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Feeding habits of blacktip sharks, Carcharhinus limbatus, and Atlantic sharpnose sharks, Rhizoprionodon terraenovae, in Louisiana coastal waters

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FEEDING HABITS OF BLACKTIP SHARKS, *CARCHARHINUS LIMBATUS*, AND ATLANTIC SHARPNOSE SHARKS, *RHIZOPRIONODON TERRAENOVAE*, IN LOUISIANA COASTAL WATERS

A Thesis

Submitted to the Graduate Faculty of the
Louisiana State University and
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in

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by
Kevin P. Barry
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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Little is known regarding the feeding behavior of many shark species. Even less is known about shark feeding habits in Louisiana coastal waters. The stomach contents of gillnet captured blacktip sharks (n=356), *Carcharhinus limbatus*, and Atlantic sharpnose sharks (n=55), *Rhizoprionodon terraenovae*, were examined in this study. Roughly half of the blacktip stomachs (52%) and sharpnose stomachs (45%) contained prey items. The primary prey item in terms of percent number, occurrence, and weight for blacktips and sharpnose was the gulf menhaden, *Brevoortia patronus*. Both blacktips and sharpnose appear to mainly be piscivores; however, no members of Sciaenidae, the most common family of teleosts in the sampling area in terms of number of species, were found in sharpnose stomachs. Based on temporal gillnet sampling, neonate blacktips undergo an increase in feeding activity in the late afternoon /early evening hours, whereas blacktips without an umbilical scar do not appear to follow this same pattern. Using a combination of the stomach content analysis and the derived Scale of Degradation for menhaden found in the stomachs of the blacktips, a digestion rate of approximately 24 hours was estimated for blacktips. Zero and one year old blacktip sharks grew at approximately 7.6 g/day and 0.47 mm/day. A comparison of the growth rate to the top 10% of stomach content weights yielded growth efficiencies between 13-25% depending on the frequency in which blacktips filled their stomachs with prey. I concluded that menhaden are an important food source for both blacktips and sharpnose in the area, providing the sharks with an abundant and nutritional food source, and directly contributing to the high growth rates for blacktips in the area.

INTRODUCTION

Despite the fact that many species of sharks are apex predators, little is known regarding their feeding habits. Blacktip sharks (blacktips), *Carcharhinus limbatus* and Atlantic sharpnose (sharpnose), *Rhizoprionodon terraenovae*, both considered top predators, are prevalent in the northern Gulf of Mexico; however, there have been few published findings on their diet and feeding behavior. Understanding the feeding patterns of these sharks is vital in assessing their influence on northern Gulf ecosystems.

Given their life history patterns (late sexual maturity, low fecundity, and a highly migratory nature) sharks are particularly susceptible to overfishing, and face the peril of being caught as bycatch in the large shrimping and menhaden fisheries in Louisiana coastal waters. de Silva et al. (2001) estimated that approximately 30,000 sharks were caught annually as releasable bycatch in the menhaden fishery alone for the 1994 and 1995 fishing seasons. Because most sharks feature late sexual maturity, low fecundity, and a highly migratory nature, they are particularly susceptible to overfishing. By understanding their feeding patterns, there is a potential for deriving new management schemes to ensure their survival and success.

Generally, blacktips are found in all tropical and subtropical waters. They are the most important commercial shark species in the southeastern United States after the sandbar shark (Castro 1996), and the most important commercial shark species in the northern Gulf of Mexico (NMFS 2001). Blacktips reach a maximum reported length of 2500 mm in the northern Gulf (Robins and Ray 1986), with males reaching maturity at approximately 1400 mm and females maturing at approximately 1500 mm. Blacktips are fast-swimming, often travel in schools, and are usually found near estuaries and river mouths. Blacktip sharks usually inhabit waters shallower than thirty meters, and they can enter freshwater environments but are rarely found there (Compagno 1984.)

The limited published research on blacktip feeding reports that blacktips are primarily piscivores. Dudley and Cliff (1993) examined stomachs of blacktip sharks (n=1290), with pre-caudal lengths (PCL) ranging from approximately 70-190 cm, caught in protective gillnets off the coast of South Africa. They reported teleosts were present in 83% of the stomachs that contained prey items. The most important prey species in terms of percent occurrence were from the jack and herring families. Bass et al. (1973) examined stomachs of blacktip sharks (n=101), ranging from approximately 65-176 cm PCL, caught off the coast of South Africa. They found teleosts were present in 93% of the stomachs that contained prey items. No further identification of the major prey items was made in this study. de Silva et al. (2001) found that blacktip sharks, ranging from 50-200 cm PCL, caught in commercial menhaden nets had stomachs that primarily contained menhaden. Menhaden occurred in approximately 55% of the blacktip stomachs that contained prey items (n=19). The researchers concluded that blacktip sharks were using menhaden schools as a forage base.

Sharpnose occur from New Brunswick to the southern Gulf of Mexico, and are the most abundant shark in the Gulf of Mexico. Sharpnose reach a maximum reported length of 110 cm (Robins and Ray 1986), with males maturing between 65-80 cm and females between 85-100 cm (Marquez-Farias and Castillo-Geniz 1998). Sharpnose are common in water depths less than 10 m off sandy beach surf zones and in enclosed bays. Sharpnose often enter estuaries but are seldom seen in freshwater. Sharpnose sharks often travel in sex-segregated schools (Branstetter 1981). In the northern Gulf of Mexico they exhibit a seasonal migration, moving into deepwater during October and November and returning inshore in April and May (Branstetter 1981).

There are very limited published data on Atlantic sharpnose feeding behavior. Gelsleichter et al. (1999) collected sharpnose using longlines on Virginia's continental shelf and reported that 38% of sharpnose stomachs examined were empty; however, upon re-calculation of their published numbers, I calculated the percentage of empty stomachs to be 48%. As reported, teleosts were the dominant food category by number, wet weight, and percent occurrence. The major prey item was from the family Bothidae, the flatfish family. Branstetter (1981) did not do a detailed stomach content analysis; he reported that there were teleost and shrimp remains in the stomachs of Atlantic sharpnose caught in the northern Gulf of Mexico. The two studies above were the only found on sharpnose feeding, and indicate that sharpnose are generalized feeders, exploiting a diverse range of teleosts and crustaceans.

Diel feeding patterns are exhibited by a wide range of fish species in both the marine and freshwater environments (e.g., Soares and Vazzoler 2001, Chen et al. 1999, Haroon et al. 1998). However, aside from Cortes et al. (1996), I found no other published studies that examined diel feeding in shark species. Cortes et al. (1996) attempted to examine the possibility of diel feeding in the bonnethead shark, *Sphyrna tiburo*, in southwest Florida. They found varying results depending on both the statistical treatment of the data and the length and choice of time intervals. When using four-hour time intervals, a significant difference was found in feeding activity; however, when using three-hour time intervals, a significant difference was not observed.

The two main objectives at the onset of this study were 1) to determine the feeding habits of blacktip and sharpnose sharks in Timbalier Bay, Louisiana, and 2) to determine if these sharks were exhibiting diel feeding patterns. In addition to the two main objectives, an estimate of the growth rates for blacktip sharks in terms of length and weight was derived from cohort analysis, as well as an estimate of the growth efficiencies of sharks used in the growth rate analysis.

MATERIALS AND METHODS

Study Site

Sampling was conducted in the Timbalier/Terrebone Bay complex of Louisiana. The majority of the sampling occurred around two islands in Timbalier Bay: Casse Tete Island, located in the south central area of the bay, and East Timbalier Island, which forms the southeastern border of the bay (Figures 1 and 2).

After comparing an older map (USDC 1984) with a more recent map (DOTD 1996), it was evident that Casse Tete Island has been decreasing in surface area over this time period through an apparent process of fragmentation and subsidence. During the two years of sampling for this study, the "island" actually consisted of a series of smaller pieces of land with numerous cuts isolating these pieces. Sampling centered around the eastern and western tips of Casse Tete, due to sufficient water depths at these areas (≥ 6 ft).

Coastal erosion was also evident at East Timbalier Island. Much of the southern side of East Timbalier Island's shoreline was lined with large slabs of rock placed between 1966 and 1974 in an attempt to reduce erosion of the island (Williams 1998). The "island" is currently separated into two parts by a tidal pass. Sampling was conducted on the south side of both parts of the island, where the water depth ranged from 13 to 20 ft.

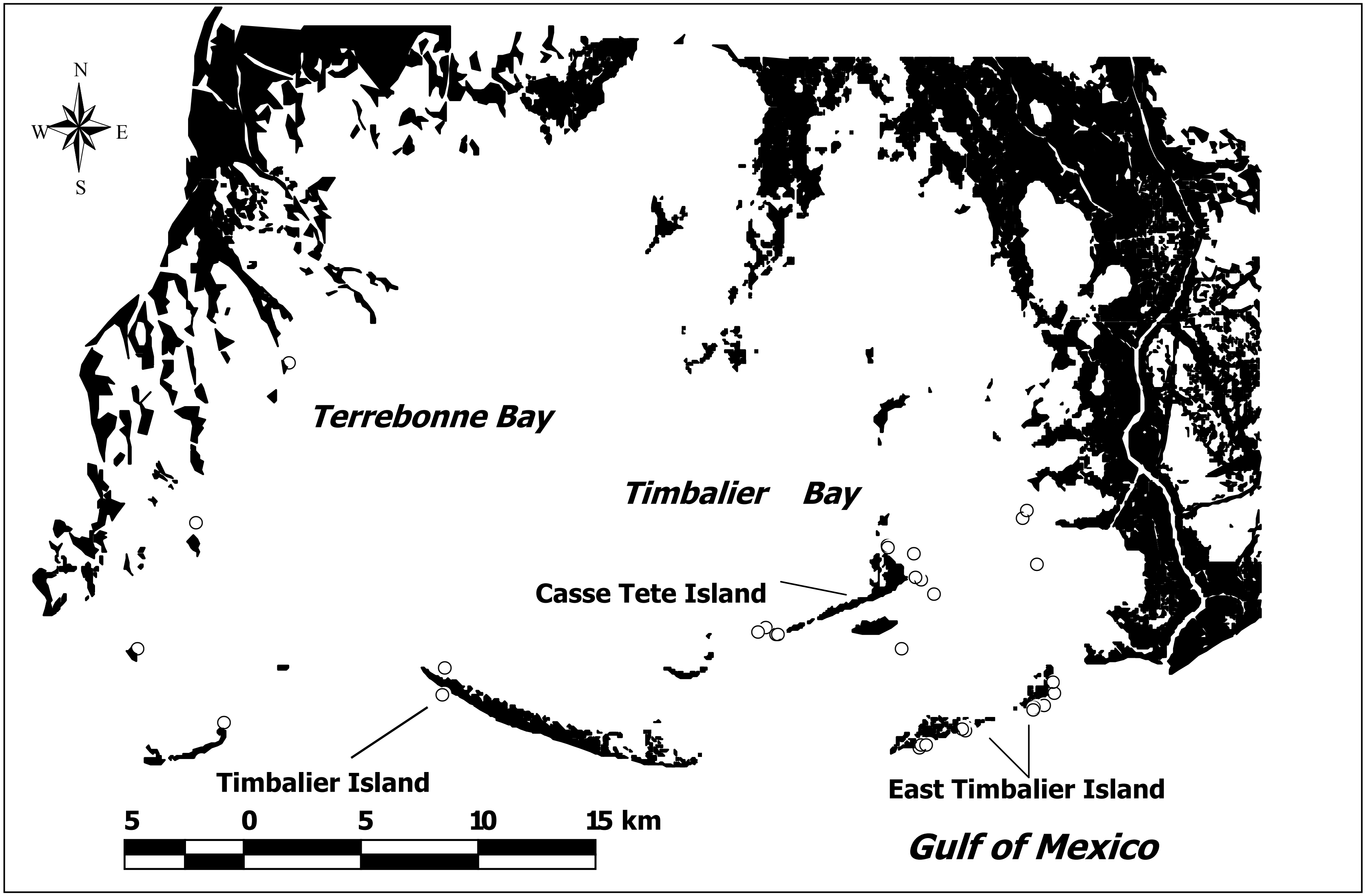

Figure 1. Gillnet sampling locations (denoted by an O) in Timbalier and Terrebone Bay, Louisiana, in 2000. Most sampling effort occurred around Casse Tete Island and East Timbalier Island.

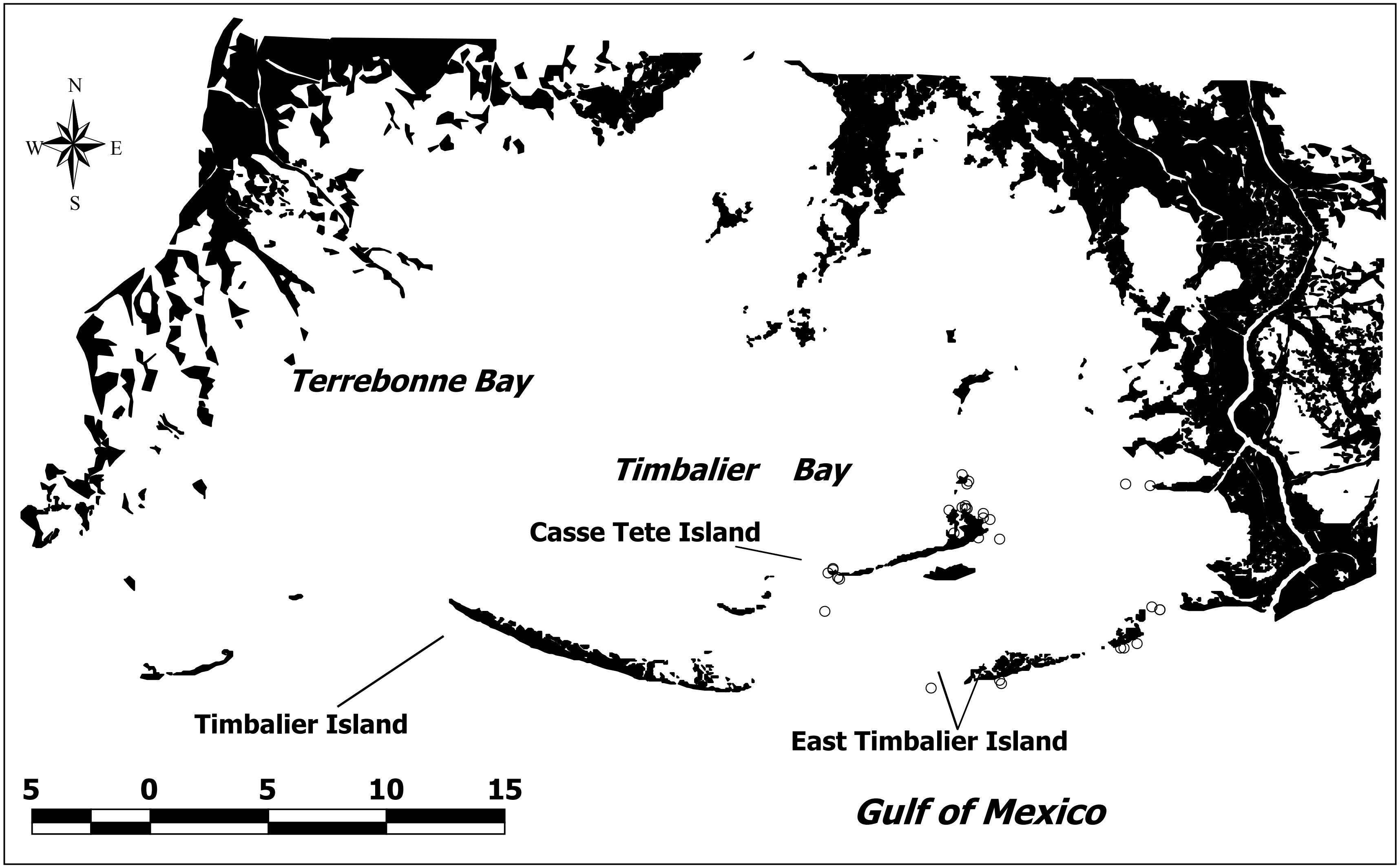

Figure 2. Gillnet sampling locations (denoted by an **o**) in Timbalier Bay, Louisiana, in 2001. Most sampling effort occurred around Casse Tete Island and East Timbalier Island.

Field Procedure

A six-panel gillnet was used to collect sharks. It consisted of six equal-sized panels ranging from 4 to 6-in stretch-mesh in one-half inch increments and an eight-inch mesh joined together. The mesh of the five smaller panels was composed of monofilament. The eight-inch mesh panel was made of nylon to provide added strength for the capture of larger organisms. Ideally, 100-ft panels were to be used throughout; however, two 75-ft panels were used early in the summer of 2000 until the arrival of replacement 100-ft panels. The net was anchored at both ends using Danforth anchors, and floats were deployed at the beginning and end of the gillnet, as well as at the connection point of the different panels. Battery-powered strobe lights were attached to the two end floats, and the remaining floats were equipped with disposable light sticks.

A preliminary sampling trip was conducted in June 2000. I conducted several gillnet net sets during daylight hours to evaluate the technique and establish a sampling protocol. Following this trip, a decision was made to collect stomach contents and to assess the possibility of a diel feeding pattern of captured sharks during future sampling. As a result, the following protocol was developed to sample each one of the following six time intervals (night-am, dawn, day-am, day-pm, dusk, and night-pm) on each trip:

One 3-hour dawn set centered around sunrise (4:30 a.m.-7:30 a.m.)

One 3-hour dusk set centered around sunset (6:30 p.m.-9:30 p.m.)

Two 3-hour sets during the daylight hours
  One day-am set between 7:30 a.m. and 12:00 p.m.
  One day-pm set between 12:00 p.m. and 6:30 p.m.

Two 3-hour sets during the nighttime hours
  One night-pm set between 9:30 p.m. and 12:00 a.m.
  One night-am set between 12:00 a.m. and 4:30 a.m.

It became obvious that this sampling schedule was overly ambitious due to time constraints and personnel fatigue. Nonetheless, I attempted to uniformly sample these six time intervals during the remainder of the 2000 sampling season.

