FINALREPORT
MONKFISH RSA 2007/2008

Report title: The Biology of Large Monkfish, *Lophius americanus*
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1. Abstract

The American monkfish, *Lophius americanus*, supports important commercial fisheries in the Northwest Atlantic. Although life history information is available for smaller *L. americanus*, the biology of large monkfish (> 70 cm) is poorly understood because relatively few large fish are caught in standard resource surveys. Between 2006 and 2008, 699 *L. americanus* 71-118 cm total length (TL) were collected from commercial gillnet fishermen operating in the mid-Atlantic Bight (n=689) and in the Gulf of Maine (*n* = 10) to investigate growth rates, reproductive biology, and feeding habits of large monkfish. All *L. americanus* collected were mature females ranging in age from 7 to 13 years. Growth was linear at an average annual rate of 7.6 cm. Hepatosomatic indices peaked in February and gonadosomatic indices peaked between February and April. Postovulatory follicles and vitellogenic oocytes were observed in the same ovaries, evidence that monkfish spawn over a protracted period and possibly more than once annually. Food habits were similar to those reported for smaller benthic phase monkfish, but cannibalism was more prevalent in large fish (5.6% frequency of occurrence). Frequencies of feeding and cannibalism were highest in females in the final stage of oocyte maturation.

2. Statement of Problem:

The monkfish (*Lophius americanus*) supports one of the most lucrative fisheries in the northwest Atlantic Ocean. The fishery was developed during the 1980s, and by the mid-1990s, monkfish surpassed traditional groundfish species (cod, haddock and flounder) to become the highest valued finfish in the northeastern U.S. (http://www.st.nmfs.gov/st1/Commercial/landings/annual_ landings.html). However, monkfish biology has been poorly known, largely because monkfish are not well-sampled by the gear used in the Northeast Fisheries Science Center's annual resource surveys. Two synoptic industry-based monkfish trawl surveys conducted in 2001 and 2004 (http://www.nefsc.noaa.gov/read/popdy/monkfish/Survey2004/2004_index.html) have helped elucidate the biology of monkfish; however, some important gaps remain. One of these is the biology of large monkfish. Relatively few specimens larger than 90 cm total length (TL) (~ 10 yr) have been caught in industry-based trawl surveys, and fewer are caught in NEFSC annual surveys. Monkfish are known to reach approximately 140 cm based on occasional catches in NEFSC surveys conducted since 1963. Information on large monkfish can enhance our knowledge of the biology of monkfish, provide more current information on age, growth and reproductive status, and contribute information that can be used to support monkfish management. The purpose of this study, therefore, was to obtain specimens of large monkfish to: 1) estimate growth rates; 2) investigate reproductive biology and 3) examine food habits.

Project Objectives

The objectives of this study were to provide information on the biology of large monkfish (90 cm and larger) that can be used to enhance the management of this species.

Objective 1: Determine age and growth patterns of monkfish
Potential yield from the fishery is unknown because growth curves (age-length relations) based on existing data (up to age 10) do not reach an asymptote. Monkfish have a steep length-weight relationship, thus potential yield increases rapidly with increasing size at least up to age 10. The point at which growth rates (and thus potential yield) begin to decline is unknown because there are no older/larger specimens in the aged data set. Elucidation of the full growth curve would provide critical information on growth, natural mortality, longevity, and potential yield for optimal fishery management.

Objective 2: Investigate spawning frequency of large monkfish
Monkfish larger than about 70 cm TL are usually females (NEFSC 2002, 2005), probably because of shorter male longevity. Females mature at around age 5 (50% maturity at age 4.8, 43 cm TL, NEFSC 2002), and are thought to spawn annually; however, annual spawning may not be the norm in older individuals. Spawning frequency is an important factor in both population productivity and resilience, yet spawning frequency of large monkfish is unknown.

