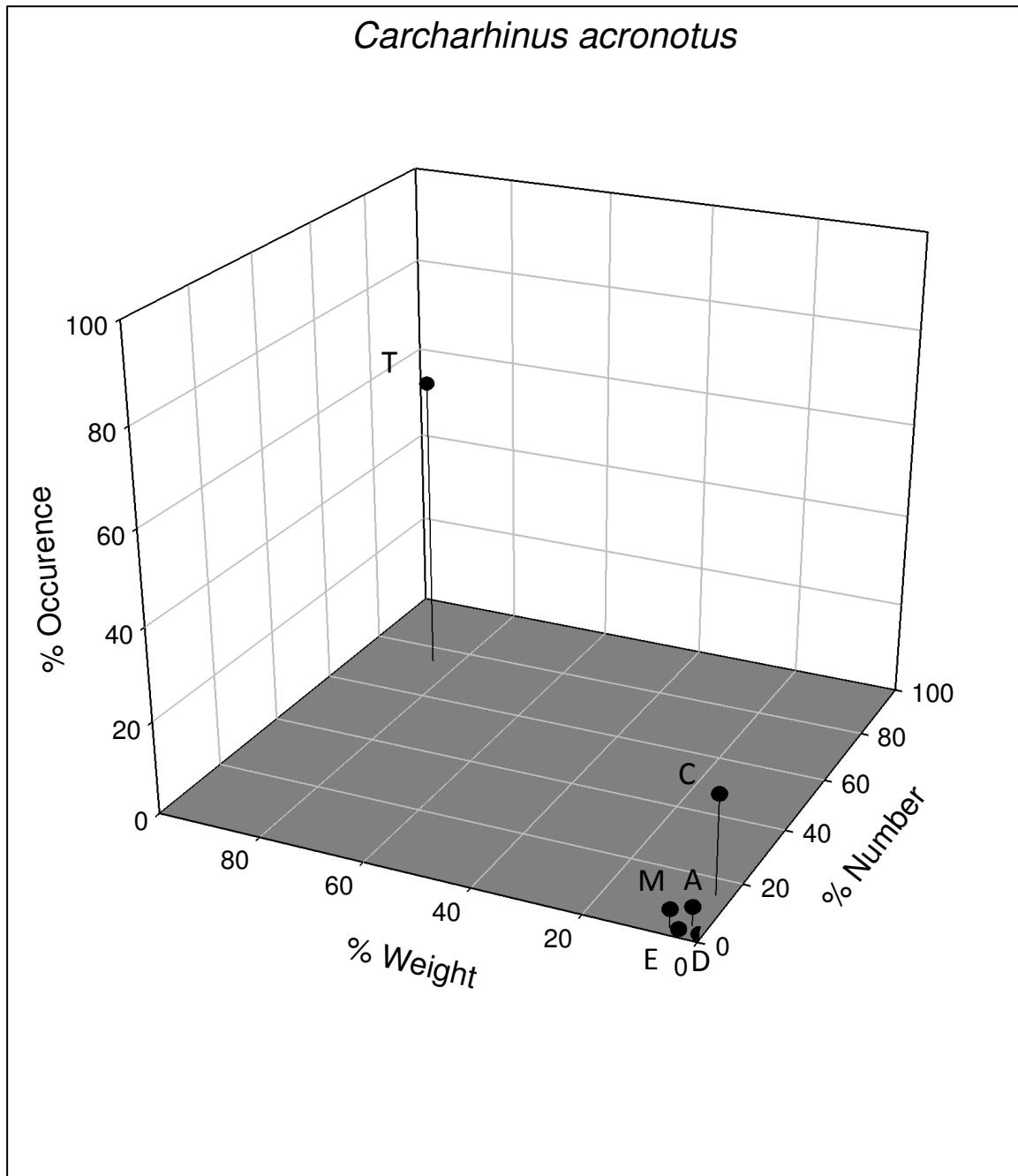


Figure 12

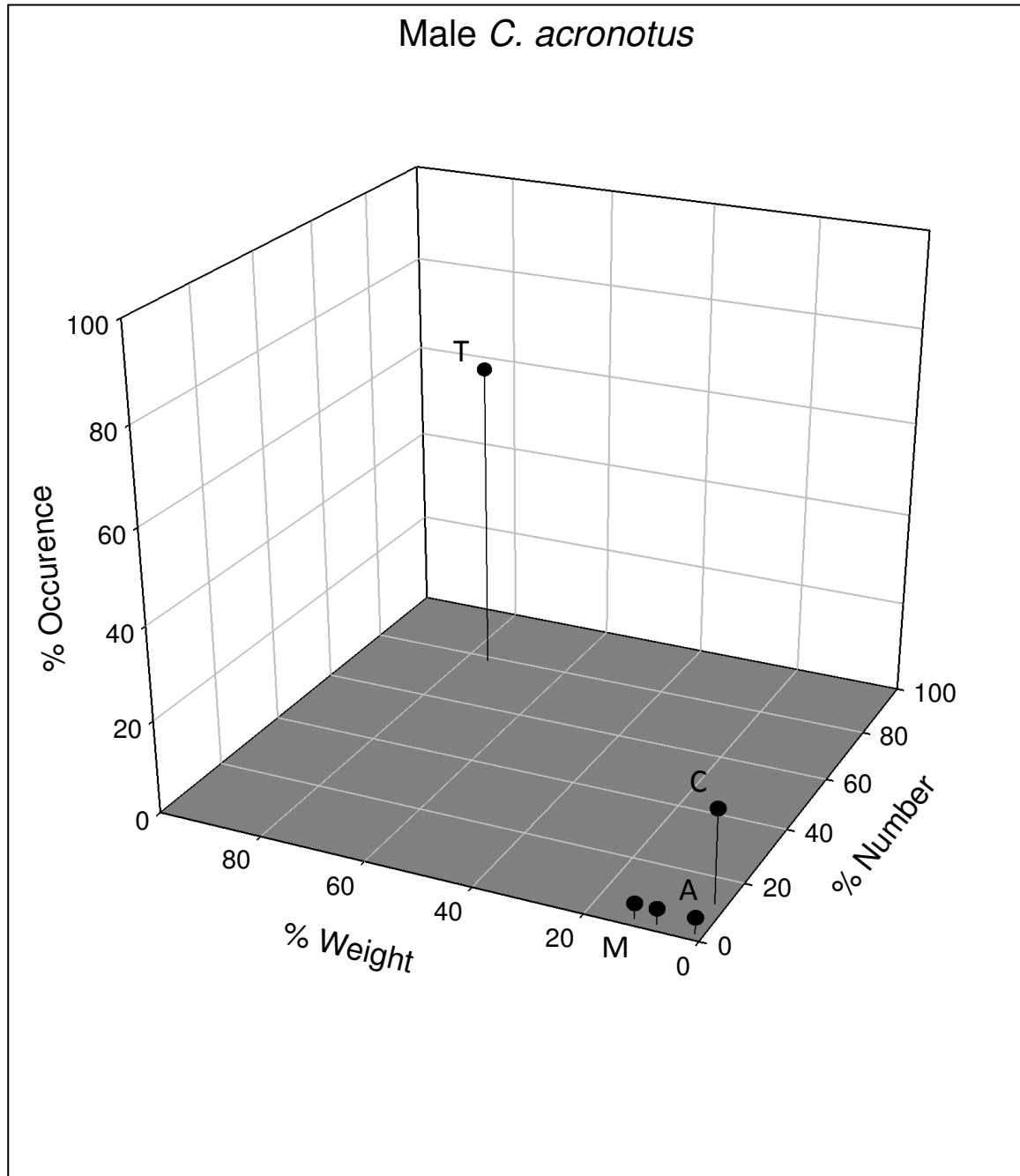


Figure 13

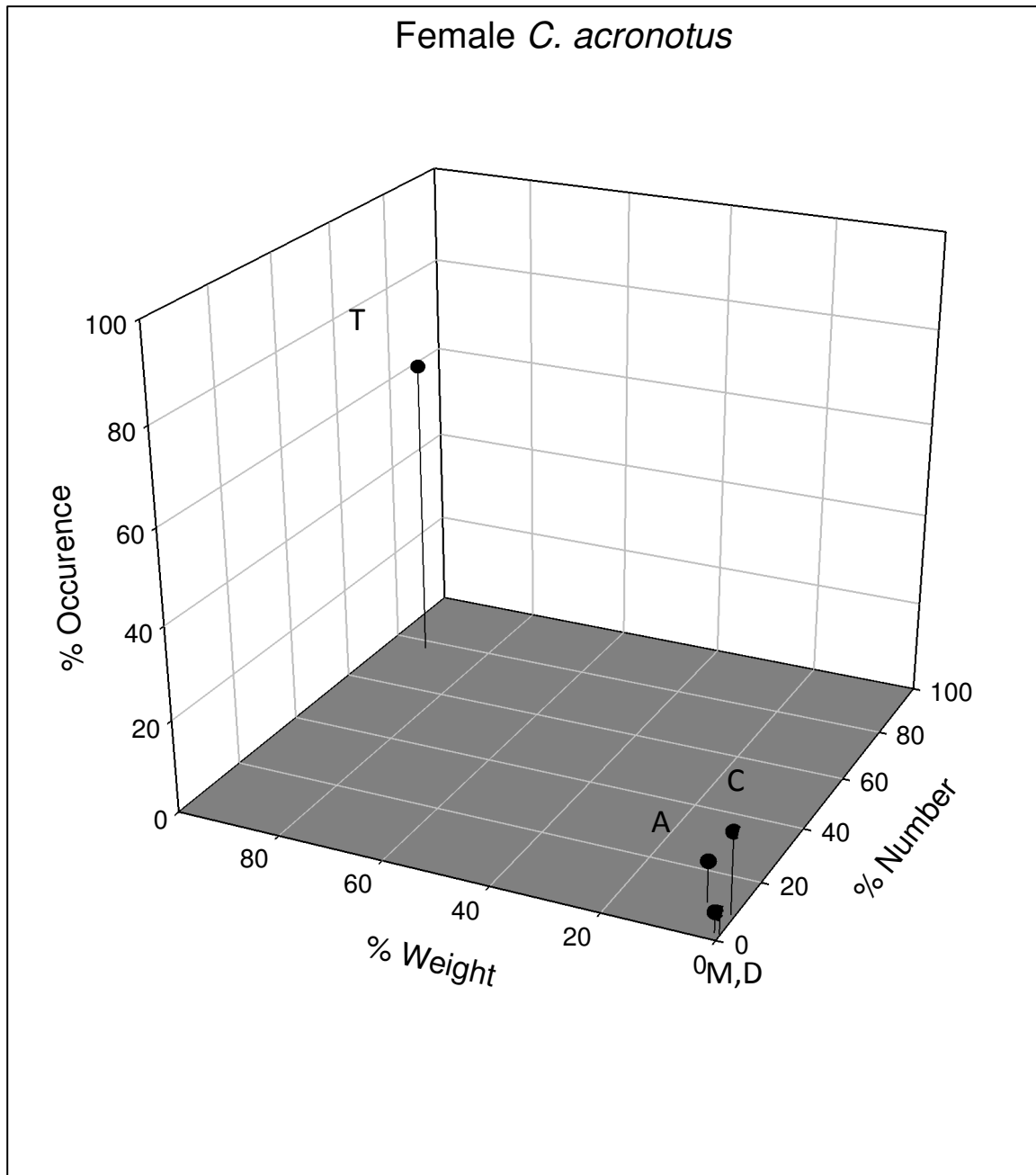


Table 1

| Source of variation | SS | DF | Mean Square | F | P |
|---------------------|---------|----|-------------|-------|---------|
| Groups | 2312.08 | 10 | 231.21 | 15.78 | <0.0001 |
| Residual | 879.06 | 60 | 14.65 | | |
| Total | 3191.14 | 70 | | | |

Table 2

| | Shannon-Weiner Index |
|-----------------|-------------------------|
| Males | 2.14 |
| Females | 1.89 |
| Morisita | 0.67 |