A designed sampling schedule was adopted for summer 2001 in order to more strictly adhere to the uniform sampling of the six time intervals. Table 1 gives the sampling schedule for the months of May and September. These months were designated as secondary months, in which one trip would be made each month. For these months, four sets were scheduled to sample dawn, dusk, day, and night. The sampling was intensified in June, July, and August, the primary months of my sampling schedule. For each of these months, two trips would be made, with the goal of having all six time intervals sampled monthly (Table 2).

Gillnet deployment is somewhat of an art, only mastered by trial and error. The first criterion that had to be met was finding water of the appropriate depth. Since the gillnet stretched six feet from top to bottom, an attempt was made to deploy the net in no less than six feet of water, thus allowing the entire depth of the net to be actively fished. The next step was to determine the wind and current direction in order to facilitate setting the gillnet in a straight line. In almost all cases, an attempt was made to deploy the net in a direction that was not directly perpendicular to the prevailing water currents. I also attempted to deploy the net in a direction that was not directly perpendicular or parallel to the prevailing wind direction, so that the process of checking the net was easier and safer.

Immediately after the gillnet was deployed, environmental parameters were recorded including time, water temperature, dissolved oxygen (ppm), conductivity (normal and

Table 1. Idealized general gillnet sampling schedule for May and September 2001 in Timbalier Bay, Louisiana. Note that trips were flexible in that the sets could be performed on any of the three days.

	DAY 1	**DAY 2**	**DAY 3**
midnight			
1 a.m.			
2 a.m.			
3 a.m.			
4 a.m.			
5 a.m.			
6 a.m.			Dawn Set
7 a.m.			
8 a.m.			
9 a.m.		day set (a.m.)	
10 a.m.			
11 a.m.			
noon			
1 p.m.			
2 p.m.			
3 p.m.			
4 p.m.			
5 p.m.			
6 p.m.		dusk set	
7 p.m.			
8 p.m.			
9 p.m.	night set (p.m.)		
10 p.m.			
11 p.m.			
midnight			

Table 2. Idealized general gillnet sampling schedule for June-August 2001 in Timbalier Bay, Louisiana. Note that the trips were flexible in that any of the three sets could be performed on any day of the trip, and sets for trip 1 could be swapped with sets from trip 2.

TRIP 1			
	DAY 1	**DAY 2**	**DAY 3**
midnight			
1 a.m.			
2 a.m.			
3 a.m.			
4 a.m.			dawn set
5 a.m.			
6 a.m.			
7 a.m.			
8 a.m.			
9 a.m.			
10 a.m.			
11 a.m.			
noon			
1 p.m.			
2 p.m.		day set (p.m.)	
3 p.m.			
4 p.m.			
5 p.m.			
6 p.m.			
7 p.m.			
8 p.m.			
9 p.m.	night set (p.m.)		
10 p.m.			
11 p.m.			
midnight			

TRIP 2			
	DAY 1	**DAY 2**	**DAY 3**
midnight			
1 a.m.			night set (a.m.)
2 a.m.			
3 a.m.			
4 a.m.			
5 a.m.			
6 a.m.			
7 a.m.			
8 a.m.			
9 a.m.		day set (a.m.)	
10 a.m.			
11 a.m.			
noon			
1 p.m.			
2 p.m.			
3 p.m.			
4 p.m.			
5 p.m.			
6 p.m.	dusk set		
7 p.m.			
8 p.m.			
9 p.m.			
10 p.m.			
11 p.m.			
midnight			

temperature compensated), salinity, water depth, turbidity, bottom type, Beaufort sea state, wind direction, and cloud cover. Water quality readings were taken using a Model 85 YSI. Water depth was obtained from a Hummingbird 200DX depthfinder. Turbidity was estimated during daylight hours using a Secchi disk. Latitude and longitude coordinates were recorded near the gillnet using a handheld Magellan GPS 315. Once the set was completed, these environmental parameters were again recorded, and the bottom type was determined from the material adhering to the anchors.

Ideally, the gillnet was checked hourly after it had been deployed. The net was examined by manually pulling the boat along the net, stopping each time an organism was encountered. By checking the gillnet in this fashion, the net was fished continuously through out the three-hour set. Only to start the third and final check of the net did we pull up the anchor from one end of the net and proceed to haul the gillnet back into the boat.

During each check of the gillnet, organisms encountered were removed from the net as quickly and carefully as possible. All sharks captured were identified to species, and their sex, maturity stage, length, and the mesh size where captured were recorded. Maturity stage was determined by the presence or absence of an umbilical scar. If a scar was visible, it was recorded as either open, partially open, or healed. Pre-caudal lengths were measured. Pre-caudal length (PCL) was measured as a horizontal line from the tip of the nose to the tip of the precaudal pit (Compagno 1999).

For analysis purposes, the time interval in which each shark became entangled in the net, Ti, was used to estimate the time of capture, Tc. Tc was estimated as the midpoint of Ti. In 2000, if a shark was collected during the first check of a set, Ti extended from the beginning of the set to the end of the first check. For a shark collected during the second check, Ti extended from the beginning of the first check to the end of the second check. For a shark collected in the third and final check, Ti extended from the beginning of the second check to the end of the set.

In 2001, the time in which each panel of the net was encountered during a check was recorded, thus effectively reducing Ti. For a shark collected in the first check, Ti extended from the beginning of the set to the beginning of the panel immediately following that in which the shark was captured. For a shark collected in a panel of the second check, Ti extended from the previous check of that panel to the current check of the following panel. For a shark collected in a panel of the third and final check, Ti extended from the previous check of that panel to either the current check of the following panel or the end of the set, whichever applied.

I had to decide whether captured sharks were healthy enough to be released and have a high chance of survival. If I determined a shark to be fit for release, a National Marine Fisheries Service (NMFS) tag was placed into the shark below the dorsal fin, and the shark was released back into the water as part of another study. If I determined a shark to be unfit for release, I placed a numbered “toe tag” around its tail and placed the shark into an ice-slurry to humanely anesthetize it. “Toe tags”, constructed using copper wire and a waterproof paper tag, were placed on each shark being kept in order to be able to identify the time and location in which the shark was caught when brought back to the field station. I retained all blacktip and Atlantic sharpnose sharks for analysis of their stomach contents beginning in May 2001.

Bycatch were identified, tallied, and recorded as the gillnet was checked. The mesh size in which the organism was caught was also noted. Towards the end of the 2000 sampling season and continuing through the 2001 sampling season, selected bycatch species were frozen and brought back to LSU for future analysis. While I did not use this limited data, they are archived at the Coastal Fisheries Institute of Louisiana State University.

Back at the field station, the identity, sex, maturity stage, and lengths of the retained sharks were again determined, and their weights were recorded. Sharks were dissected by making a cut immediately behind the pectoral fin down to the belly, and continuing along the belly to the anus, being careful not to cut any of the internal organs. The stomach was then located and gently pulled away from the other internal organs. The duodenum was cut, freeing the lower portion of the stomach. The esophagus was sealed with either a zip-tie or a piece of nylon fishing line, and cut anterior to the seal to free the stomach from the shark. Each removed stomach was placed into a labeled zip-lock freezer bag and held on ice until frozen.

Laboratory Procedure

Frozen stomachs were thawed, and contents were collected as below. The lower end of the stomach was cut and the contents poured into a labeled specimen jar. After all of the noticeable contents were removed, the stomach was placed into a pan and sliced lengthwise to expose the interior. The inside of the exposed stomach was flushed with 70% ethanol in order to collect any contents that may have been lodged or trapped inside the folds of the stomach (Cortes and Gruber 1990). The contents in the jar were then preserved in 70% ethanol.

The process of identifying and weighing the stomach contents from each shark began by pouring the contents into a wire sieve with a mesh size (approximately 1 mm) fine enough to retain eye lenses and otoliths. The contents were washed lightly with a stream of water in order to facilitate identification and weighing by removing unidentifiable slimy residue. From the sieve, each discrete mass was removed and identified to the lowest taxonomic level possible. As the contents were removed, they were placed onto paper towels to remove excess water before weighing. Each discrete mass was weighed separately, except for eye lenses and otoliths, and the weights were recorded (± 0.01 g). After weighing, the contents of each stomach were returned to their labeled jar and archived.

Eye lenses and otoliths were not weighed because of the precision of the balance that was used. An experiment using the eye lenses of the retained bycatch was performed in order to determine the effectiveness of using eye lenses as a method of back-calculating the original weight of the prey. In this experiment, I attempted to mimic the pH of shark stomach acid with the goal of weighing the eye lenses over designated time intervals. I used the reported pH of nurse sharks stomach acids (Caira 1989) because no literature was found giving stomach acid pH values for blacktips or sharpnose. Shortly after the experiment began, no discernable eye lenses remained, indicating either eye lenses degrade too quickly in shark stomachs to be used for back-calculation or, more likely, the solution used was too acidic. Because I had insufficient numbers of eye lenses to run subsequent experiments using less acidic solutions, I determined that eye lenses could not be used for my analyses.

A visual Scale of Degradation was derived for menhaden found in the stomachs of the blacktip sharks. This Scale was constructed by laying out all of the menhaden from the stomachs and comparing them to one another. The Scale of Degradation was composed of five categories with Category 1 being the most freshly ingested menhaden and Category 5 being the most digested menhaden. The presence of pieces of the gillnet still attached to two of the menhaden allowed us to confidently assign the Category 1 distinction to those menhaden, and offered a starting and reference point for categorization of the other menhaden. Two researchers compared each menhaden, and a consensus was reached before the menhaden was assigned a category. Once all the menhaden had been assigned to categories, the menhaden in each category were compared for uniformity in apparent state of degradation.

Statistical Analysis

Quantitative descriptions of the diets of blacktip and sharpnose sharks were accomplished using three approaches: percent frequency of occurrence, percent composition by number, and percent composition by weight. Percent frequency of occurrence is obtained by summing the number of stomachs containing a particular food category, then dividing by the total number of stomachs with the quotient expressed as a percentage (Hyslop 1980). Percent composition by number is obtained by determining the fraction of the number of food items from each food category for each stomach. These fractions are then summed for each food category and divided by the total number of stomachs with the quotient expressed as a percentage (Bowen 1996). Percent composition by weight is obtained by determining the fraction of the weight of each prey category for each stomach. These fractions are then summed for each prey category and divided by the total number of stomachs with the quotient expressed as a percentage (Bowen 1996).

The Index of Relative Importance (Pinkas et al. 1971) incorporates the three previous approaches into a compound index. In this method, the percent frequency of occurrence of each prey category is multiplied by the sum of the percent weight and percent number:

$$\mathbf{IRI = \%O\ (\%W + \%N)}$$

Cortes (1997) suggested that the Index of Relative Importance (IRI) be expressed as a percentage in order to make comparisons easier among food types. The equation for %IRI for a specific food category, **f**, is as follows:

$$\%\mathrm{IRI}_f = 100\ \mathrm{IRI}_f / \sum_{f=1}^{n} \mathrm{IRI}_f$$

where **n** is the total number of food categories.

To test for differences in feeding activity in blacktips, an Analysis of Variance, with class variables consisting of time interval, sex, year, umbilical scar, and month, was performed (Neter et al. 1985). The dependent variable that was used was the Index of Relative Fullness, Irf. Irf was derived by dividing the total weight of stomach contents for a given shark by the weight of that shark. The assumption of normality of the residuals was not met in this ANOVA; therefore, a non-parametric test, the Kruskal-Wallis test, was used.

A Kruskal-Wallis test was performed to test whether time of day significantly affected the feeding activity of blacktip sharks. Because a pattern of feeding activity emerged for sharks of younger maturity stages in the ANOVA, a Kruskal-Wallis test was also performed to examine whether feeding activity differed among maturity stages.

Due to the presence of differing feeding patterns for sharks of differing maturity stages, regressional analysis was also performed on the data. However, in these analyses, Tc was used instead of time interval. Tc allowed me to look at these feeding patterns using narrower estimates of when each shark was captured. Irf was again used in the regressional analysis of each maturity stage. The data from each maturity stage was fit to quadratic regression of Irf on time interval.

Visual cohort analysis, as described in Ricker (1975), was performed by examining plots of the blacktips captured from 2000 and 2001 in terms of their length against date of capture. Visible breaks in the data from these plots indicated separate cohorts.

Regressional analysis was performed on length and weight against date of capture to estimate the growth rates of the blacktip shark cohorts. Lengths (L) were fit to a linear regression against date of capture, and weights (W) were fit to a quadratic regression against date of capture.

RESULTS

Twenty-five sets were made during the 2000 sampling season, with an average elapsed time of 209 min per set. Thirty-three sets were made during the 2001 sampling season, with an average elapsed time of 199 min per set. Six sets were performed in May of 2000 and 2001, 19 sets in June, 15 sets in July, 13 in August, and five in September. Date, general area, specific coordinates, time interval, total elapsed time, and the number of blacktips captured for each set are given in Tables 3 and 4. Sets ranged from a total elapsed time of 75 minutes to 349 minutes; set times varied due factors such as inexperience, weather, large numbers of organisms, and net damage. The highest number of blacktips captured in a set in 2000 was 69, and the highest number captured in a set in 2001 was 32. A total of nine sets in 2000 resulted in no blacktips being captured, with twelve sets in 2001 resulting in no blacktips being captured.

The possibility of a bias in my results due to sampling intensity was explored. I was concerned that some time intervals may have been sampled more frequently than others. For this reason, I examined the number of sets that were made for each time interval during the primary months of sampling, Casse Tete Island during the months of June-August for the years 2000 and 2001. Four sets were made during the night-am time interval, three sets during dawn, three during day-am, five during day-pm, five during dusk, and three during night-pm. Although the six time intervals were not identical in terms of number of sets, unequal sampling effort of the time intervals did not negatively affected my results.

Table 3. Date, general area, coordinates, time interval, total gillnet soak time, and the number of blacktips captured for each set of the gillnet for the year 2000.

Date	General Area	Latitude	Longitude	Time Interval	Total Soak Time (min)	Blacktips captured
Jun-06-00	East Timbalier Island	29°03.54 N	90°20.02 W	day pm	349	16
Jun-07-00	Casse Tete Island	29°06.28 N	90°24.02 W	day pm	305	35
Jun-19-00	East Timbalier Island	29°03.61 N	90°20.01 W	night pm	202	1
Jun-20-00	East Timbalier Island	29°04.40 N	90°16.96 W	night am	220	0
Jun-20-00	Casse Tete Island	29°07.25 N	90°19.83 W	day pm	220	0
Jun-20-00	Casse Tete Island	29°07.96 N	90°20.78 W	dusk	196	3
Jun-21-00	East Timbalier Island	29°03.59 N	90°19.83 W	day am	190	1
Jun-21-00	East Timbalier Island	29°03.95 N	90°18.91 W	day pm	155	0
Jun-22-00	Casse Tete Island	29°07.87 N	90°20.03 W	dawn	210	15
Jun-28-00	Wine Island	29°03.61 N	90°38.90 W	day am	189	0
Jun-28-00	Wine Island	29°04.45 N	90°38.24 W	day pm	75	0
Jul-11-00	Casse Tete Island	29°07.32 N	90°20.04 W	dusk	254	67
Jul-13-00	East Timbalier Island	29°04.66 N	90°16.50 W	dawn	207	0
Jul-13-00	East Timbalier Island	29°04.94 N	90°16.58 W	day am	215	1
Jul-13-00	Casse Tete Island	29°06.09 N	90°23.72 W	day pm	281	69
Jul-18-00	W Terrebone Bay	29°06.13 N	90°40.44 W	day pm	219	29
Jul-19-00	Timbalier Island	29°04.99 N	90°32.48 W	day am	205	3
Jul-19-00	W Terrebone Bay	29°12.36 N	90°36.34 W	day pm	215	2
Jul-25-00	Casse Tete Island	29°06.13 N	90°23.65 W	night am	223	29
Aug-08-00	E Timbalier Bay	29°08.60 N	90°17.21 W	dusk	300	31
Aug-15-00	East Timbalier Island	29°04.30 N	90°17.12 W	dusk	230	0
Aug-16-00	Casse Tete Island	29°05.77 N	90°20.45 W	day am	207	7
Aug-28-00	W Terrebone Bay	29°08.87 N	90°38.86 W	day pm	215	22
Sep-18-00	E Timbalier Bay	29°08.78 N	90°17.09 W	dusk	138	0
Sep-19-00	Casse Tete Island	29°06.20 N	90°24.20 W	day am	226	0

Table 4. Date, general area, coordinates, time interval, total gillnet soak time, and the number of blacktips captured for each set of the gillnet for the year 2001.