Objective 3: Estimate the rates of cannibalism by large monkfish
Monkfish are cannibalistic, and although the overall population rate of cannibalism is low (~0.11% frequency of occurrence, ~1.2% of diet composition; Jason Link, NEFSC, personal communication), there is some evidence that cannibalism rates are higher in large monkfish (Armstrong et al. 1996; NEFSC 2002). If this is accurate, it holds important implications for population models and fishery management.

3. Methods

Study sites were located within the two management areas (NMA and SMA). The NMA included areas north of 41° 30´N (Figure 1), with all samples collected in the western Gulf of Maine (WGOM). The SMA was subdivided into the northern Mid-Atlantic Bight (NMAB) and southern Mid-Atlantic Bight (SMAB) based on latitude. The NMAB included the area between latitudes 39°30´N and 41°30´N, and the SMAB between 35°N and 39°30´N (Figure 1). A total of 699 *L. americanus* specimens ranging in size from 71 to 118 cm total length (TL) was collected by commercial gillnetters (n = 12) using 12 inch mesh nets between Cape Ann, Massachusetts and Chincoteague, Virginia, from January 2006 to April 2008 (Table 1; Figure 1). Of the total, 268 monkfish were collected between May 2007 and April 2008. Approximately 99% of the specimens came from the SMA (Figure 1) and 73% were collected during the first half of the year (Table 1). *L. americanus* were shipped from the port of landing to the University of

Maryland Eastern Shore where 99% were processed in a fresh (unpreserved) state, within 1-2 days of capture. Each fish was weighed to the nearest 0.1 kg and measured (TL) to the nearest 0.5 cm. Samples were collected for studies of growth, food habits and reproductive biology, as described below.

Age and growth

Vertebrae (n = 661) were used for age determination following the procedures of Armstrong *et al*. (1992) and Hartley (1995). Armstrong et al. (1992) established that vertebrae meet the minimum criteria for the use of structures for age determination (Van Oosten, 1929), but the method has not been validated directly. From each fish, vertebrae numbers 3-11 were excised and vertebra number 8 (or number 9, if number 8 was damaged) was cleaned and stored frozen for 1-2 months before baking. Vertebra number 8 was baked in a drying oven for 1-1.5 h at 230°C to enhance the contrast in presumed annual rings before counts were made using a dissecting microscope at 60x magnification. Most vertebrae (n = 523) were read by two independent readers and the remainder (n=138) by one reader. If age readings differed by 1 year (n=110), the estimate from the most experienced reader was used. If readings differed by 2 years (n=24), the average age was used. Vertebrae were classified as "unreadable" and removed from the sample set if readings disagreed by 3 years or more (n = 2).

Reproduction

All specimens collected in this study were female and gonad samples for histological examination were taken from 630 of them. Samples were fixed in 10% neutral buffered formalin, dehydrated, embedded in paraffin, sectioned at 5 μm and stained with hematoxylin and eosin (H&E). Histological sections were examined by light microscopy and assigned maturity stages following the criteria of Wallace and Selman (1981), Armstrong *et al*. (1992), and Martinez (1999). Ovarian stages [perinucleolar, cortical alveoli, vitellogenic and final stage of oocyte maturation (FOM, hydrated)] were classified based on the stage of maturity of the most advanced stage oocytes.

Ovaries and livers were weighed, and the gonadosomatic index (I_G) and hepatosomatic index (I_H) calculated as:

$$I_G = 100 W_G (W - W_G)^{-1} \text{ and } I_H = 100 W_H (W - W_H)^{-1},$$

where W_G= gonad weight, W_H = liver weight and W= body weight.

Analysis of variance (ANOVA, SAS Ver. 9.1; SAS Institute Inc, Cary, NC, USA) was used to test the influence of month and gonad stage on $\log_e$-transformed I_G and I_H. Significant ANOVAs ($p < 0.05$) were followed by Tukey's multiple comparison tests (Neter *et al*., 1996).