Table 3

| Prey Items | %N | %W | %O | %IRI | (%IRI _{Type}) |
|--------------------------------|------|------|------|------|-------------------------|
| Unknown | 2.8 | 0.5 | 4 | 1.9 | 1.9 |
| Teleost | | | | | 63.4 |
| Unknown | 27.7 | 24 | 22.7 | 5.1 | |
| Sciaenidae | | | | | |
| <i>Leiostomus xanthurus</i> | 24.8 | 40.6 | 12 | 12.1 | |
| <i>Cynoscion regalis</i> | 0.7 | 3.8 | 1.3 | 7.5 | |
| <i>Micropogonias undulatus</i> | 2.8 | 3.7 | 2.7 | 5.4 | |
| <i>Menticirrhus littoralis</i> | 2.8 | 2.2 | 4 | 2.8 | |
| <i>Stellifer lanceolatus</i> | 0.7 | 0.4 | 1.3 | 1.8 | |
| Unknown | 5.7 | 4.7 | 4 | 10.6 | |
| Pleuronectiformes | | | | | |
| Unknown | 3.5 | 0.8 | 5.3 | 1.8 | |
| Sparidae | | | | | |
| <i>Lagodon rhomboides</i> | 0.7 | 1 | 1.3 | 2.9 | |
| Triglidae | | | | | |
| <i>Prionotus spp.</i> | 0.7 | 1.1 | 1.3 | 3.1 | |
| Trichiuridae | | | | | |
| <i>Trichiurus lepturus</i> | 0.7 | 0.8 | 1.3 | 2.5 | |
| Macrouridae | | | | | |
| <i>Nezumia spp.</i> | 0.7 | 0.8 | 1.3 | 2.5 | |
| Clupeidae | | | | | |
| <i>Brevoortia spp.</i> | 1.4 | 0.3 | 2.7 | 1.4 | |
| Synodontidae | | | | | |
| <i>Synodus spp.</i> | 0.7 | 0.5 | 1.3 | 2.1 | |
| Scombridae | | | | | |
| <i>Scomber scombrus</i> | 0.7 | 0.4 | 1.3 | 1.9 | |
| Elasmobranchii | | | | | 7.1 |
| Carcharhinidae | | | | | |
| <i>Rhizoprionodon</i> | 0.7 | 3.5 | 1.3 | 7.1 | |
| Anguilliformes | | | | | 3.8 |
| Anguillidae | | | | | |
| <i>Anguilla spp.</i> | 4.3 | 2.6 | 4 | 3.8 | |
| Crustacea | | | | | 11.3 |
| Decapoda | | | | | |
| Brachyura | | | | | |
| unknown | 2.1 | 0.2 | 4 | 1.3 | |
| Caridea | | | | | |
| Unknown | 8.5 | 1.6 | 14.7 | 1.5 | |
| Penaeidae | | | | | |
| <i>Litopenaeus setiferus</i> | 3.5 | 0.6 | 1.3 | 6.8 | |

| | | | | | |
|-------------------------|-----|-----|-----|-----|------|
| Squilla | | | | | |
| <i>Squilla spp.</i> | 0.7 | 0.3 | 1.3 | 1.6 | |
| Mollusca | | | | | 11.4 |
| Cephalopoda | | | | | |
| Unknown | 1.4 | 0.4 | 2.7 | 1.5 | |
| Octopoda | | | | | |
| <i>Octopus vulgaris</i> | 0.7 | 5.2 | 1.3 | 9.9 | |
| Echinodermata | | | | | 1.2 |
| Ophiuroidia | | | | | |
| Unknown | 0.7 | 0 | 1.3 | 1.2 | |

Table 4

| Prey Item | %N | %W | %O | IRI | %IRI | (%IRI _{Type}) |
|--------------------------------|------|------|------|-----|------|-------------------------|
| Teleost | | | | | | 75.2 |
| Unknown | 14.6 | 18.5 | 17.4 | 1.9 | 11.4 | |
| Sciaenidae | | | | | | |
| <i>Leiostomus xanthurus</i> | 43.8 | 64.2 | 17.4 | 6.2 | 37.3 | |
| <i>Menticirrhus littoralis</i> | 6.3 | 4.5 | 8.7 | 1.2 | 7.4 | |
| <i>Stellifer lanceolatus</i> | 2.1 | 0.6 | 4.3 | 0.6 | 3.6 | |
| Pleuronectiformes | | | | | | |
| Unknown | 6.3 | 1.2 | 8.7 | 0.9 | 5.2 | |
| Macrouridae | | | | | | |
| <i>Nezumia spp.</i> | 2.1 | 2.2 | 4.3 | 1.0 | 6.0 | |
| Clupeidae | | | | | | |
| <i>Brevoortia spp.</i> | 2.1 | 1.0 | 4.3 | 0.7 | 4.3 | |
| Anguilliformes | | | | | | 11.1 |
| <i>Anguilla spp.</i> | 10.4 | 5.7 | 8.7 | 1.9 | 11.1 | |
| Crustacea | | | | | | 6.3 |
| Decapoda | | | | | | |
| Brachyura | | | | | | |
| unknown | 4.2 | 0.3 | 8.7 | 0.5 | 3.1 | |
| Caridea | | | | | | |
| Unknown | 4.2 | 0.4 | 8.7 | 0.5 | 3.2 | |
| Molluska | | | | | | 4.3 |
| Cephalopoda | | | | | | |
| Unknown | 2.1 | 1.0 | 4.3 | 0.7 | 4.3 | |
| Echinodermata | | | | | | 3.2 |
| Ophiuroidia | | | | | | |
| Unknown | 2.1 | 0.2 | 4.3 | 0.5 | 3.2 | |