Date	General Area	Latitude	Longitude	Time Interval	Total Soak Time (min)	Blacktips Captured
May-14-01	East Timbalier Island	29°04.40 N	90°17.06 W	dusk	200	1
May-15-01	Casse Tete Island	29°07.68 N	90°20.19 W	day am	196	2
May-29-01	Casse Tete Island	29°07.91 N	90°20.46 W	dawn	203	8
May-29-01	Casse Tete Island	29°06.29 N	90°24.02 W	day pm	200	21
May-29-01	E Timbalier Bay	29°08.55 N	90°16.94 W	night pm	75	0
May-30-01	Casse Tete Island	29°07.70 N	90°20.32 W	dusk	200	0
Jun-12-01	East Timbalier Island	29°04.53 N	90°16.70 W	day pm	208	5
Jun-12-01	Casse Tete Island	29°07.96 N	90°20.75 W	dusk	219	4
Jun-13-01	Casse Tete Island	29°08.80 N	90°20.85 W	day pm	195	4
Jun-13-01	Casse Tete Island	29°07.92 N	90°21.15 W	night pm	201	1
Jun-20-01	East Timbalier Island	29°04.40 N	90°16.98 W	dawn	227	1
Jun-26-01	Casse Tete Island	29°05.33 N	90°24.08 W	day am	200	0
Jun-27-01	Casse Tete Island	29°08.00 N	90°20.82 W	night am	190	0
Jun-27-01	East Timbalier Island	29°03.38 N	90°21.56 W	day am	190	9
Jul-10-01	East Timbalier Island	29°06.82 N	90°11.09 W	day am	260	0
Jul-11-01	Casse Tete Island	29°07.84 N	90°20.34 W	night am	196	6
Jul-11-01	Casse Tete Island	29°08.66 N	90°20.70 W	dawn	227	4
Jul-11-01	E Timbalier Bay	29°05.37 N	90°16.12 W	day pm	130	1
Jul-30-01	Casse Tete Island	29°05.38 N	90°16.12 W	dusk	243	32
Jul-30-01	Casse Tete Island	29°05.38 N	90°16.12 W	night pm	169	7
Jul-31-01	East Timbalier Island	29°07.33 N	90°21.05 W	day pm	151	0
Aug-01-01	Casse Tete Island	29°06.41 N	90°23.91 W	day am	227	9
Aug-13-01	Casse Tete Island	29°07.16 N	90°19.94 W	dusk	201	2
Aug-13-01	Casse Tete Island	29°08.57 N	90°20.71 W	night pm	187	0
Aug-14-01	East Timbalier Island	29°03.52 N	90°19.92 W	day pm	198	0
Aug-14-01	Casse Tete Island	29°06.21 N	90°23.79 W	dusk	193	12
Aug-25-01	Casse Tete Island	29°08.01 N	90°20.76 W	night am	200	0
Aug-25-01	Casse Tete Island	29°06.16 N	90°23.74 W	dawn	200	0
Aug-26-01	East Timbalier Island	29°03.59 N	90°19.93 W	day am	202	1
Aug-26-01	E Timbalier Bay	29°05.46 N	90°16.33 W	day pm	213	0
Sep-21-01	Casse Tete Island	29°07.96 N	90°20.73 W	day am	242	0
Sep-21-01	Casse Tete Island	29°06.38 N	90°23.91 W	day pm	220	4
Sep-21-01	Casse Tete Island	29°06.18 N	90°23. 79 W	night pm	204	3

Of the sharks captured, a total of 356 blacktip stomachs and 55 Atlantic sharpnose stomachs were analyzed. Of the 356 blacktip stomachs, 171 (48%) were empty. Of the 55 sharpnose stomachs, 30 (55%) were empty (Tables 5, 6, 7, and 8).

Of the blacktips analyzed for stomach contents, 203 were female and 153 were male. Most blacktips were caught during the afternoon (41%) and dusk hours (35%). July was the month of highest capture for blacktips (50%). Two blacktips possessed an open umbilical scar, 53 had a partially-open umbilical scar, 191 had a healed umbilical scar, and 107 showed no signs of an umbilical scar (three unrecorded). The majority of blacktips were under 600 mm (79%) and weighed less than 6000 g (92%) (Tables 5 and 6). Of the 185 blacktip stomachs that were not empty, a total of 60 had at least one identifiable prey item in their stomachs

A total of 15 female and 40 male Atlantic sharpnose sharks were analyzed for stomach contents. Most sharpnose were caught during afternoon hours (45%), with July being the month of highest capture (49%). Fifteen sharpnose had at least one identifiable prey item in their stomachs. Sixteen sharpnose possessed a healed umbilical scar and 38 showed no visible umbilical scar. Two major size ranges in terms of length and weight of sharpnose occurred: under 400 mm (33%) and less than 1500 g (42%), and over 600 mm (55%) and 3000 g (33%) (Tables 7 and 8).

Stomach Content Analysis

Thirteen prey species from 13 families were found in the stomachs of blacktips in 2000 and 2001 (Table 9). Eye lenses and otoliths were not included, and stomachs that contained only these items were excluded from the calculations shown in this table. Also,

Table 5. Summary statistics by time interval for blacktips caught in Timbalier Bay, Louisiana, in 2000-2001. For the umbilical scar category, OS = open scar, POS = partially open scar, HS = healed scar, and NS = no scar.

Time Interval	Total Number	Sex		Stomach Contents		Umbilical Scar				Pre-Caudal Length (mm)			Shark Weight (g)		
		F	M	Ident. Prey	Empty	OS	POS	HS	NS	< 650	< 850	< 1050	< 6500	< 13000	< 19500
night am	23	12	11	7	4	0	6	15	2	22	1	0	22	1	0
dawn	27	13	14	8	12	1	6	15	5	25	1	1	25	2	0
day am	23	19	4	2	12	0	3	10	10	10	10	3	16	5	2
day pm	147	80	67	24	56	1	24	58	61	126	16	5	138	5	4
dusk	126	71	55	18	80	0	13	89	24	119	7	0	121	5	0
night pm	10	8	2	1	7	0	1	4	5	7	3	0	7	3	0

Table 6. Summary statistics by month for blacktips caught in Timbalier Bay, Louisiana, in 2000-2001. For the Umbilical Scar category, OS = open scar, POS = partially open scar, HS = healed scar, and NS = no scar.

Month	Total Number	Sex		Stomach Contents		Umbilical Scar				Pre-Caudal Length (mm)			Shark Weight (g)		
		F	M	Ident. Prey	Empty	OS	POS	HS	NS	< 650	< 850	< 1050	< 6500	< 13000	< 19500
May	31	14	17	9	5	0	4	6	21	24	4	3	25	4	2
June	77	40	37	13	42	2	24	24	26	65	8	4	73	1	3
July	179	105	74	31	82	0	24	119	34	167	18	2	169	9	1
August	62	37	25	6	40	0	1	42	19	54	8	0	58	4	0
September	7	7	0	1	2	0	0	0	7	2	5	0	4	3	0

Table 7. Summary statistics by time interval for Atlantic sharpnose caught in Timbalier Bay, Louisiana, in 2000-2001. For the Umbilical Scar category, OS = open scar, POS = partially open scar, HS = healed scar, and NS = no scar.

Time Interval	Total Number	Sex		Stomach Contents		Umbilical Scar				Pre-Caudal Length (mm)			Shark Weight (g)		
		F	M	Ident. Prey	Empty	OS	POS	HS	NS	< 400	< 600	< 800	< 1600	< 3200	< 4800
night am	2	2	0	0	2	0	0	2	0	2	0	0	2	0	0
dawn	11	0	11	4	6	0	0	0	11	0	1	10	1	8	2
day am	5	2	3	0	4	0	0	2	3	2	1	2	2	2	1
day pm	25	3	22	9	8	0	0	2	23	3	4	18	6	8	11
dusk	12	8	4	2	10	0	0	10	1	11	1	0	12	0	0
night pm	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 8. Summary statistics by month for Atlantic sharpnose caught in Timbalier Bay, Louisiana, in 2000-2001. For the Umbilical Scar category, OS = open scar, POS = partially open scar, HS = healed scar, and NS = no scar.

Month	Total Number	Sex		Stomach Contents		Umbilical Scar				Pre-Caudal Length (mm)			Shark Weight (g)		
		F	M	Ident. Prey	Empty	OS	POS	HS	NS	< 400	< 600	< 800	< 1600	< 3200	< 4800
May	15	0	15	5	5	0	0	0	15	0	1	14	1	6	8
June	10	1	9	5	2	0	0	0	9	0	4	6	3	2	5
July	27	12	15	5	20	0	0	14	13	15	2	10	16	10	1
August	3	2	1	0	3	0	0	2	1	3	0	0	3	0	0
September	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 9. Diet composition blacktips caught in Timbalier Bay, Louisiana, in 2000-2001 expressed as percent by number (%N), percent weight (%W), frequency of occurrence (%O), Index of Relative Importance (IRI), and IRI on a percent basis (% IRI). Only stomachs with at least one identifiable prey item were used.

Prey item	**%N**	**% W**	**%O**	**IRI**	**%IRI**
Osteichthyes	**92.22**	**92.22**	**93.44**	**17234.07**	**99.49**
Clupeidae					
Brevoortia patronus	38.05	40.80	47.54	3748.53	74.79
Sciaenidae					
Micropogonias undulatus	16.67	16.61	19.67	654.62	13.06
Cynoscion arenarius	4.92	4.92	4.92	48.41	.97
Bairdiella chrysoura	3.28	3.28	3.28	21.52	.43
Menticirrhus americanus	2.73	3.06	3.28	18.99	.38
Bothidae					
Unidentifiable flatfish	3.28	3.28	3.28	21.52	.43
Trichiuridae					
Trichiurus lepturus	3.47	3.87	6.56	48.15	.96
Stromateidae					
Peprilus burti	3.28	3.28	3.28	21.52	.43
Triglidae					
Prionotus tribulus	1.74	1.67	3.28	11.18	.22
Carangidae					
Chloroscombrus chrysurus	1.64	1.64	1.64	5.38	.11
Ariidae					
Arius felis	.55	.12	1.64	1.10	.02
Atherinidae					
Menidia beryllina	1.64	1.64	1.64	5.38	.11
Engraulidae					
Anchoa mitchilli	1.64	1.64	1.64	5.38	.11
Unidentifiable teleosts	9.33	6.41	21.31	335.42	6.69
Crustacea	**5.74**	**5.39**	**6.56**	**73.01**	**.42**
Diogenidae					
Clibinarius vittatus	.82	.47	1.64	2.12	.04
Penaeidae					
Unidentifiable shrimp	4.92	4.92	4.92	48.41	.97
Mollusca	**2.05**	**2.39**	**3.28**	**14.56**	**.08**
Loliginidae					
Unidentifiable squid	2.05	2.39	3.28	14.56	.29

only stomachs that included at least one identifiable prey item were included in all calculations.

Gulf menhaden (menhaden), *Brevoortia patronus*, received the highest value for percent composition by number (%N) at 38.05%. Atlantic croaker (croaker), *Micropogonias undulatus*, followed at 16.67%, and the unidentifiable teleost category was next with a value of 9.33%. The sand seatrout, *Cynoscion arenarius*, and the unidentifiable shrimp category received values of 4.92%. Cutlassfish, *Trichiurus lepturus*, followed with a value of 3.47%. Silver perch, *Bairdiella chrysoura*, gulf butterfish (butterfish), *Peprilus burti*, and the unidentifiable flatfish category received values of 3.28%. Southern kingfish, *Menticirrhus americanus*, the bighead searobin, *Prionotus tribulus*, the Atlantic bumper (bumper), *Chloroscombrus chrysurus*, hardhead catfish, *Arius felis*, inland silverside, *Menidia beryllina*, the gulf anchovy (anchovy), *Anchoa mitchilli*, the hermit crab, *Clibinarius vittatus*, and the unidentifiable squid category all received values less than or equal to 2.73%.

A similar pattern emerged in percent composition by weight (%W) values. Menhaden received the highest value at 40.80%, followed by croaker at 16.61% and the unidentifiable teleost category at 6.41%. Sand seatrout and the unidentifiable shrimp category followed with values of 4.92%. Cutlassfish received a value of 3.87%, and silver perch, butterfish, and the unidentifiable flatfish category received values of 3.28%. All other species received values less than or equal to 3.06%.

The values of percent composition by number (%O) are as follows. The highest value was for menhaden at 47.54%. The unidentifiable teleost category followed with a value of 21.31%, and croaker received a value of 19.67%. Cutlassfish received a value of 6.56%, followed by the unidentifiable shrimp category and sand seatrout at 4.92%. Butterfish, the unidentifiable flatfish category, the bighead sea robin, the silver perch, the southern kingfish, and the unidentifiable squid category all received values of 3.28%. All other categories received values of 1.64%.

With the Percent Index of Relative Importance (%IRI) menhaden received a value of 74.79%, followed by croaker with a value of 13.06% and the unidentifiable teleost category at 6.69%. Sand seatrout and the unidentifiable shrimp category both received values of 0.97%. Cutlassfish received a value of 0.96%, and all other species received values less than or equal to 0.43%.

Figure 3 is a graphical representation of percent occurrence, percent number, and percent weight for blacktip sharks. In Figure 3, graph a) is an overall representation of the prey categories, and graph b) is a representation of the prey categories that received small values for the three prey indices. In both graphs the relative rank and position of % W and %N for the prey categories closely parallel each other.

Six identifiable species and nine families were found in the stomachs of Atlantic sharpnose for the years 2000 and 2001 (Table 10). Only stomachs that contained at least one identifiable prey item were used for these calculations.

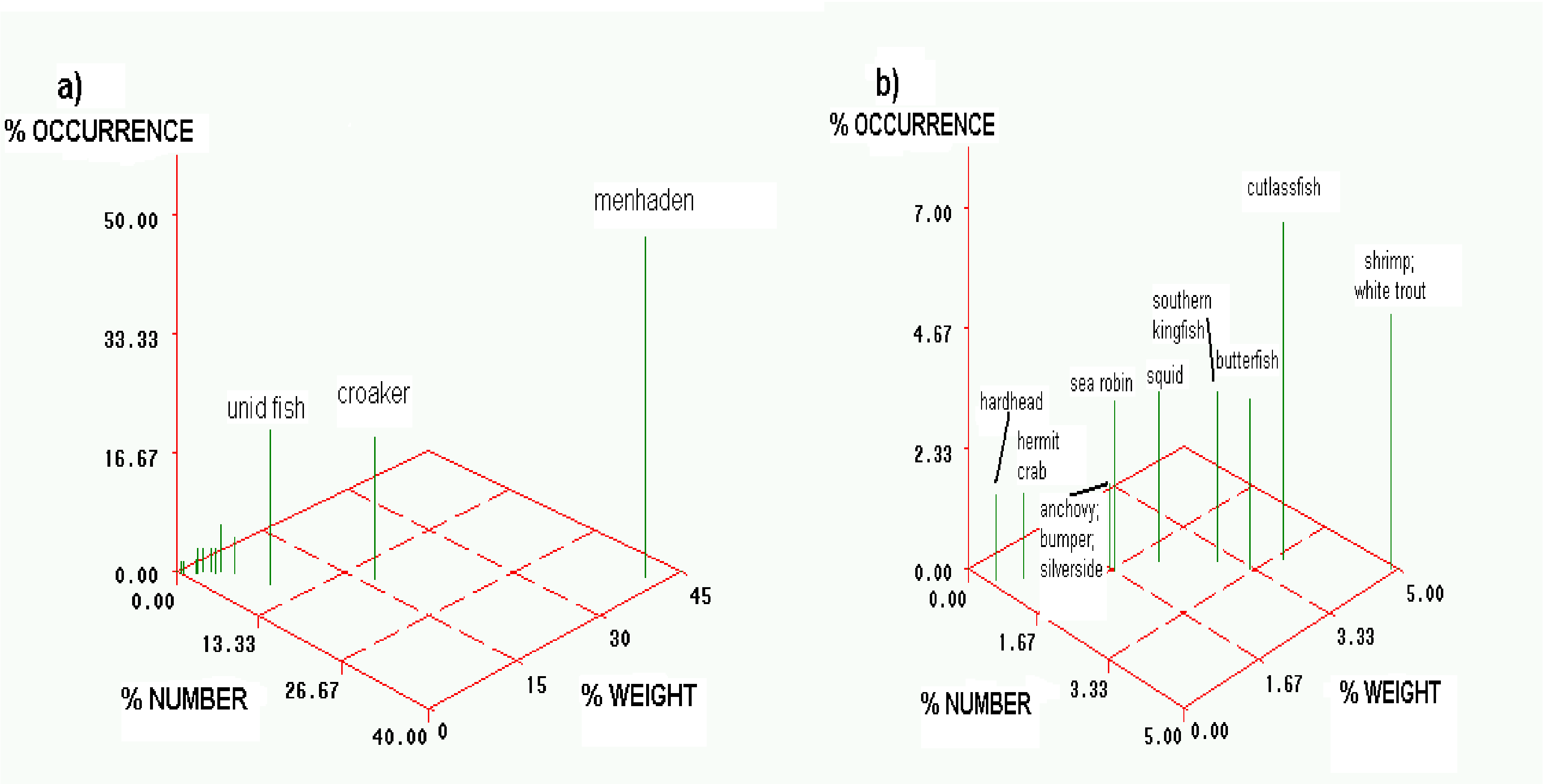

Figure 3. Graphical representation of prey items from the stomachs of blacktips caught in Timbalier Bay, Louisiana, in 2000-2001. Percent occurrence, percent number, and percent weight calculations are based on stomachs that contained at least one identifiable prey item. Graph a) presents the entire range of prey and their statistics, highlighting the prey items with the largest values: menhaden, croaker, and unidentified teleosts. Graph b) is a magnification of the portion of Graph a) that contains small values for the three statistics.

Table 10. Diet composition of Atlantic sharpnose caught in Timbalier Bay, Louisiana, in 2000-2001 expressed as percent by number (%N), percent weight (%W), frequency of occurrence (%O), Index of Relative Importance (IRI), and IRI expressed on a percent basis (% IRI). Only stomachs with at least one identifiable prey item were used.

Prey item	%N	%W	%O	IRI	%IRI
Osteichthyes	**81.24**	**81.26**	**87.50**	**14218.75**	**97.33**
Clupeidae					
Brevoortia patronus	20.31	21.31	25.00	1290.50	43.09
Achiridae					
Trinectes maculatus	2.08	4.01	6.25	38.06	1.24
Carangidae					
Chloroscombrus chrysurus	12.50	12.50	12.50	312.50	10.19
Triglidae					
Prionotus tribulus	7.29	4.79	12.50	151.00	4.93
Bothidae					
Unidentified flatfish	12.50	12.50	12.50	312.50	10.19
Atherinidae					
Menidia beryllina	6.25	6.25	6.25	78.12	2.55
Ariidae					
Bagre marinus	6.25	6.25	6.25	78.12	2.55
Catfish eggs	3.12	5.29	6.25	52.56	1.71
Unidentified teleosts	10.94	8.36	18.75	361.88	11.80
Crustacea	**12.50**	**12.50**	**12.50**	**312.50**	**2.14**
Penaeidae					
Unidentified Shrimp	12.50	12.50	12.50	312.50	10.19
Mollusca	**6.25**	**6.25**	**6.25**	**78.12**	**.53**
Loliginidae					
Unidentified Squid	6.25	6.25	6.25	78.12	2.55

Menhaden received the highest value for percent composition by number (%N) at 20.31%. Bumper, the unidentifiable flatfish category, and the unidentifiable shrimp category all received values of 12.50%. The unidentifiable teleost category received a value of 10.94%, followed by the bighead searobin at 7.29%. Inland silverside, the gaftopsail catfish, *Bagre marinus*, and the unidentifiable squid category all received values of 6.25%. Catfish eggs followed at 3.12% and hogchoker, *Trinectes maculatus* received a value of 2.08%.