Food habits

Lophius americanus stomachs were removed and contents weighed to the nearest gram. Prey items were sorted, identified to the lowest taxon possible, enumerated, weighed individually and by prey category, and measured if possible. Intact *L. americanus* prey (n = 4) were measured, weighed, and dissected to determine gender. The relative abundance of prey species were calculated as percentage frequency by number (%N), weight (%W) and index of relative importance (%IRI) for major taxonomic prey groups (Armstrong *et al*., 1996). The incidence of

cannibalism was determined for *L. americanus* at each microscopic gonad stage.

4. Results and Conclusions

All monkfish (n = 699) collected were females ranging in size from 71 to 118 cm, with a modal length of 90 cm TL (Figure 2). Most (67%) were collected during February and from April to June, very few being collected during the rest of the year (Table 1) because of the seasonality in fishing effort. The SMA accounted for 99% of the total (n = 689; Figure 1), because fishery regulations in the NMA made it more difficult to obtain collaborators there. In the SMA, 58% of the samples came from the NMAB and 42% from the SMAB (Figure 1).

Age and Growth

Age was successfully estimated for 659 fish ranging in size from 71 to 118 cm. Agreement between readers was 74%, and most readings that disagreed varied by just 1 year (81%). Ages ranged from 7 to 13 years, but most specimens were ages 8-11. Growth increased linearly with age (Figure 3) with an average annual increment of 7.6 cm (based on quarter 2 samples which were represented by all ages, n =336). The greatest increase in length occurred between the 2nd and 3rd quarters of the year (Figure 3).

A primary goal of this study was to extend the maximum observed age to fully elaborate the growth curve for *L. americanus*. Specimens up to 138 cm were collected in NEFSC surveys prior to the development of aging methods (Richards *et al*., 2008), but in this study, fish larger than 118 cm (13 years of age) were not obtained, and only 7% were > 100 cm TL. The lack of large specimens is likely the result of high fishing mortality in recent years (Haring and Maguire, 2008). The location of our sampling may have been a factor as well. The geographic distribution of large monkfish caught in NEFSC resource surveys indicates that the largest monkfish were more common in the NMA.

Reproduction

All the monkfish examined were mature (Figures 4); immature ovaries containing perinucleolar oocytes as the most advanced stage were not observed. Ovaries at each stage (except FOM) contained primary oogonia, chromatin nucleolar and perinucleolar stage oocytes (Figure 4). Of the 4 ovarian stages observed in these mature females, atretic stage ovaries were the most common (56%) followed by hydrated (18%) and vitellogenic oocytes (18%). Ovaries with cortical alveoli as the most advanced stage oocytes were least common (8%). Large female *L. americanus* spawned between January and August (Figure 5; Figure 6). Mean I_G values were significantly higher for February and March than all other months (Figure 6). Mean I_H was significantly higher for February than all other months except January and December (Figure 6). Comparisons of I_G and I_H to gonad histology in females showed that mean I_G peaked during FOM, while I_H was highest in females with vitellogenic oocytes (Figure 7). Mean I_G values were significantly different at each stage of gonad development whereas mean I_H values were significantly higher in females with vitellogenic oocytes than those at all other stages of gonad development (Figure 7). As a result of the small number of samples collected from the NMA, latitudinal differences in spawning of *L. americanus* could not be determined. Within the MAB, there were no differences between NMAB and SMAB.

The gonad histology and temporal patterns in I_G and I_H values indicated a protracted reproductive season for large *L. americanus* from January-August with the most active spawning occurring between February and April. We observed no differences in reproductive season between the NMAB and the SMAB. Protracted spawning periods, as long as 4-12 months, have been reported for anglerfishes around the world. In contrast, Armstrong *et al*. (1992) reported a shorter spawning period (May to June) for *L. americanus* collected from the Mid-Atlantic Bight than that observed during this study. The truncated spawning season observed by Armstrong *et al.* (1992) may reflect the small number of ripe females they caught (*n* = 13), the lack of mature females collected between January and February, and the use of trawlnets to sample fish. The presence of oocytes at different stages of development in mature females caught during the breeding season could be taken as evidence that *L. americanus* is a multiple spawner, releasing several batches of oocytes over a protracted spawning period. The presence of postovulatory follicles in females with vitellogenic oocytes throughout the spawning season further supports this suggestion.