Table 5

| Prey Item | %N | %W | %O | IRI | %IRI | %IRIT |
|-----------------------------------|------|------|------|------|------|-------|
| Unknown | 3.9 | 1.1 | 3.3 | 5.0 | 5.1 | 5.1 |
| Teleost | | | | | | 60.0 |
| Unknown | 39.2 | 26.5 | 23.3 | 9.4 | 9.6 | |
| Sciaenidae | | | | | | |
| <i>Leiostomus xanthurus</i> | 19.6 | 32.4 | 13.3 | 13.0 | 13.3 | |
| <i>Micropogonias undulatus</i> | 2.0 | 1.8 | 3.3 | 3.8 | 3.9 | |
| Unknown | 5.9 | 6.3 | 6.7 | 12.2 | 12.5 | |
| Pleuronectiformes | | | | | | |
| Unknown | 2.0 | 0.5 | 3.3 | 2.5 | 2.5 | |
| Sparidae | | | | | | |
| <i>Lagodon rhomboides</i> | 2.0 | 2.3 | 3.3 | 4.2 | 4.3 | |
| Triglidae | | | | | | |
| <i>Prionotus spp.</i> | 2.0 | 2.6 | 3.3 | 4.5 | 4.6 | |
| Trichiuridae | | | | | | |
| <i>Trichiurus lepturus</i> | 2.0 | 1.8 | 3.3 | 3.8 | 3.8 | |
| Clupeidae | | | | | | |
| <i>Brevoortia spp.</i> | 2.0 | 0.2 | 3.3 | 2.2 | 2.2 | |
| Synodontidae | | | | | | |
| <i>Synodus spp.</i> | 2.0 | 1.2 | 3.3 | 3.2 | 3.2 | |
| Elasmobranchii | | | | | | |
| Carcharhinidae | | | | | | 10.2 |
| <i>Rhizoprionodon terraenovae</i> | 2.0 | 8.0 | 3.3 | 10.0 | 10.2 | |
| Anguilliformes | | | | | | 3.5 |
| Anguillidae | | | | | | |
| <i>Anguilla spp.</i> | 2.0 | 1.4 | 3.3 | 3.4 | 3.5 | |
| Crustacea | | | | | | 7.0 |
| Squillidae | | | | | | |
| <i>Squilla spp.</i> | 2.0 | 0.6 | 3.3 | 2.6 | 2.6 | |
| Caridea | | | | | | |
| Unknown | 7.8 | 1.3 | 13.3 | 2.3 | 2.3 | |
| Unknown | 2.0 | 0.0 | 3.3 | 2.0 | 2.0 | |
| Molluska | | | | | | 14.2 |
| Octopoda | | | | | | |
| <i>Octopus vulgaris</i> | 2.0 | 11.9 | 3.3 | 13.9 | 14.2 | |