Menhaden received the highest value for percent composition by weight (%W) at 21.31%, followed by bumper, the unidentifiable flatfish category, and the unidentifiable shrimp category at 12.50%. The unidentifiable teleost category received a value of 8.36%. Inland silverside, gaftopsail, and the unidentifiable squid category received values of 6.25%. Catfish eggs were next at 5.29%, followed by bighead searobin at 4.79% and hogchoker at 4.01%.

The highest value percent frequency of occurrence (%O) went to menhaden at 25.00%. The unidentifiable teleost category followed with a value of 18.85%. Bumper, the unidentifiable flatfish category, the unidentifiable shrimp category, and the bighead searobin all received values of 12.50%. Catfish eggs, gaftopsail, hogchoker, and the unidentifiable squid category all received values of 6.25%.

The highest value for the Percent Index of Relative Importance belonged to the menhaden with a value of 43.09%, followed by the unidentifiable teleost category at 11.80%. Bumper, the unidentifiable flatfish category, and the unidentifiable shrimp category all received values of 10.19%. Bighead searobin was next at 4.93%, followed by inland silverside, gaftopsail, and the unidentifiable squid category at 2.55%. Catfish eggs were next at 1.71%, followed by hogchoker at 1.24%.

A graphical representation of percent occurrence, percent number, and percent weight for Atlantic sharpnose sharks is given in Figure 4. These percentages were based on all sharpnose stomachs that contained weighed prey remains. This stipulation excluded only those stomachs that were either empty or those that contained only eye lenses or otoliths. The relative rank and position of %W and %N for the prey categories parallel each other, although not as closely as was observed in the similar graphs for blacktip sharks (Figure 3).

Figure 5 gives the most prevalent families of prey items found in the stomachs of blacktips and Atlantic sharpnose from 2000 and 2001 in terms of percent composition by number. Clupeidae, the herring family, represented 43% of the identifiable diet of the blacktip shark. Sciaenidae, the croaker family, represented 32% of the identifiable diet. Stromateidae, the butterfish family, and Penaeidae, the family of commercially important shrimp in Louisiana coastal waters, each represented 6% of the diet of blacktips. Trichiuridae, the cutlassfish family, and Bothidae, the flounder family, each represented 4% of the diet. Loliginidae, the common squid family in Louisiana coastal waters, represented 3% of the blacktips' diet, and Triglidae, the searobin family, represented 2% of the blacktips' identifiable diet.

Clupeidae represented 23% of the sharpnose diet. Penaeidae, Bothidae, and Carangidae, the jack family, each represented 14% of the diet. Ariidae, the saltwater catfish family, represented 11% of the diet, with Triglidae representing 8%. Loliginidae and Atherinidae, the silverside family, each represented 7% of the diet, and Achiridae, the sole family, represented 2% of the identifiable diet of the Atlantic sharpnose.

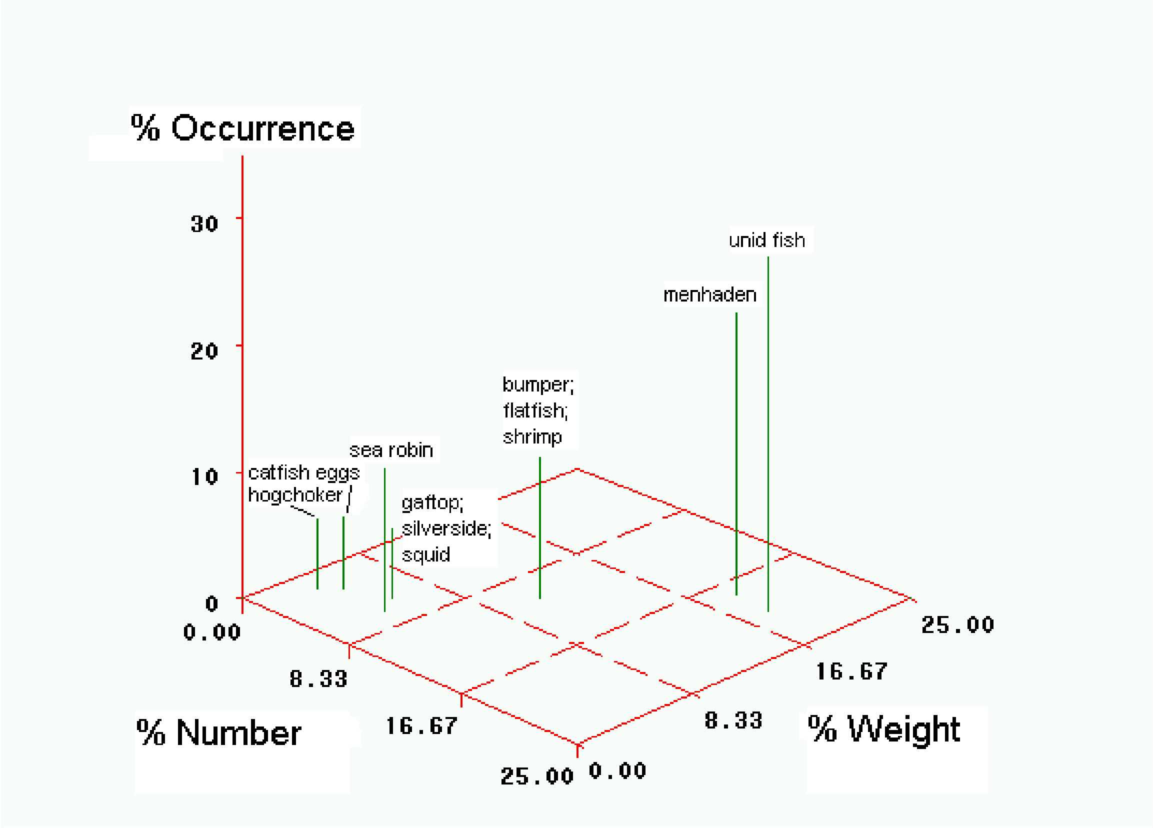

Figure 4. Graphical representation of prey items from the stomachs of Atlantic sharpnose caught in Timbalier Bay, Louisiana, in 2000-2001. Percent occurrence, percent number, and percent weight calculations are based on all stomachs that contained weighable contents.

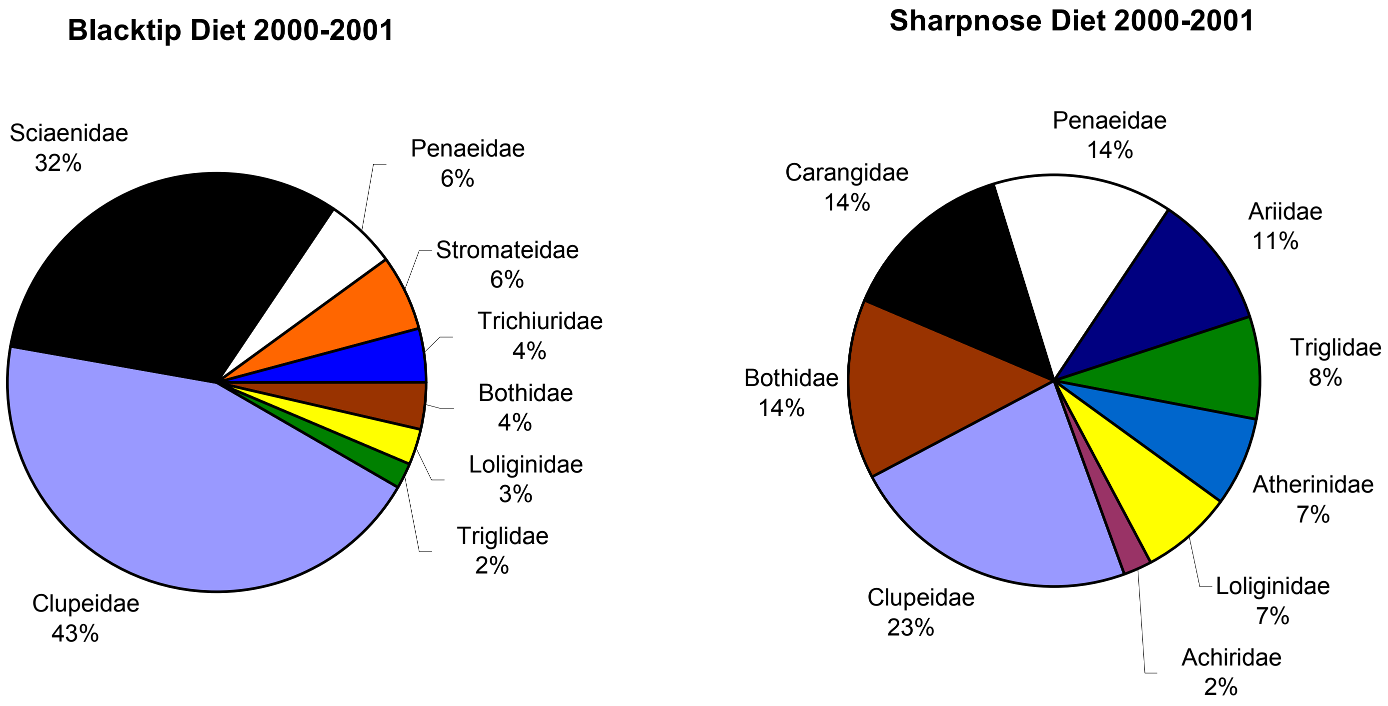

Figure 5. Comparison of the diet composition of blacktips and Atlantic sharpnose caught in Timbalier Bay, Louisiana, in 2000-2001 according to prey family, presented as percent by number (%N). Only identifiable prey was included. Prey families that obtained values of less than 2% were excluded from the blacktip chart.

Scale of Degradation Derivation

The Scale of Degradation for menhaden found in the stomachs of blacktip sharks was comprised of five categories, with Category 1 being the freshest and Category 5 being the most degraded. There was overlap between categories, and each menhaden was placed into a category based on its comparison to the other menhaden. Physical features such as the presence of eyes, skin, and fin rays were examined when comparing the menhaden. The criteria for assigning a category to menhaden from the stomachs of blacktip sharks into the Scale of Degradation are summarized in Table 11.

Menhaden that had an intact protective membrane covering the eye were placed into either Categories 1 or 2. Category 3 menhaden no longer had the protective membrane over their eyes, and in some cases one or both eyes were absent as well. Both eyes were absent in Category 4 and 5 menhaden.

Category 1 and 2 menhaden exhibited no skin loss anywhere on their bodies except at bite marks. Some skin was absent from Category 3 menhaden, exposing minimal amounts of flesh. Most of the skin was absent from Category 4 menhaden, and the exposed flesh was flaky and layered. Most, if not all, skin was absent from Category 5 menhaden. As with Category 4, these menhaden had flaky and layered flesh, but also had areas of exposed bone as well.

The fin membrane was completely intact, connecting all fins rays, in Category 1 menhaden. Fin rays in Category 2 menhaden were beginning to separate on some or all of the fins. Category 3 menhaden had fin rays that were separated almost to the base of the fins.

Table 11. Description of each category in the Scale of Degradation for menhaden found in the stomachs of blacktip sharks caught in Timbalier Bay, Louisiana, in 2000-2001.

Category 1:	eyes with protective membrane intact; no skin absent except for possible bite marks; tail and fin rays 'connected' by fin membrane;
Category 2:	eyes still present with membrane intact; no skin absent except for possible bite marks; tail and fin rays beginning to separate;
Category 3:	eyes may or may not be present; membrane absent; some skin absent exposing minimal amounts of flesh; tail and fin rays separated almost to base of fin;
Category 4:	eyes absent; much of skin absent; flesh flaky and layered; tail and fin rays separate if present;
Category 5:	eyes absent; most, if not all, skin absent; flesh layered and flaky; some bones exposed; tail and fin rays not connected by membrane; many of them absent;

Fin rays in Category 4 and 5 menhaden were completely separated, with most fin rays absent from the Category 5 menhaden.

Because there were insufficient numbers of other prey species to make meaningful indices for their degradation, only menhaden were used to derive the Scale of Degradation. It is my belief that indices of degradation should be species-specific based on the assumption that some prey species degrade at different rates than others; therefore, I did not derive a Scale of Degradation that encompassed all prey items from the blacktip stomachs.

Menhaden from sharpnose stomachs were not combined into the Scale of Degradation because sharpnose and blacktip sharks may not digest prey at the same rates. Because only four menhaden were found in the stomachs of the sharpnose, I did not derive a separate Scale of Degradation for menhaden found in sharpnose stomachs.

Diel Feeding Determination

As expected, there was a curvilinear relationship between the overall weights of blacktips and their lengths. When these two variables were log-transformed, a linear relationship emerged (Figure 6), the equation of which is:

$$\mathbf{\log(W) = 2.959\log(L) - 10.703}$$

($R^2 = 0.985$).

Since I expected the weight of a full stomach to increase in a similar curvilinear pattern as the overall weight of a blacktip, I plotted the weight of the blacktips versus their length, and overlayed a graph of the stomach content weight versus the length of each blacktip. The weights of the stomach contents were multiplied by a factor of 10 in order to illustrate the pattern graphically. Upon examination of Figure 7, I found that the

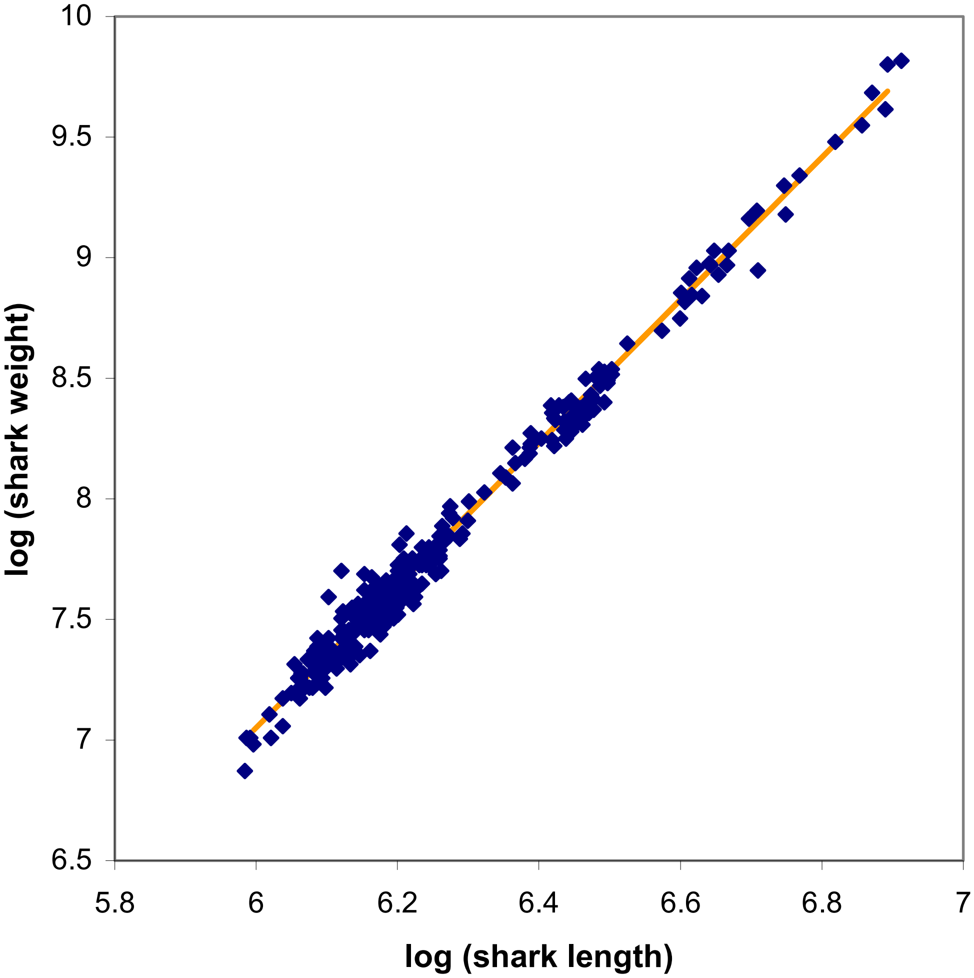

Figure 6. Plot of the log (shark weight) versus log(shark length) with an overlay of the predicted regression line for blacktips caught in Timbalier Bay, Louisiana, in 2000-2001. Shark weight was recorded in grams and shark length was recorded in millimeters.