Food Habits

Of the 699 stomachs examined, 34.9% contained prey remains. Incidence of feeding was 30% (n = 10) for GOM, 33.4% (n = 398) for NMAB, and 35.4% (n = 291) for SMAB. In all, 17 prey species were identified, including pelagic and benthic species belonging to four major taxonomic groups: Cephalopoda, Decapoda, Elasmobranchii, and Teleostei, of which the last was most important in both the NMAB (%IRI = 93.9) and the SMAB (%IRI = 57.8). Bony fish, elasmobranchs, and long-finned squid made up the greatest proportions in number and weight of prey of *L. americanus* from both the NMAB (%N = 96; %W = 99) and SMAB (%N = 99; %W = 99; Figure 8). Atlantic mackerel, skate, northern stargazer, and monkfish were the most common identifiable prey items (Figure 8). The smallest identifiable prey species was a Gulf Stream flounder (9.5 cm) and the largest was a female Atlantic cod (82 cm) taken from a 97cm *L. americanus*. There was no relationship between predator length and prey length within the size range of specimens in our study (Figure 9).

The overall frequency of cannibalism was 5.6%. Evidence of cannibalism ranged from jaw bones (NMAB, *n* = 2; SMAB *n* = 4) to partially digested monkfish (NMAB, *n* = 21; SMAB, *n* = 11). One incidence of a partially digested *L. americanus* was found for W GOM. The gender of *L. americanus* prey was identifiable in four specimens, one female (36.5 cm TL) and three males (36 cm TL; 48 cm TL; 53 cm TL) taken from specimens >90 cm TL. The incidence of prey items was highest in hydrated (FOM) females (50.4%) and lowest in post-spawning (atretic) females (32.4%; Figure 10). The frequency of *L. americanus* in the diet was greatest in females undergoing FOM (9.6%) and lowest in those with cortical alveoli (4.3%; Figure 10).

The high percentage of *L. americanus* with empty stomachs suggests that feeding is sporadic or possibly that *L. americanus* regurgitate when captured. Laurenson and Priede (2005) attributed high proportions of empty stomachs in large *L. piscatorius* to infrequent feeding. The large proportions of unidentified bony fish and skates found within stomachs from all seasons

could be an indication that the digestion process is slow, especially for larger prey items (Valentim *et al*., 2008). However, estimates of daily ration and gastric evacuation rates are not available for *L. americanus*. We observed a relatively high frequency of cannibalism in our samples (5.6% overall). In contrast, the rate of cannibalism was only 0.13% in >10,000 *L. americanus* stomachs collected in NEFSC resource surveys during 1977-2007 (NEFSC, unpublished data), but the median TL of *L. americanus* sampled during these surveys was 42 cm compared to 91 cm in the current study. These results suggest that cannibalism is more common in large females and rates are highest in ripe (FOM) females.

Benefits and/or contributions to management decision making: Our results have the potential to improve several aspects of the population assessment for monkfish. Several aspects of the life history of the American monkfish *L. americanus* has been revealed, some of which have not been evident through study of younger individuals. In particular, we found that size continued to increase linearly with age, and although the annual increment was somewhat smaller than for younger monkfish, we found no indication that growth rates had reached an asymptote. Cannibalism was much more important in the diets of large females than in the population as a whole, which begs the question of what impact this may have on productivity of the population if age structure is allowed to rebuild. Inferences from reproductive histology suggested the possibility that large female monkfish may spawn more than once per year, which also has important implications for stock productivity. These aspects of monkfish life history warrant further investigation and application to modeling studies.

5. Project management: list individuals and/or organizations actually performing the work and how it was done.

The major collaborators on this project were from UMES, NEFSC and the fishing industry.