WORKS CITED

- Carrier, J.C. Musick, J.A. and Heithaus M.R., editors. Biology of Sharks and their Relatives. CRC pp. 225 – 246.
- Castro, J.I. (2011). The sharks of North America. Oxford University Press.
- Compagno, L., Dando, M, Fowler, S. (2005). Sharks of the World. *Princeton Univ. Press* pgs. 288 – 289.
- Compagno, L.J.V. (1984). Sharks of the World. An annotated and illustrated catalogue of Shark species known to date. Part 2: Carcharhiniformes. FAO Fish Synopsis 4 (125), Part 2: 251 – 655.
- Cortés, E. (1997). A critical review of methods of studying fish feeding based on analysis of stomach contents: Application to elasmobranch fishes. *Canadian Journal of Fisheries and Aquatic Sciences*. **54**: 726 – 738.
- Driggers, W. B. and Hoffmayer, E. R. (2009). Variability in the reproductive cycle of finetooth sharks, *Carcharhinus isodon*, in the northern Gulf of Mexico. *Copeia* **2**: 390 – 393
- Driggers, W. B., Oakley, A. A., Ulrich, G., Carlson, J. K., Cullum, B. J., Mean, J. M. (2004). Reproductive biology of *Carcharhinus acronotus* in the coastal waters of South Carolina. *Journal of Fishery Biology*. **64**: 1540 – 1551
- Ferry, L. A., and Cailliet, G. M. (1996). Sample size and data analysis: Are we Characterizing diet properly? In: Feeding Ecology and Nutrition in Fish: Proceedings of the Symposium on the Feeding Ecology and Nutrition in Fish. (D. MacKinlay and K. Shearer, eds.). American Fisheries Society. International Congress on the Biology of Fishes, San Francisco, CA. pp. 71 – 80.
- Gelsleichter, J., Musick, J. A., Nichols, S. (1999). Food habits of the smooth dogfish, *Mustelus canis*, dusky shark, *Carcharhinus obscurus*, Atlantic sharpnose shark, *Rhizoprionodon terraenovae*, and the sand tiger, *Carcharhinus taurus*, from the north Atlantic Ocean. *Env. Biol. of Fish.* **54**: 205-217.
- Govoni, J. J., Ortner, P.B., Al-Yamani, F., Hill, L.C. (1986). Selective feeding of spot, *Leiostomus xanthurus*, and Atlantic croaker, *Micropogonias undulatus*, larvae in the northern Gulf of Mexico. *Marine Ecology*. **28**: 175-183.
- Hazin, F. H. V., Oliveira, P. G., Broadhurst, M. K. (2002). Reproduction of the blacknose shark (*Carcharhinus acronotus*) in coastal waters off northeastern Brazil. *Fishery Bulletin* **100**: 143 – 148.
- Maruska, K.P., Cowie, E. G., Tricas, T. C. (1996). Periodic gonadal activity and protracted mating in elasmobranch fishes. *Journal of Experimental Zoology*. **3**: 219 – 232.
- NMFS. (2011). SEDAR 13 HMS Atlantic Blacknose Shark. Pg. 9 - 43.
- NMFS. (2007). SEDAR 13 SCS. Pg 1 – 130.
- NOAA. (2011). Clarifying the relationships among ecosystem based management; integrated ecosystem assessments; and, coastal and marine special planning. Pg. 1 - 14.
- Pinkas, L. M., Oliphant, S., Iverson, L. K. (1971). Food habits of albacore, bluefin tuna, and bonito in Californian waters. *California Fish and Game* **152**: 1 – 105.
- Recks, M.A., and Seaborn, G. T. (2008). Variation in fatty acid composition among nine forage species from a southeastern US estuarine and nearshore coastal ecosystem. *Fish Physiol Biochem*. **34**: 275-287.

- Schick, D., Brown, M., and Gallagher, D. (1999). Reduction of finfish and juvenile shrimp bycatch in the Gulf of Main northern shrimp fishery through the use of a modified double Nordmore grate, Grant number NA76FD0097. NMFS Northeast Regional Office, 1 Blackburn Dr. Gloucester, MA.
- Sulikowski, J. A., Driggers, W. B., Ford, T. S., Boonstra, R. K., Carlson, J. K. (2007). Reproductive cycle of the blacknose shark *Carcharhinus acronotus* in the Gulf of Mexico. *Journal of Fishery Biology*. **70**: 428 – 440.
- Thorpe, T. and Frierson, D. (2009). Bycatch mitigation assessment for sharks caught in coastal anchored gillnets. *Fisheries Research*. **98**: 102 – 112
- Trent, L., Parsgley, D.E., Carlson, J.K. (1997). Catch and bycatch in the shark drift gillnet fishery off Georgia and east Florida. *Marine Fisheries. Rev* **59**(1): 19 – 28
- Wetherbee, B.M. and Cortés, E. (2004). Food consumption and feeding habits. in: *Biology of sharks and their relatives*. CRC pp. 225 – 246.
- Zapfe, G. A. and Rakocinski, C.F. (2008). Coherent growth and diet patterns in juvenile spot (*Leiostomus xanthurus*) reflect effects of hydrology on access to shoreline habitat. *Fisheries Research* **91**: 107-111.

VITA

Ryan Michael Ford was born . At an early age he began learning about the ocean from books and his parents. After graduating from Lawton Chiles High School in 2003, he enrolled in the Bachelors of Science program at Florida State University where he studied Biology. During his time at FSU, Ryan worked at a barista at a local bookstore. As an upperclassman Ryan enrolled in the Marine Biology Certificate Program where he got his first chance to work with sharks as an intern at the Virginia Institute of Marine Science in Gloucester, VA. After graduating in from FSU in 2009 with a B.S. degree and a Marine Biology Certificate, Ryan enrolled in the graduate program at the University of North Florida. There he spent countless hours on the water and lab collecting and analyzing samples for his Master's Thesis. Ryan currently works for Florida Fish and Wildlife Conservation Commission as a Biological Scientist.