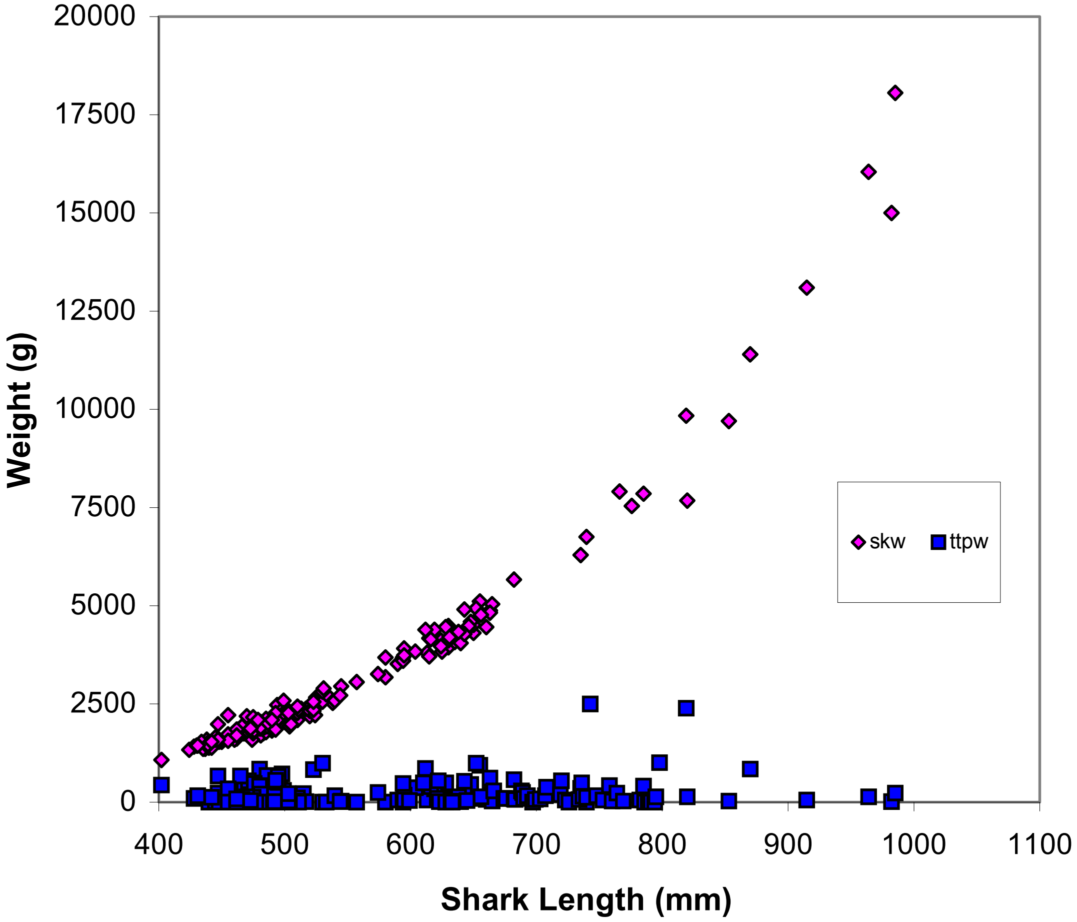

Figure 7. Plot of shark weight in grams (skw) versus shark length combined with a plot of the weight of the stomach contents in grams multiplied by 10 (ttpw) versus shark length for blacktips caught in Timbalier Bay, Louisiana, in 2000-2001. The variable ttpw is equal to the weight of the contents of each stomach in grams multiplied by ten.

stomachs with the highest content weights increased in a similar curvilinear pattern versus blacktip length as overall blacktip weight. Many values of stomach content weights fell below this curvilinear pattern, thus reflecting either stomachs that were not full due to digestion.

The Index of Relative Fullness, Irf, was derived by dividing the total stomach content weight for each blacktip by the overall weight of each blacktip. Although Irf did decline with respect to increasing blacktip length (Figure 8), it did not decline much in the size range of the majority of the blacktips analyzed; therefore, I determined that Irf was a useful index of stomach fullness for each blacktip.

An ANOVA on Irf was performed with the following class variables: time interval, sex, year, scar, and month. Sharks with empty stomachs were excluded from this analysis. Sex (Pr>F=0.2479), year (Pr>F=0.5766), scar (Pr>F=0.6902), and month (Pr>F=0.5738) were all not significant. Time interval was the only variable determined to be significant (Pr>F=0.010). An estimate of Irf for each time interval was calculated, and when these estimates were plotted, a curvilinear trend was observed (Figure 9). Irf estimates decreased from night am (Pr>F=0.011) through dawn (Pr>F=0.007), increased from dawn and day am (Pr>F=0.011), then abruptly decreased from day am to day pm (Pr>F=0.004). An abrupt increase between day pm and dusk (Pr>F=0.012) was observed, and a decrease between dusk and night pm (Pr>F=0.010) completed the cycle. Figure 9 indicates that in addition to what appears to be a primary peak in feeding around dusk, there also is a possibility of a secondary peak in feeding around dawn. However, the assumption of normality for this model was not met, with a Shapiro-Wilkes test for normality being highly significant (Pr>F=0.0001).

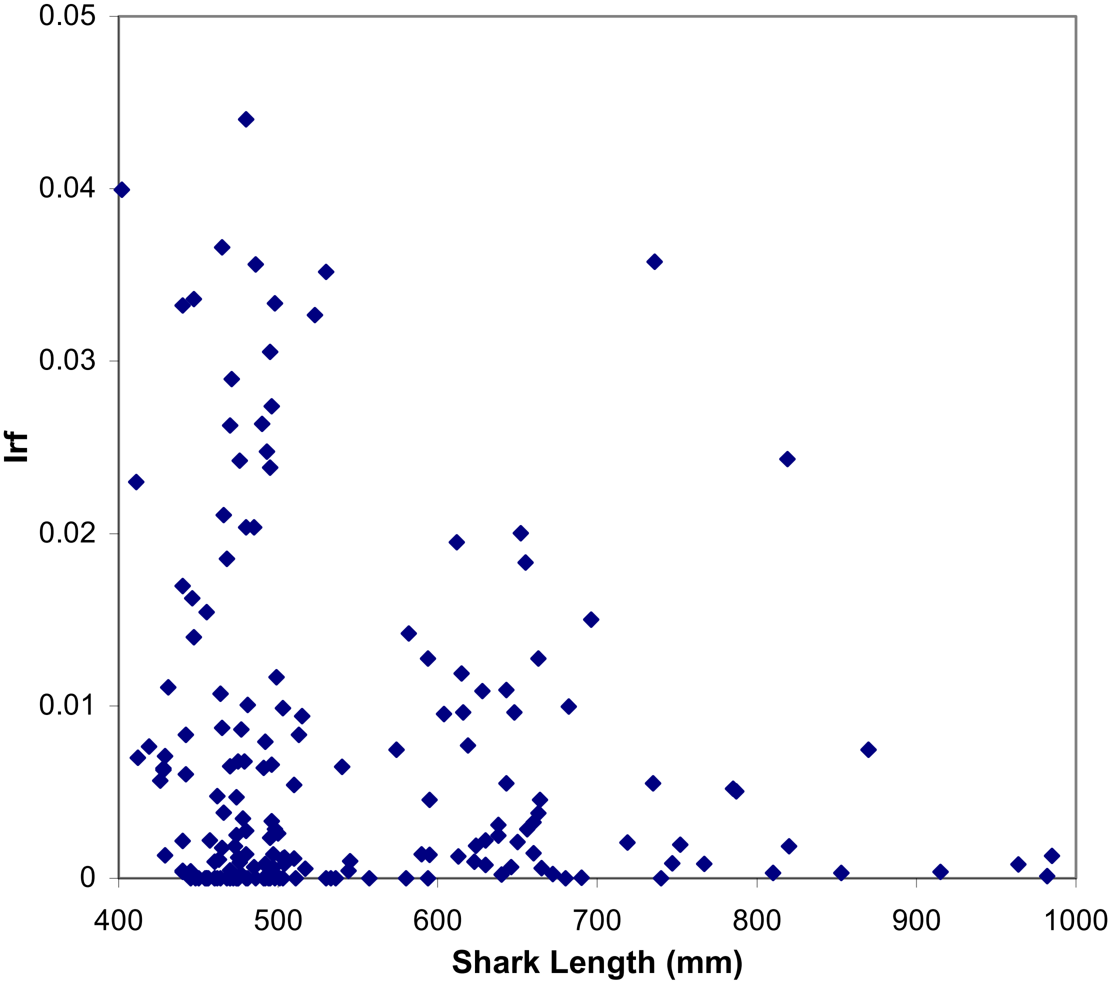

Figure 8. Plot of the Index of Relative Fullness (Irf) versus shark length for blacktips caught in Timbalier Bay, Louisiana, in 2000-2001. The points on the x-axis represent sharks with empty stomachs. Irf was calculated by dividing the weight of the stomach contents by the weight of the shark

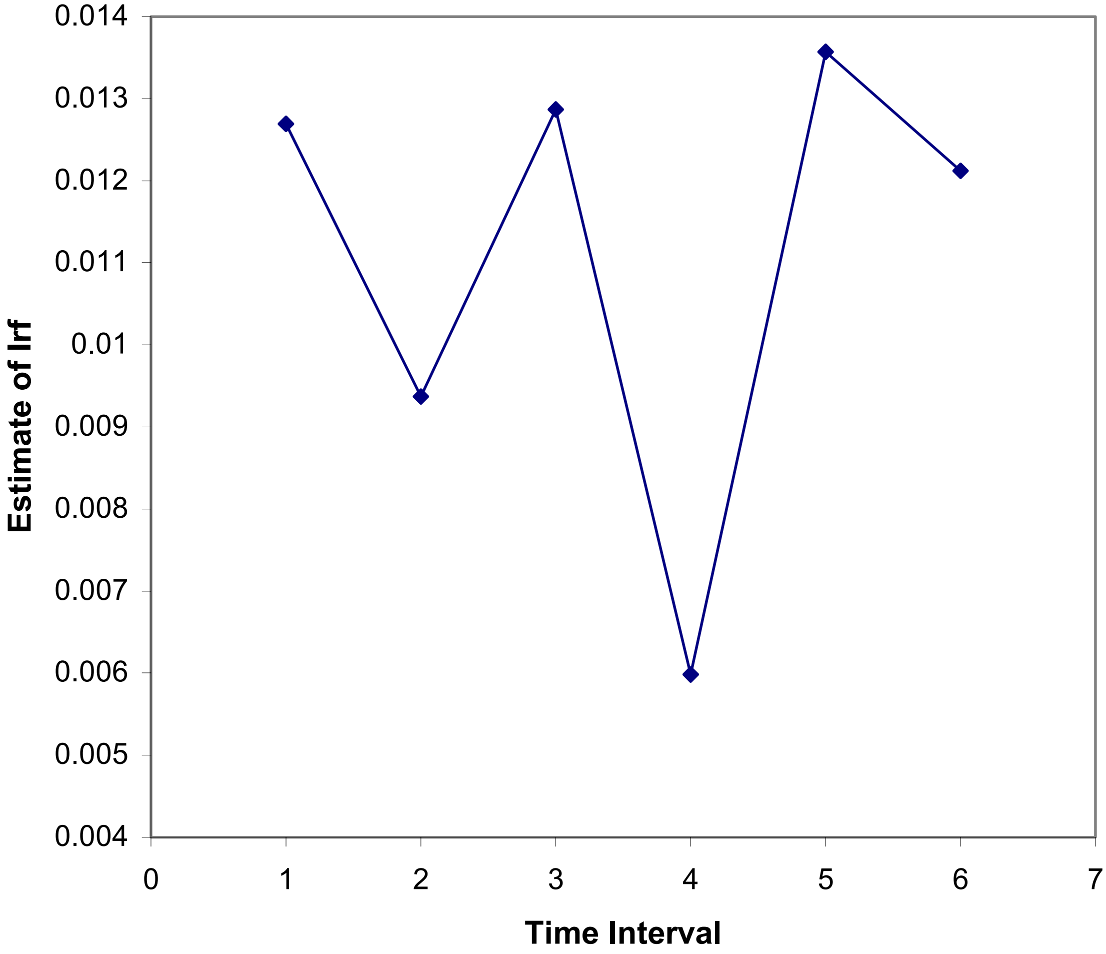

Figure 9. Plot of the estimates of the Index of Relative Fullness (Irf) versus time interval for blacktips caught in Timbalier Bay, Louisiana, in 2000-2001. Time intervals are as follows: 1 = night-am, 2 = dawn, 3 = day-am, 4 = day-pm, 5 = dusk, 6 = night-pm. Note the large decrease between time interval 3 and time interval 4, and the subsequent large increase between time interval 4 and time interval 5.

An ANOVA on Irf was also run on the entire data set, including empty stomachs. Although still significant, the variable time interval dropped in significance from (Pr>F=0.010) to (Pr>F=0.040). However, the variable scar, which was not significant in the first analysis (Pr>F=0.488), became significant in this ANOVA run on the entire data set (Pr>F=0.035). Because it was apparent that there was a correlation between Irf and scar, further analyses were performed.

An ANCOVA of Irf versus Tc by scar was performed, and a surprisingly similar pattern was found between the sharks with partially open scars and sharks with healed scars in terms of feeding activity. These two groups of sharks showed a decline in feeding activity from midnight to approximately 3 p.m, followed by an increase in feeding activity from approximately 3 p.m to midnight (Figures 10 and 11). Time of day was found to be significant at the 0.1 level for sharks with a partially open scar (Pr>F=0.0961), and significant at the 0.05 level for sharks with a healed scar (Pr>F=0.0186). Sharks with no scar did not show a similar pattern when plotted, and was found to not be significant (Pr>F=0.6988). Again, the assumption of normality was not met for these ANCOVA's. Because the assumption of normality was not met, a non-parametric test, the Kruskal-Wallis test, was used in order to determine that time interval was indeed significant. Time interval was found to be significant at the 0.1 level (Pr>chi-square=0.077). Because a pattern was seen in the sharks with partially open and healed scars that was not seen in sharks without a scar in previous analyses, a Kruskal-Wallis test was run in which all sharks with an open, partially open, or healed scar were combined. The combined group of sharks with scars was significant at the 0.05 level (Pr>chi-square=0.018).

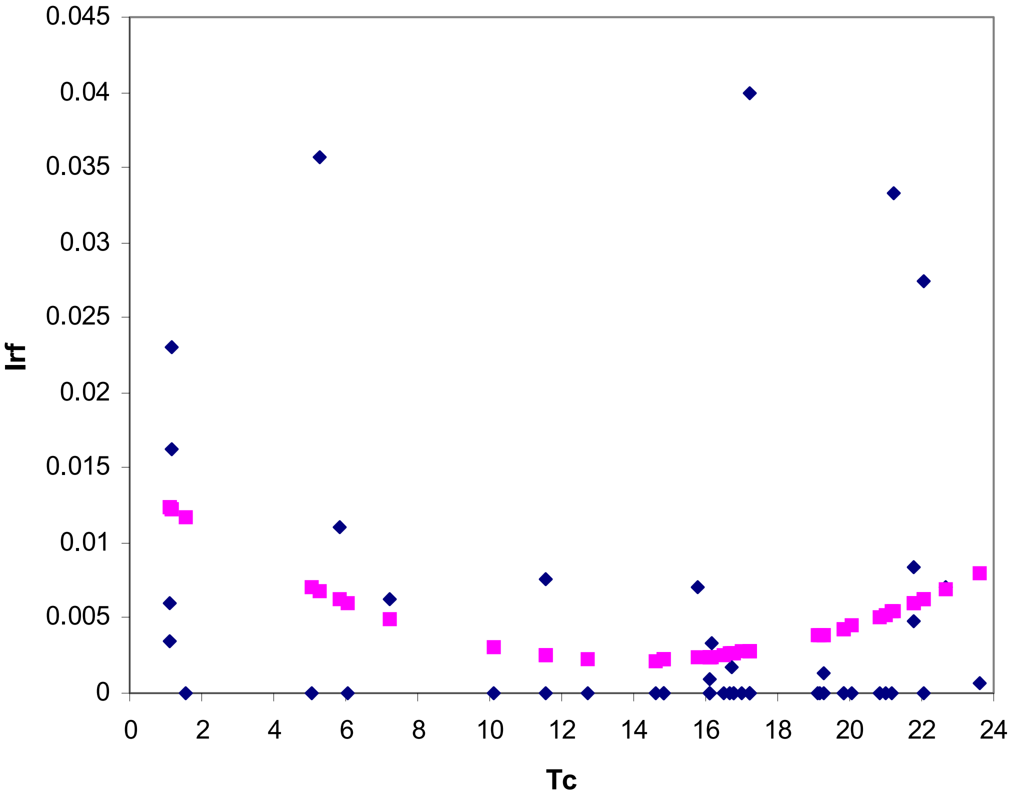

Figure 10. Plot of the actual values of the Index of Relative Fullness (Irf) versus time of capture (Tc) for blacktips with partially open umbilical scars (denoted by diamonds) overlayed with a plot of the predicted values of Irf for blacktips with partially open umbilical scars (denoted by squares) caught in Timbalier Bay, Louisiana, in 2000-2001. Predicted values were forced to fit a quadratic. The relationship was significant at the 0.1 level (0.096).

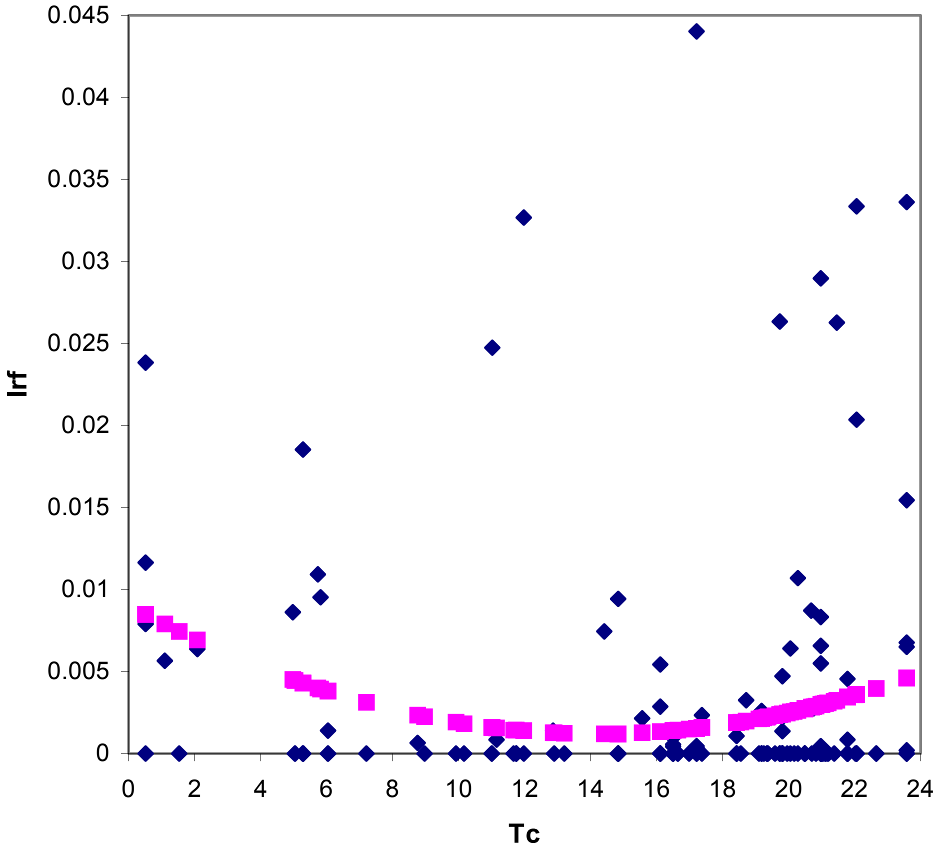

Figure 11. Plot of the actual values of the Index of Relative Fullness (Irf) versus time of capture (Tc) for sharks with healed umbilical scars (denoted by diamonds) overlayed with a plot of the predicted values of Irf for blacktips with healed umbilical scars (denoted by squares) caught in Timbalier Bay, Louisiana, in 2000-2001. Predicted values were forced to fit a quadratic. The relationship was significant at the 0.05 level (0.019).