1. **University of Maryland Eastern Shore**
   Monkfish samples were processed for age and growth, reproduction and feeding habits. All data were analyzed by Dr. Johnson, Mr. Daniel Cullen in collaboration with Dr. Anne Richards from the NEFSC.
   Northeast Fisheries Science Center
   The students were trained in preparation of monkfish vertebrae for aging and age-reading techniques and in the biological sampling of monkfish by experts from the NEFSC laboratory. One of the three age readers was from the NEFSC.
2. **Monkfish gillnetters**
   Monkfish were collected by gillnetters from both management areas (Table 4 below). A total of 74.17 DAS were used by our industry collaborators from May, 2007 to April, 2008 (Table 3). Additional monkfish were collected during the year with funds from the NOAA Living Marine Resources Cooperative Science Center and these are included in the final report.

6. Financial Report

A total of $42,344.48 was received from sale of monkfish by gillnetters participating in the RSA (see Table 5). So far, a total of $22,093 has been spent (see below).

RESEARCH BUDGET			
GRANTEE:	Project Title:	The biology of large monkfish, *Lophius americanus*	
A. SALARIES AND WAGES			
1. SENIOR PERSONNEL		**Total Time (Months)**	**Expenditures**
a. Principal Investigator:	Andrea Johnson	3	
b. Graduate Student:	Daniel Cullen	12	
c. Undergraduate Students (2):			$9,411
Total Salaries and Wages			$9,411
B. PERMANENT EQUIPMENT			
C. EXPENDABLE SUPPLIES AND EQUIPMENT			$3,028
D. TRAVEL			$9,653.85
E. PUBLICATIONS AND DOCUMENTATION COSTS			
F. OTHER COSTS			
TOTAL DIRECT COSTS			$22,093

7. Evaluation

A. Describe the extent to which the project goals and objectives were attained. This description should address the following:

1. Were the goals and objectives attained? How? If not, why?
2. Were modifications made to the goals and objectives? If so, explain.

Objective 1: Age and growth of monkfish were determined from vertebrae samples aged by both NEFSC and UMES personnel. We were not able to elucidate the full growth curve for monkfish (Objective 1) because of a lack of very large specimens in the data set. Thus, our growth curve did not reach an asymptote but remained linear (Fig. 4).

Both objectives 2 and 3 were attained.

Objective 2: Spawning in these large females seems to occur more than once annually in these large females. The gonad histology showed the presence of oocytes at different stages of development in these large females during the breeding season even in post-spawning females. This could be taken as evidence that monkfish is a multiple spawner.

Objective 3: Cannibalism rates were determined from gut contents of monkfish collected during the study. Cannibalism rates were much higher (5.6%) than those obtained by the NEFSC (0.13% frequency of occurrence, ~1.2% of diet composition; Jason Link, NEFSC, personal communication). There were no modifications to the objectives.

B. If significant problems developed which resulted in less than satisfactory or negative results, they should be discussed.

The problems that occurred during this study were not significant but they did affect the results of the study. For example, not as many large monkfish were collected as anticipated. This is reflected in the size distribution of monkfish (Fig. 2); the median size was 90cm TL and the largest monkfish was 118 cm TL. In addition, most of the samples were collected in the spring and fall leaving gaps in the sampling during the other times of the year. This variability reflects the seasonality in the monkfish fishery. Also, because of the low numbers of samples collected from the NFMA, comparisons between the two management areas were not possible. During 2007/2008 study period, we only collected 268 samples. This was due to many factors ranging from high fuel prices to changes in allotment of DAS during that year.

2. Dissemination of project results:

Explain, in detail, how the project=s results have been, and will be disseminated.