To examine the hypothesis that blacktips were feeding primarily at dusk, I examined the distribution of empty stomachs through the time intervals, with the idea that time periods with high increases in percentages of empty stomachs could indicate times when blacktips were actively searching for food. Figure 12 is a plot of the number of both total and empty stomachs for each time interval. Time intervals 4 and 5 (day-pm and dusk) were the time intervals with the highest number of captured sharks, which may be due to an increase in their activity due to feeding. Time intervals 4 and 5 also had the highest number of captured sharks with empty stomachs. When the time intervals were represented in terms of their percentage of sharks with empty stomachs (Figure 13), an overall increasing trend in the percentage of empty stomachs with increasing time intervals was observed. Between night-am and dawn, and between day-pm and dusk, sharp increases in the percentages of empty stomachs were observed, indicating that blacktips could possibly be more inclined to feed during the dawn and dusk hours.

Gastric Evacuation Rate Calculation

In order to calculate a gastric evacuation rate for blacktips, I first examined the relationship between Irf and a revised Scale of Degradation (Figure 14). Two new categories were added to the existing Scale of Degradation, Categories 6 and 7. Category 6 included all blacktip stomachs that contained only unidentifiable teleosts, and Category 7 included all blacktip stomachs that were determined to be empty. Generally, as Irf decreased, the revised Scale of Degradation increased. The lone exception to this trend was that the value of Irf increased between Category 1 and Category 2 of the Scale.

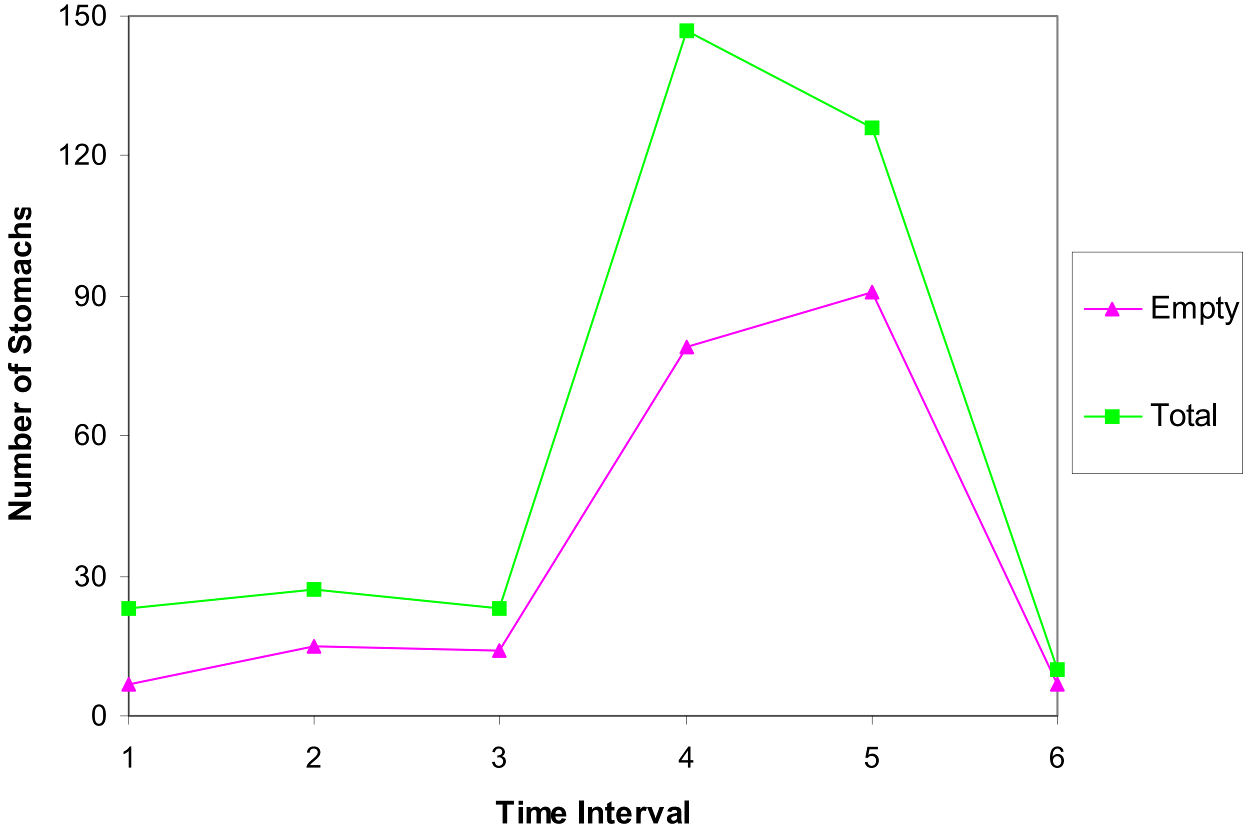

Figure 12. Plot of the number of total stomachs and empty stomachs versus time interval for blacktips caught in Timbalier Bay, Louisiana, in 2000-2001. Time intervals were as follows: 1= night-am, 2 = dawn, 3 = day-am, 4 = day-pm, 5 = dusk, 6 = night-pm.

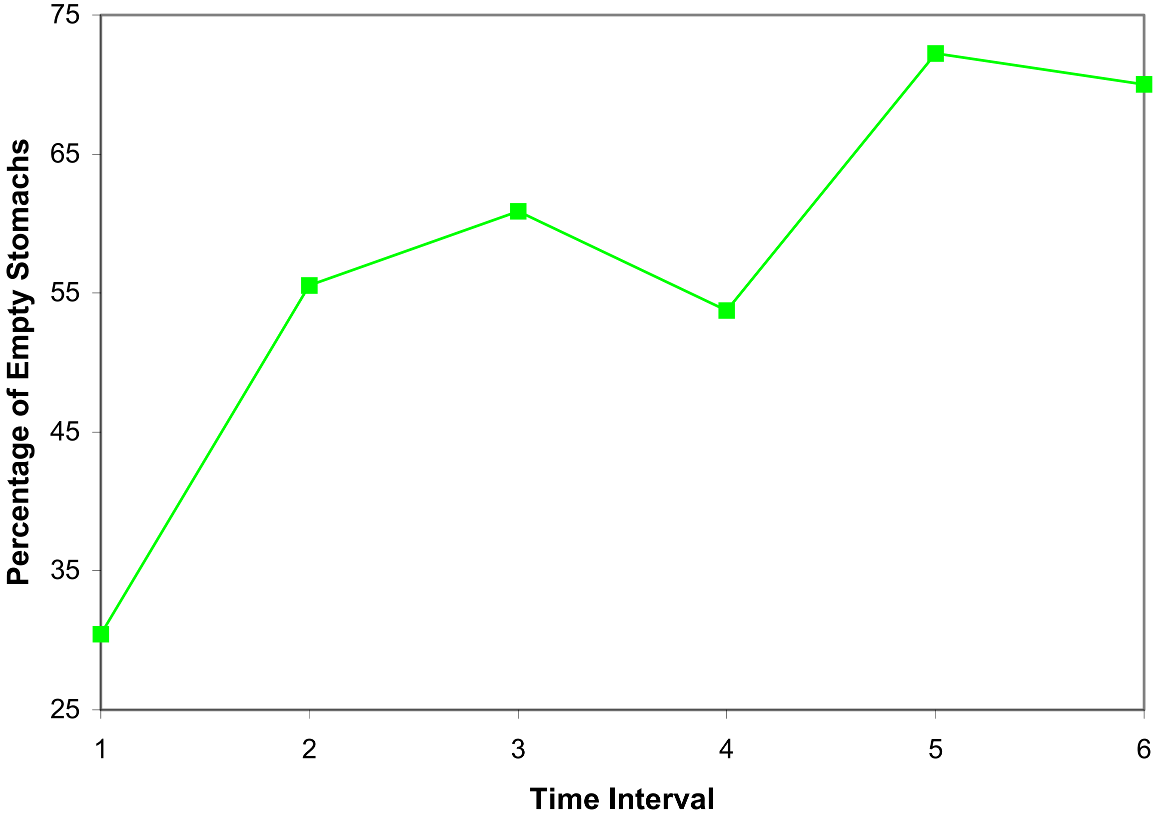

Figure 13. Plot of the percentage of empty stomachs versus time interval for blacktips caught in Timbalier Bay, Louisiana, in 2000-2001. Time intervals were as follows: 1= night-am, 2 = dawn, 3 = day-am, 4 = day-pm, 5 = dusk, 6 = night-pm.

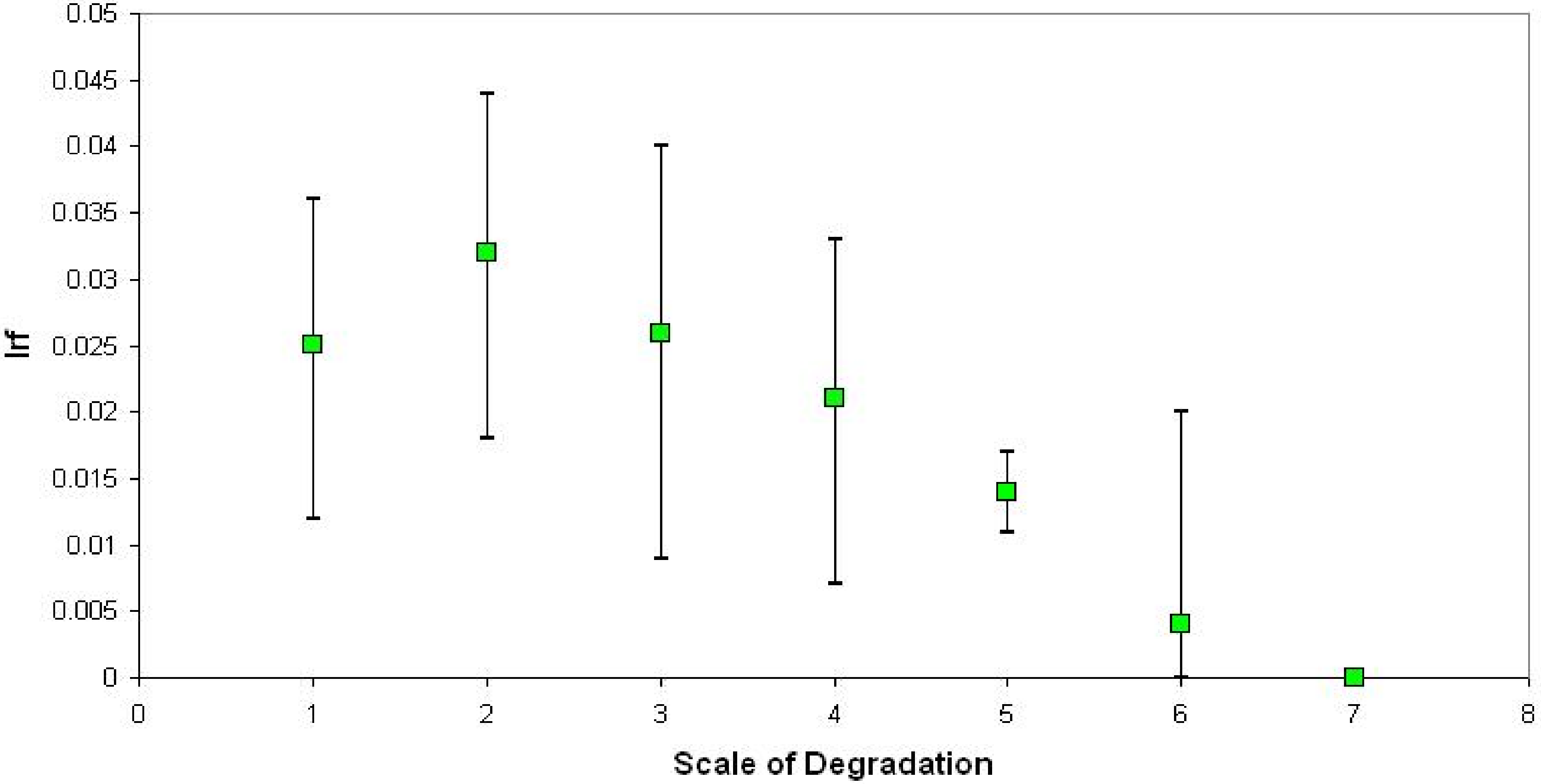

Figure 14. Plot of the Index of Relative Fullness values (Irf) versus the revised Scale of Degradation for blacktips caught in Timbalier Bay, Louisiana, in 2000-2001. Categories 1-5 of the Scale of Degradation corresponded to menhaden found in the stomachs, ranging from least to most degraded. Category 6 consisted of all stomachs that only contained unidentifiable teleost remains, and Category 7 consisted of all empty stomachs. The square symbol indicated the mean Irf values and the lines drawn through the square indicated the ranges of Irf values. The revised Scale of Degradation ranged from Categories 1-7, values of 0 and 8 on the x-axis were only included for cosmetic purposes.

In addition, I included time interval with Irf and the Scale of Degradation (Figure 15). An overall pattern was difficult to distinguish.

One pattern that did emerge from Figure 15 was that freshly-ingested menhaden were only found in stomachs of blacktips that were captured from two of the six time intervals: 4 (day-pm) and 5 (dusk). I assigned the midpoint between these two time intervals (4.5) as the best estimate of the time when menhaden were being ingested. In order to convert the new time interval values into values on a 24-hour cycle, referred to here as digestion time, I re-assigned time interval 4.5 as digestion time 0. The remaining five time interval values were converted to digestion times by calculating the midpoint of the range of each time interval, and calculating the midpoint of those two midpoints (i.e. the midpoint of dusk was 8:00 p.m.; the midpoint of night-pm was 10:45 p.m.; therefore, the new value would be the midpoint of these midpoints, or 9:22:30 p.m.).

The values of Irf were plotted against these newly calculated time estimates (Figure 16), and a pattern similar to the one in Figure 14 was evident. A regression was performed on these data points, and the equation of the linear regression was:

$$\mathbf{Irf = 0.03190 - 0.00130\ (Digestion\ Time)}$$

($R^2 = 0.87$). Under the assumption that the sharks were ingesting a single menhaden at dusk, the linear regression indicated that the menhaden comprised approximately 3.19% of the sharks' body weight. This menhaden degraded at the same hourly rate (0.13% of the shark's body weight / hr) until it was essentially digested after a duration of 24 hours.

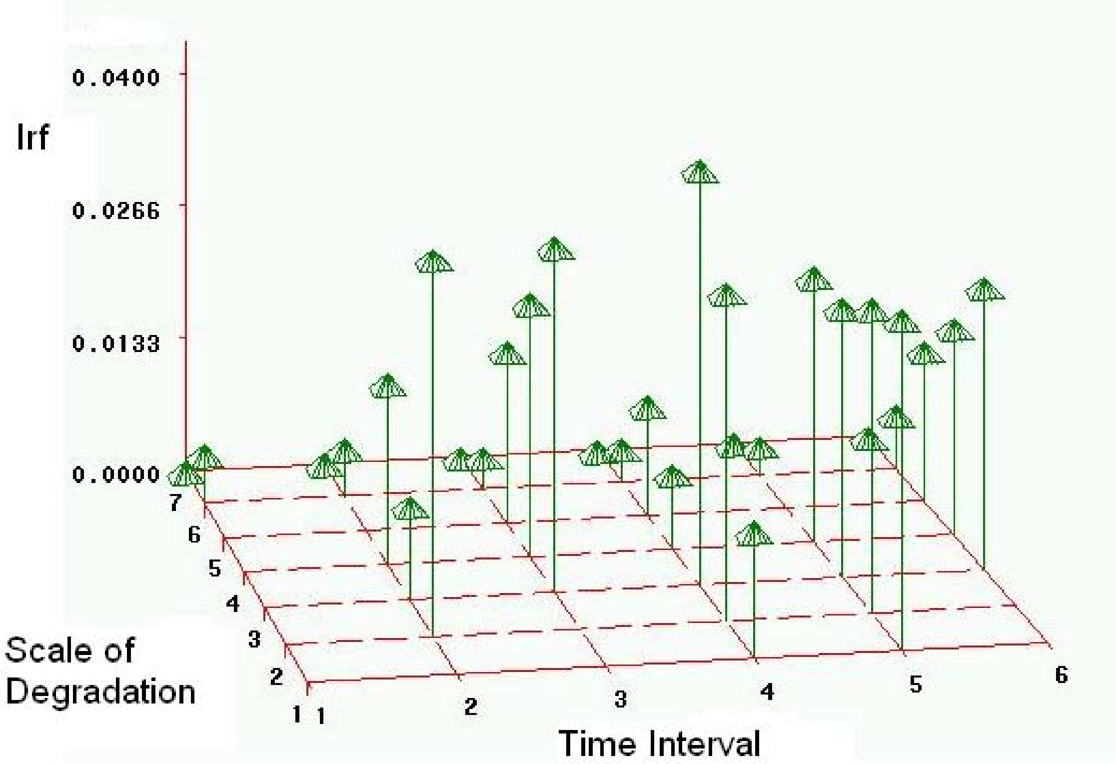

Figure 15. Three-dimensional plot of time interval, the revised Scale of Degradation, and the Index of Relative Fullness (Irf) for blacktips caught in Timbalier Bay, Louisiana, in 2000-2001. Only blacktip sharks that contained menhaden, unidentifiable teleosts only, or sharks with empty stomachs were used for this graph. Time intervals were as follows: 1 = night-am, 2 = dawn, 3 = day-am, 4 = day-pm, 5 = dusk, 6 = night-pm. Categories 1-5 of the Scale of Degradation were for the freshest menhaden to the remains barely distinguishable as menhaden. Category 6 consisted of stomachs with only unidentifiable teleosts, and Category 7 consisted of all empty stomachs.

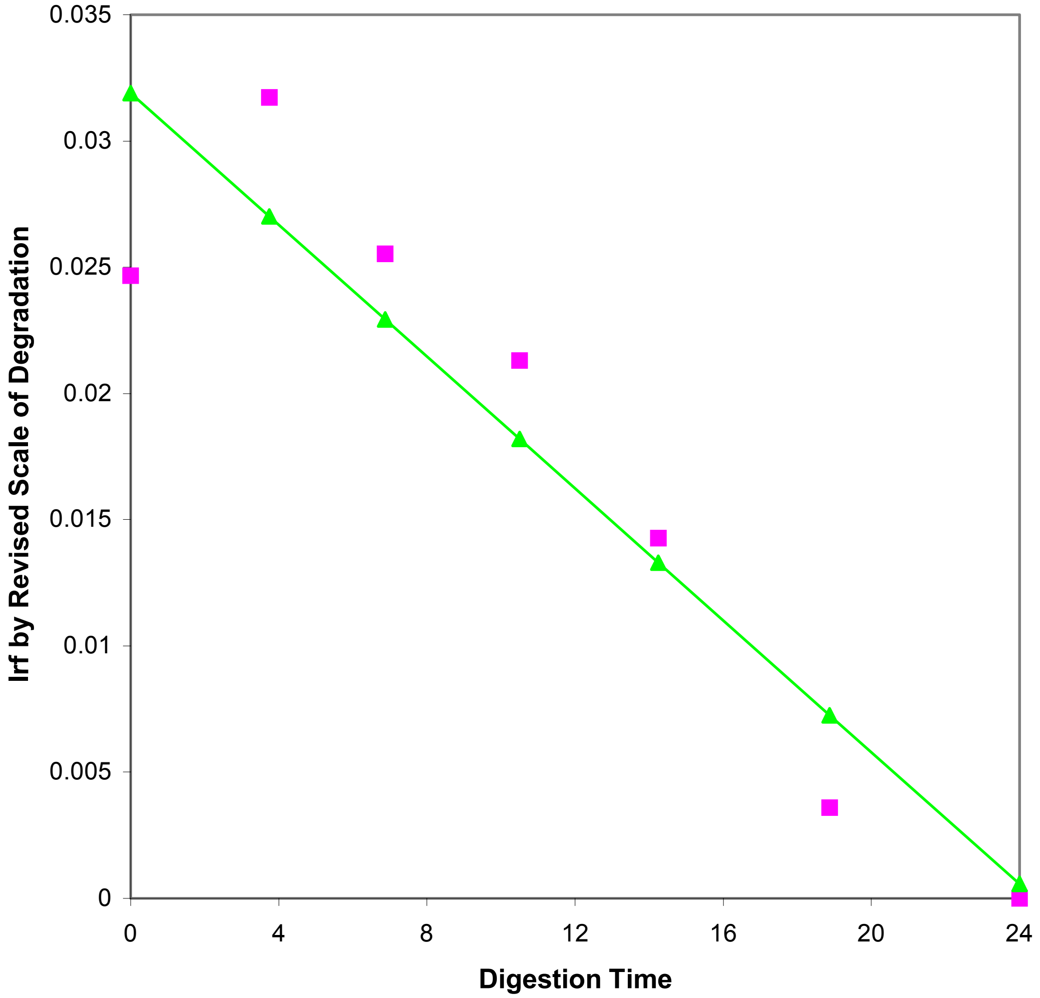

Figure 16. Plot of the Index of Relative Fullness values (Irf) by the revised Scale of Degradation versus digestion time for blacktips caught in Timbalier Bay, Louisiana, in 2000-2001. The predicted linear regression was overlayed, indicating that blacktips completely digested a menhaden in approximately 24 hours.

A simple equation to determine how much the ingested menhaden was being digested hourly was:

% hourly digestion of prey = 100 / 24

where **100** represents 100% of the menhaden present at time zero and **24** being approximately the number of hours it took to completely digest the menhaden. Solving the preceding equation gave a value of approximately 4.19%, indicating that the ingested menhaden lost 4.19% of its original body weight hourly. When using the average weight of the top 10% of the stomach contents, or 60.5 grams, as the weight of the menhaden at the time of ingestion, the menhaden would have lost 2.54 g per hour.

Growth Rate Calculation

Cohort analysis was performed on blacktip sharks captured in 2000 and 2001 by examining plots of blacktips in terms of their length versus Tc. Blacktips were divided into three year class groupings: the zero-year olds, one-year olds, and sharks older than the one-year olds. These groupings were created by assuming that visible breaks in terms of length in the plot indicated separate cohorts (Figure 17). Although breaks were not as clear in 2001, and several points could have been included on different groupings, these points did not affect the results because they did not influence the central trends in the data.

Under the assumption that growth rates were the same for blacktips from both years, the year classes were combined in order to increase sample size. To do this, I subtracted 365 days from the date of capture of the zero-year old sharks caught in 2001. This manipulation gave a combined data set where all the zero-year old and one-year old blacktips appeared to be caught in 2000. I called the new time interval Dcc, date of cohort combination.

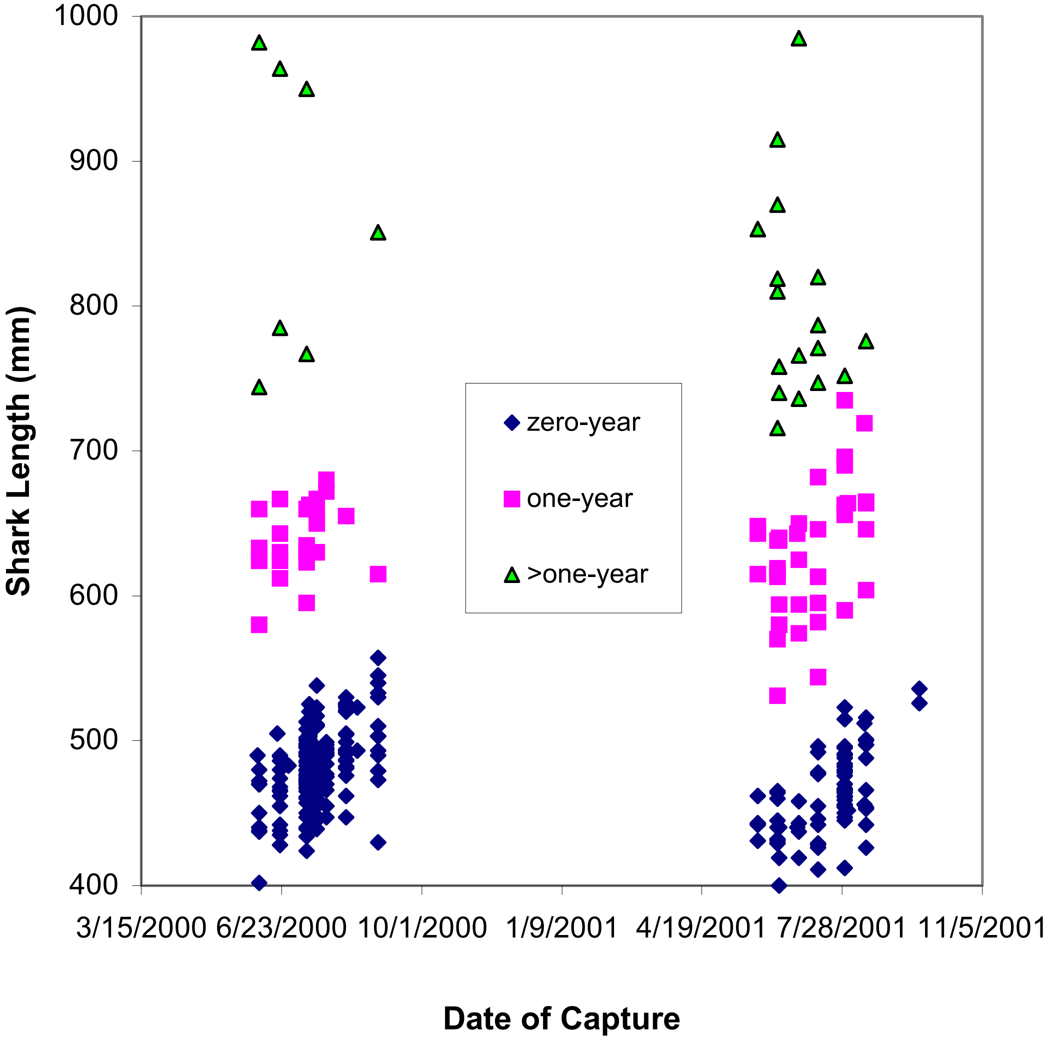

Figure 17. Plot of shark length versus date of capture for blacktips caught in Timbalier Bay, Louisiana, in 2000-2001. Year classes (cohorts) were designated according to visual breaks in the graph.

The combined year classes were then re-plotted in terms of their length (Figure 18). The previously designated year classes held true in that visible breaks still remained among the three groupings. Two separate regressions were then run on the combined zero-year olds and the combined one-year olds. The first regression fit a linear growth rate in terms of length. The second regression fit a curvilinear growth rate in terms of weight. The equation for the growth rate in length was:

$$\mathbf{L = -6439.285 + 0.467\ (Dcc)}$$

($R^2 = 0.863$). The growth rate in terms of length of 0.47 mm/day was equal to the slope from the above equation. The equation for the growth in terms of weight was:

$$\mathbf{W = -7.155\ (Dcc) + 0.005\ (Dcc)^2}$$

Figure 19 was an overlay plot of the blacktips in terms of length and their predicted linear growth rate. Figure 20 was an overlay plot of the blacktips in terms of their weight and their predicted curvilinear growth rate. Figure 21 indicated that the daily growth rate in terms of weight ranged from approximately 7.3 to 7.8 grams/day.

Growth Efficiency Estimation

Under the assumption that the upper 10% of the stomach content weights equaled the blacktips' ingestion rate, growth efficiency was estimated using the equation:

$$\mathbf{Growth = Growth / Ingestion}$$

Using a growth rate of 7.6 g/day, and using the average weight of the top 10% of the stomach content weights, 60.5 grams, a growth efficiency of 12.6% was calculated under the

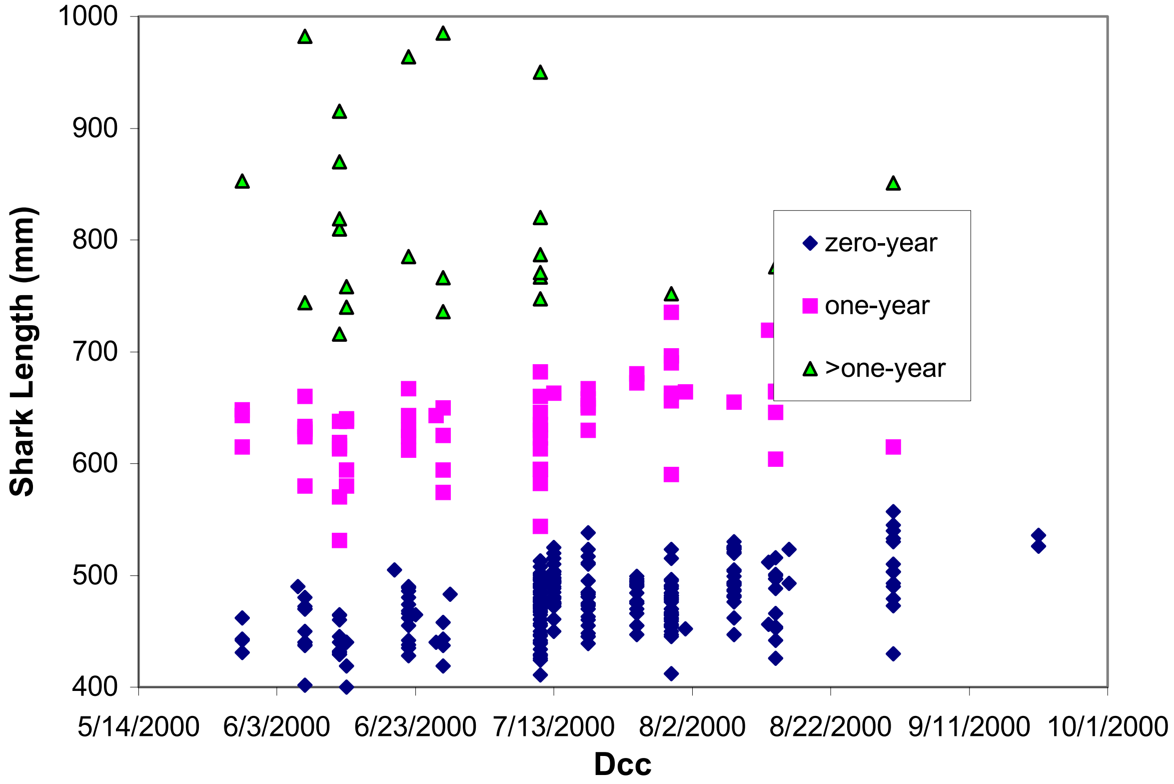

Figure 18. Plot of shark length versus date of cohort combination (Dcc) for blacktips caught in Timbalier Bay, Louisiana, in 2000-2001. The cohorts from both years were combined and plotted as if they all were captured in the same year (2000).

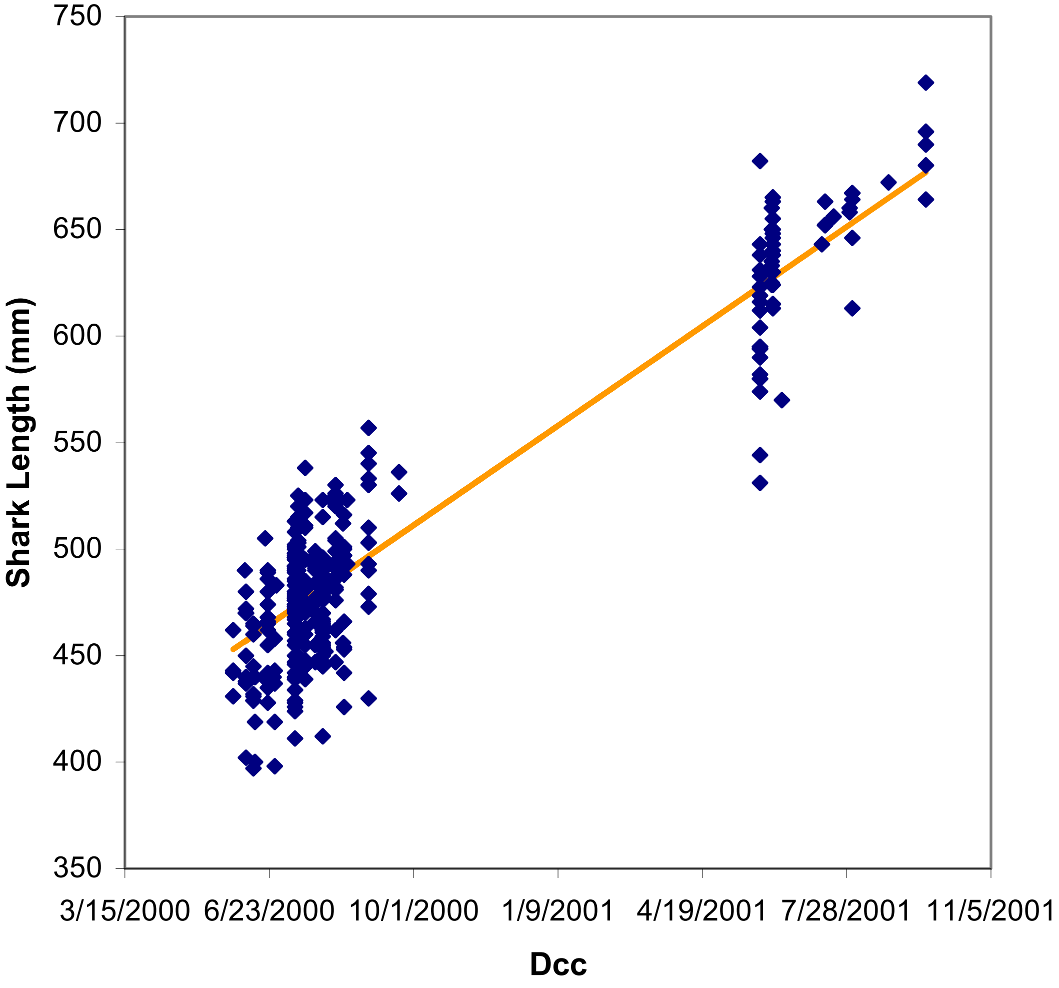

Figure 19. Plot of shark length versus date of cohort combination (Dcc) for the cohort that consisted of the zero-year old blacktips from 2000 and the one-year old blacktips from 2001. Blacktips were caught in Timbalier Bay, Louisiana. The predicted linear growth rate(mm/day) was overlayed.