The results of this study have been published in the ICES Journal of Marine Science. The results have been presented at the following scientific conferences below:

1. "Variation in gonadal development in large female monkfish along the northwestern Atlantic Ocean" American Fisheries Society Lake Placid, New York (September 22-26, 2006). Poster presentation by Vincent Dominique III (UMES undergraduate student).
2. "Comparison of two methods of aging monkfish: Vertebrae vs. Illicia" American Fisheries Society Lake Placid, New York (September 22-26, 2006). Poster presentation by Belita Nguluwe (UMES undergraduate student)
3. Feeding Habits of the Large Monkfish, *Lophius americanus* (NOAA EPP Education and Science Forum, Florida A&M, Tallahassee, FL (October 30-Nov. 1, 2006). Poster presentation by Abram Townsend (UMES undergraduate student).
4. "Comparing Age and Growth Estimates for Large Monkfish (*Lophius americanus* V.) using Illicium and Vertebral Ageing Methods" American Fisheries Society 137th Annual Meeting, San Francisco, California (September 2-6, 2007). Poster presentation by Daniel Cullen (UMES M.S. student).
5. "Comparing Age and Growth Estimates for Large Monkfish (*Lophius americanus* V.) using Illicium and Vertebral Ageing Methods" International Council for the Exploration of the Sea (ICES), Helsinki, Finland (September 17-21). Poster presentation by Daniel Cullen (UMES M.S. student).
6. "Biology of Large Monkfish, *Lophius americanus*" International Council for the Exploration of the Sea (ICES), Helsinki, Finland (September 17-21, 2007). Oral presentation by Andrea Johnson (PI)
7. "Growth, Reproduction and Feeding of Large Monkfish, *Lophius americanus*" American Fisheries Society 138th Annual Meeting, Ottawa, Canada (August 17-21, 2008).Oral presentation by Andrea Johnson (PI)

Table 1. Monthly collection of female *L. americanus* from three regions of the Northwest Atlantic, 2006-2008.

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	TOTAL
GOM[1]				4		5	1						10
N MAB[2]	23	53		31	33	95	46	23	5	32	44	13	398
S MAB[3]	12	57	12	77	107	4					10	12	291
TOTAL	35	110	12	112	140	104	47	23	5	32	54	25	699

[1]Gulf of Maine
[2]Northern Mid-Atlantic Bight
[3]Southern Mid-Atlantic Bight

Table 2. Industry collaborators from the Northern and Southern Fishery Management Areas

Monkfish gillnetters	**Fishing Vessel**	**Port**
Charlie Dodge	Lady Irene	Chatham, MA
	Stranglehold	Gloucester, MA
	Edward & Joseph	Cape Cod, MA
John Roberts	Misty Marie	Cape Cod, MA
Scott Eshenfelder	Sharon E	New London, CT
John Stolgitis	Martha Porter	Pt. Judith, RI
Peter Krasowski	Critical	Pt. Pleasant, NJ
Roger Wooleyhan	Wooley Bully	Ocean City, MD
Chris Hickman	Bout Time	Chincoteague, VA

Table 3. Days-at-Sea (DAS), monkfish samples collected and funds generated from sale of catch during the 2007/2008 Monkfish RSA Program.