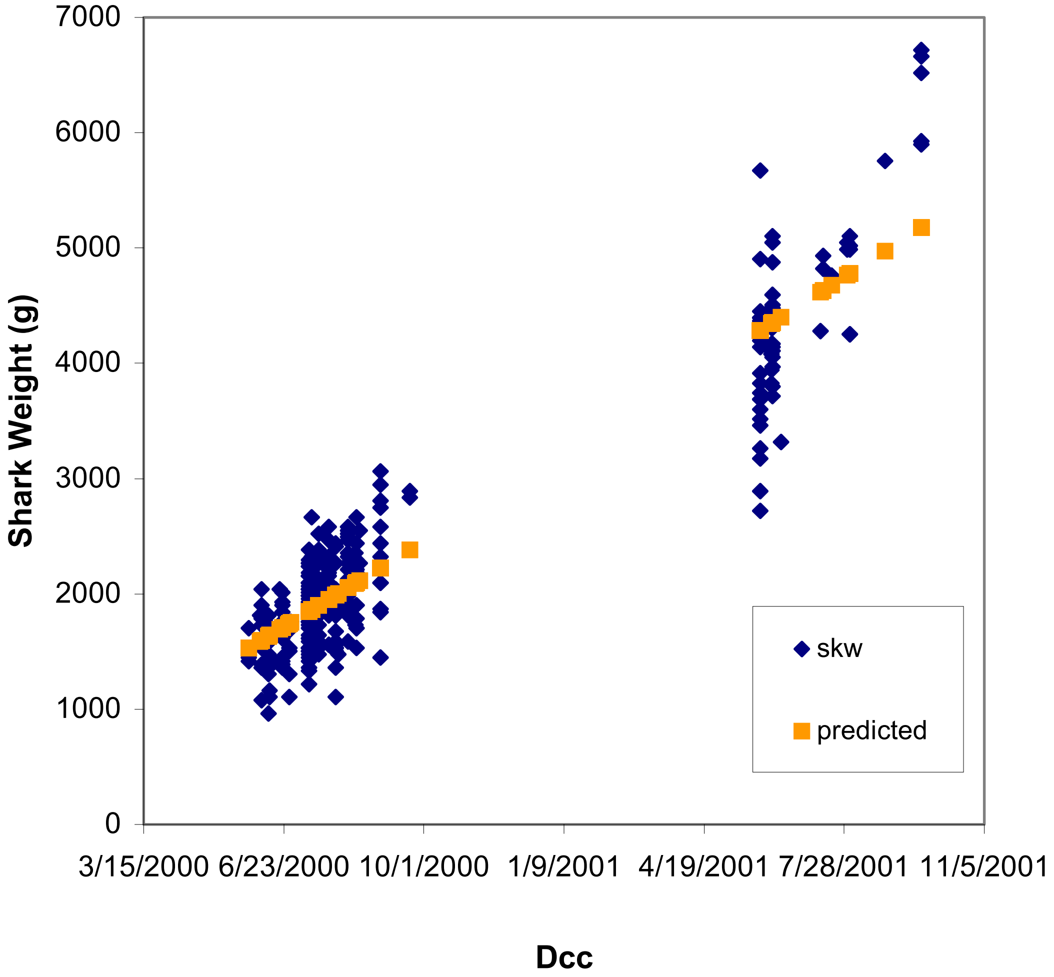

Figure 20. Plot of shark weight in grams (skw) versus date of cohort combination (Dcc) for the cohort that consisted of the zero-year old blacktips from 2000 and the one-year old blacktips from 2001. Blacktips were caught in Timbalier Bay, Louisiana. The predicted curvilinear growth rate (g/day) was overlayed.

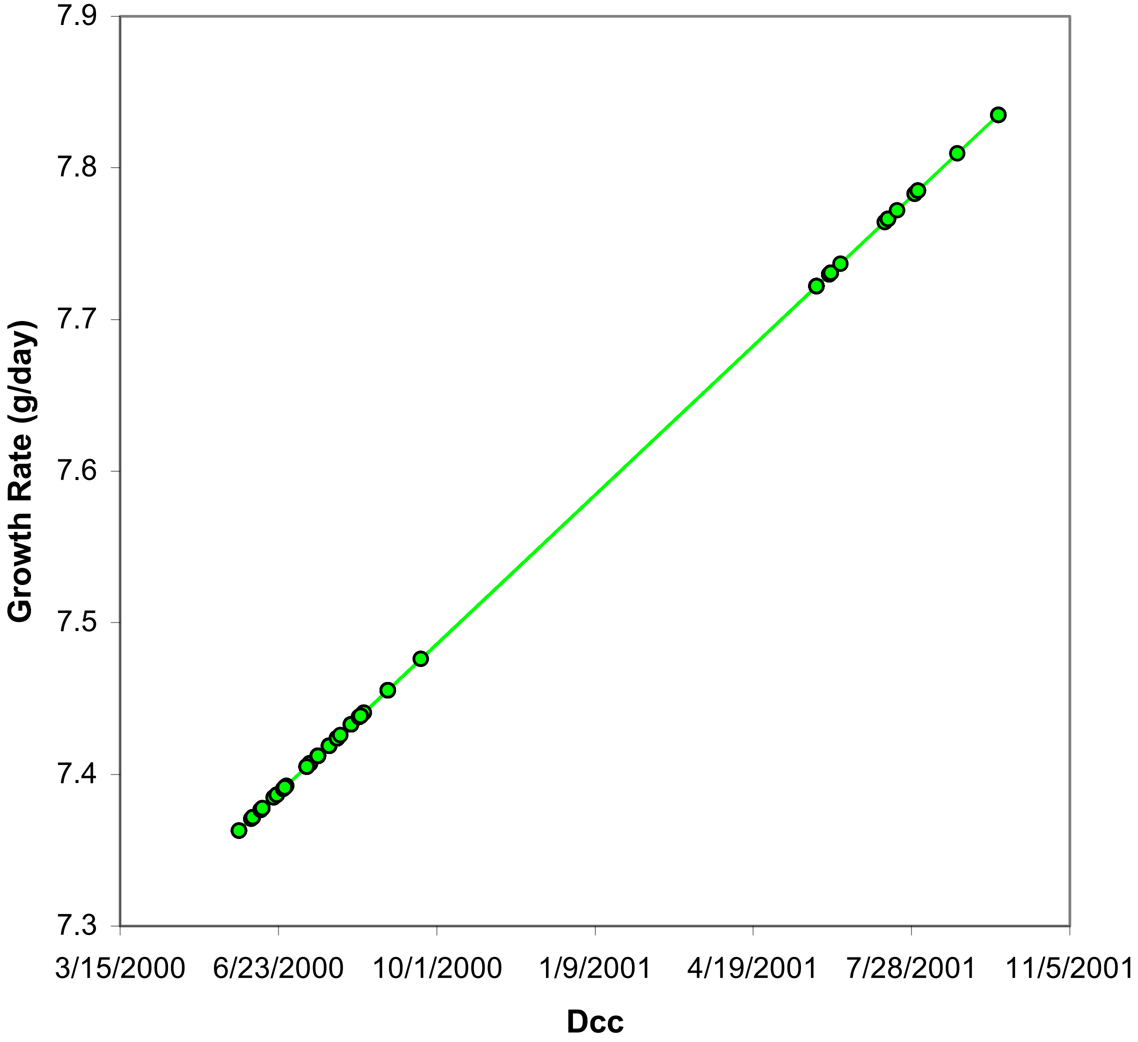

Figure 21. Plot of growth rate (g/day) versus date of cohort combination (Dcc) for blacktips caught in Timbalier Bay, Louisiana, in 2000-2001. Growth rates ranged from 7.36 to 7.84 g/day.

assumption that the sharks were filling their stomach once per day. Under the assumption that the sharks were filling their stomachs once every other day, the growth efficiency was calculated as being 25.1%. Because these seem to be the only two feasible scenarios, the growth efficiency was determined to be between the range of 13-25%.

DISCUSSION

The percentage of empty blacktip stomachs from my study (48%) paralleled the findings of other studies on blacktip feeding. Dudley and Cliff (1993) found that 49% of the blacktip stomachs from South Africa were empty. A similar study from South Africa by Bass et al. found that 46% of blacktips examined contained empty stomachs. Likewise, the percentage of empty Atlantic sharpnose stomachs from my study (55%) paralleled the findings of Gelsleichter et al. (1999), who found that 48% (after my re-calculation) of the sharpnose examined from the northwest Atlantic Ocean contained empty stomachs.

Although regurgitation has been mentioned as a potential problem when performing food studies using gillnets to capture predatory fishes (Treasurer 1988), my study on the feeding habits of blacktips and sharpnose did not appear to be biased by regurgitation. According to Treasurer (1988), the stomach of a fish that has regurgitated was said to be large, with thin walls, distended, and with little internal ridging, as opposed to genuinely empty stomachs that were generally smaller, with thick, heavily-ridged walls. Although not recorded or quantified, few, if any, blacktip or sharpnose stomachs exhibited the characteristics of a regurgitated stomach in my study.

Teleosts occurred in 96.5% of blacktip stomachs that contained a prey item. This percentage of occurrence for teleosts in blacktip stomachs was consistent with the literature. Bass et al. (1973) found that 93% of blacktips from their study in South Africa contained teleost prey in their stomachs. Dudley and Cliff (1993) recorded that 82.7% of the blacktip stomachs they examined from South Africa contained teleost prey. In all, I identified ten families of teleosts in the stomachs of blacktip sharks from my study, each family contributing one representative, with the exception of Sciaenidae, which had four species represented.

Atlantic sharpnose have been reported to be highly opportunistic, exploiting teleosts, crustaceans, and mollusks (Gelsleichter et al. 1999). Previous studies have found that sharpnose feed on a number of species of crabs, as well as species of shrimp and squid (Gelsleichter et al. 1999). I found no evidence of crabs being ingested by sharpnose in this study. However, I did encounter shrimp from the family Penaeidae and squid from the family Loliginidae. Interestingly, no members of the family Sciaenidae (drum family) were found in the stomachs of Atlantic sharpnose sharks. This fact seemed odd in that sharpnose were primarily piscivores, and the Sciaenids made up the largest family in the sampling area in terms of numbers of species. Gelsleichter et al. (1999) found only one species of Sciaenid in the stomachs of Atlantic sharpnose caught from the northwest Atlantic Ocean; however, Sciaenids were not as abundant in terms of number of species in that region (Robins and Ray 1986). My findings indicated that although sharpnose in coastal Louisiana waters were feeding on teleosts, crustaceans, and mollusks, they appeared to be primarily ingesting teleost prey, with the unusual exception of Sciaenids.

To my knowledge, this was the first study on sharks that resulted in conclusively finding a diel feeding behavior. Cortes et al. (1996) performed a diel study on the bonnethead shark, and the techniques employed in their study closely compare to the techniques used in my study. The researchers' findings indicated that their results differed due to manipulation of the time intervals designated in their study. When using 4-hr intervals, they found significant differences in I_f as a percentage. However, when using 3-hr intervals, no such pattern emerged. As discussed below, my findings offered evidence that juvenile blacktip sharks in coastal Louisiana waters were exhibiting a diel feeding behavior in the summers of 2000 and 2001.

In order to test the hypothesis that the blacktips and sharpnose were actively selecting menhaden as their primary prey items, I reviewed existing literature on the distribution of organisms in Timbalier Bay. The Louisiana Department of Wildlife and Fisheries used a variety of standardized gears, stations, and procedures to monitor Louisiana's estuarine-related fin and shellfish resources. Two of its most outstanding programs monitored 1) the macro-benthic community exploited by the estuarine portion of the Louisiana shrimp fishery and 2) the macro-pelagic community exploited by estuarine finfishers. Early findings of the first program (hereafter termed the Benthic Program) were reported by Perret et al. (1971). Early findings of the predecessor of the second program (hereafter termed the Pelagic Program) were reported by Adkins and Bourgeois (1982). These publications were reviewed and were the best available indicators of the relative abundance of both benthic and pelagic organisms that were of a size range to be exploitable by both blacktip and Atlantic sharpnose sharks in my study.

The Pelagic Program obtained 42 species of animals in the gill net samples it took during April 1979 through March 1981 in the Timablier-Terrebonne Bay system. Adkins and Bourgeois (1982) reported that blue crabs, *Callinectes sapidus*, were numerically the dominant catch (32% by number), followed by hardhead catfish (24%); spotted seatrout, *Cynoscion nebulosus*, (23%); gulf menhaden (6%), black drum, *Pogonias cromis*, (3%), and spot (2%). No other species captured accounted for more than one percent of the total number of individuals captured (Adkins and Bourgeois 1972).

The Benthic Program obtained 100 species of fin fish and 19 species of invertebrates in the 1,390 trawl and 130 seine samples it made from April 1968 through March 1969 throughout the Louisiana coast. Five fin fish and three shell fish accounted for 92.2% of the catch (Perret et al. 1972). Of these, the most abundant fin fish were bay anchovy and Atlantic croaker (accounting for 42% and 24% of the total fin fish catch by number), followed by gulf menhaden; Atlantic threadfin herring, *Opisthonema oglinum*, and spot, *Leoistomus xanthurus*, (collectively accounting for approximately 24% of the fin fish catch by number). Brown, white, and pink shrimp were the three most abundant shell fish in the Benthic Program's catch. Though bay anchovy dominated the fin fish catch in numbers, Perret et al. (1972, p. 65) noted that "fishes in the family Sciaenidae were caught in the greatest number" by family and that high catches of bay anchovy may have been attributable to the size of mesh used in their experimental trawls.

These published findings suggested that menhaden were not the most abundant species in terms of percent composition by number in the general area of my sampling, Timbalier Bay. The fact that I found menhaden to be the most abundant prey item in terms of percent composition by number in both blacktip and sharpnose stomachs suggested that these two species of sharks were actively pursuing menhaden as their primary prey.

Published studies calculating gastric evacuation rates for sharks were rare. Medved (1985) calculated a gastric evacuation rate of 92.3 hours for sandbar sharks, *Carcharhinus plumbeus*, to evacuate 98% of a force-fed menhaden. This study took place in Chincoteague Bay, Virginia, and sharks were held in an enclosure within the bay. Cortes and Gruber (1992) found that juvenile lemon sharks, *Negaprion brevirostris*, that were force-fed either snapper or grunt had a gastric evacuation rate of 28.4 to 40.8 hours. This study was performed in penenclosures at Bimini Lagoon, Bahamas, and Lower Matecumbe, Florida Keys, U.S.A. My calculation of a 24 hour gastric evacuation rate for juvenile blacktips in Timbalier Bay, Louisiana, was thus the shortest gastric evacuation rate reported for any shark species.

To my knowledge, this was the first study that combined daily estimates of ingestion with daily estimates of growth in order to achieve a balance in terms of expected growth efficiency. The calculated range of growth efficiency of 13-25% was dependent upon an assumption of how frequently blacktips were filling their stomachs with prey. Due to my findings that blacktips appeared to be feeding mainly at late afternoon / early evening, I assumed that the majority of blacktips are not filling their stomachs more than once a day. Based on the calculated growth rates and the apparent "rapid" rate of degradation for menhaden observed in my Scale of Degradation, I assumed that blacktips were feeding no less than once every other day. Therefore, when using the assumption that blacktips filled their stomachs once a day, a growth efficiency of 12.6% was estimated. When using the assumption that blacktips filled their stomachs once every other day, a growth efficiency of 25.1% was estimated. Because it was reported that growth efficiencies in nature typically range from 6-20% (Thurman and Burton, 2001), I felt confident that my estimates of growth efficiencies for these juvenile blacktip sharks were reasonable and accurate.

Many stomachs contained otoliths and eye lenses from previously ingested prey items. Initially, I had hoped to use the weights of eye lenses from several species of common bycatch as a comparison with the weights of eye lenses found in the shark stomachs in order to gain some insight on to the approximate time that the prey was ingested. Tests were run mimicking the pH of shark stomach acid over given time periods, after which the eye lenses were weighed. However, the eye lenses in the experiment degraded at a quicker rate than were expected. I believed this to be explained by the fact that stomach acidity in sharks was constantly changing, depending not only upon the presence or absence of food, but also the stage of digestion of any food present in the stomach. I still believe that eye lenses can serve a useful function in stomach content analysis; however, appropriate and sufficient tests must be performed---tests that I was not able to perform during this research project.

The absence of adults from the sample of blacktips (defined as males with calcified claspers and females with developed ovaries) captured during this study indicated that the Timbalier Bay region of coastal Louisiana served as an area where juvenile blacktips spent their summer months. It seemed reasonable to infer that these young sharks used Timbalier Bay as an area where they fed on the abundant food supplies, and also escaped predation by larger sharks that seem to remain offshore of this region. The presence of two blacktips with open umbilical scars and 53 blacktips with a partially open umbilical scar suggested that Timbalier Bay also served as a nursery ground where adult female blacktips either had their pups in Timbalier Bay or in nearby waters.

However, both adult and juvenile Atlantic sharpnose sharks appeared to be utilizing Timbalier Bay for its rich feeding grounds and protective shelter. No sharpnose were captured with an open or partially open umbilical scar, however, indicating that this species of shark may not have been using Timbalier Bay as a primary nursery ground. The majority of sharpnose, in fact, showed no signs of an umbilical scar, indicating that most were either adults or sub-adults. No adult females were captured during our sampling; it was believed that they remained in deeper water throughout the summer months.

As mentioned previously, the following environmental parameters were collected immediately following the deployment of the gillnet: time, water temperature, dissolved oxygen, conductivity, salinity, water depth, turbidity, bottom type, Beaufort sea state, wind direction, and cloud cover. Although there may be patterns relating the sharks' behavior with some of these parameters, I did not use any of them in my data analysis. The opportunity exists for future examination of these parameters and their relationship with such things as shark capture rates, feeding activity, or species composition.

Finally, catch per unit effort was not explored in this study for two reasons. First, sharks were seldom simply gilled in the net. Rather, they frequently appeared to have wrapped a substantial portion of the net around their bodies after the initial encounter with the net. Second, the gillnet panels received considerable damage by sharks and other organisms prior to and during each check of the gillnet. This damage often resulted in large holes (greater than 1 m in diameter). Therefore, no discernable "unit effort" could be derived. "Unit effort" required that a surface area be reproducible for future sets of the net. Because sharks often twisted the net and large holes occurred unpredictably yet quite often, no measure of the surface area was possible.

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