DAS	VTR	F/V	Fishermen	Date Landed	Port Landed	No. Fish	Amt. Sold ($)	Research Funds ($)
0.63	10578948	Bout Time	Chris Hickman	5/1/2007	Chincoteague, VA	4	1791.80	378.53
0.63	10578949	Bout Time	Chris Hickman	5/3/2007	Chincoteague, VA	0	1218.10	249.76
0.63	10578950	Bout Time	Chris Hickman	5/5/2007	Chincoteague, VA	4	1058.20	267.95
0.63	10578951	Bout Time	Chris Hickman	5/13/2007	Chincoteague, VA	0	455.75	117.34
0.63	10783152	Bout Time	Chris Hickman	5/14/2007	Chincoteague, VA	6	1127.95	285.39
0.63	10783153	Bout Time	Chris Hickman	5/17/2007	Chincoteague, VA	0	1209.20	305.72
0.63	10783156	Bout Time	Chris Hickman	5/20/2007	Pt Pleasant, NJ	0	1073.35	239.74
0.63	10783155	Bout Time	Chris Hickman	5/22/2007	Pt Pleasant, NJ	4	1247.00	278.46
0.63	10783156	Bout Time	Chris Hickman	5/24/2007	Pt Pleasant, NJ	0	1252.10	279.6
0.63	10783159	Bout Time	Chris Hickman	5/29/2007	Pt Pleasant, NJ	0	1264.75	278.24
1.09	10783165	Bout Time	Chris Hickman	12/5/2007	Pt Pleasant, NJ	3	2720.55	598.21
1.04	10783173	Bout Time	Chris Hickman	12/28/2007	Pt Pleasant, NJ	0	2478.00	545.16
1.02	10783175	Bout Time	Chris Hickman	1/4/2008	Chincoteague, VA	0	3239.50	712.69
1.01	10783177	Bout Time	Chris Hickman	1/7/2008	Chincoteague, VA	0	3107.52	683.65
1.01	10783180	Bout Time	Chris Hickman	1/12/2008	Chincoteague, VA	0	2921.00	575.19
1.02	10783181	Bout Time	Chris Hickman	1/17/2008	Chincoteague, VA	0	2067.00	411.95
1.08	10783185	Bout Time	Chris Hickman	1/26/2008	Chincoteague, VA	0	2247.20	494.38
1.03	10783188	Bout Time	Chris Hickman	2/8/2008	Chincoteague, VA	0	1978.54	435.27
0.63	10783193	Bout Time	Chris Hickman	3/28/2008	Chincoteague, VA	0	1136.36	250.00
1.21	10783197	Bout Time	Chris Hickman	4/23/2008	Chincoteague, VA	0	2282.50	502.15
1.3	10783198	Bout Time	Chris Hickman	4/25/2008	Chincoteague, VA	3	2711.50	596.30
1.05	10783200	Bout Time	Chris Hickman	4/30/2008	Chincoteague, VA	0	1623.60	357.19
18.79						**24**	40211.47	8842.87
0.63	10754891	Critical	Peter Krasowski	6/18/2007	Pt Pleasant, NJ	18	1751.82	350.36
0.63	10754892	Critical	Peter Krasowski	6/25/2007	Pt Pleasant, NJ	12	1501.87	300.37
0.63	10754893	Critical	Peter Krasowski	6/30/2007	Pt Pleasant, NJ	14	974.91	194.98
0.63	10754894	Critical	Peter Krasowski	7/6/2007	Pt Pleasant, NJ	4	1670.57	334.11
0.63	10754895	Critical	Peter Krasowski	7/13/2007	Pt Pleasant, NJ	5	1358.32	271.664
0.63	10754896	Critical	Peter Krasowski	7/19/2007	Pt Pleasant, NJ	5	1622.48	324.496
0.63	10754899	Critical	Peter Krasowski	7/25/2007	Pt Pleasant, NJ	7	1235.51	247.10
0.63	10828207	Critical	Peter Krasowski	7/31/2007	Pt Pleasant, NJ	3	1620.65	324.13
0.63	10828208	Critical	Peter Krasowski	8/7/2007	Pt Pleasant, NJ	4	1105.04	221.00
5.67						**72**	12841.17	2568.21
1.2	10845949	Lady Irene	Charlie Dodge	6/8/2007	Stage Harbor, MA	2		
1.2						**2**		

non-RSA	10919380	Martha Porter	John Stolgitis	5/3/2007	Point Judith, RI	2		
non-RSA	10919383	Martha Porter	John Stolgitis	5/8/2007	Point Judith, RI	2		
0.63	10919384	Martha Porter	John Stolgitis	5/9/2007	Point Judith, RI	1	2570.70	575.00
0.63	10919386	Martha Porter	John Stolgitis	5/13/2007	Point Judith, RI	2	2616.00	601.00
0.63	10919389	Martha Porter	John Stolgitis	5/20/2007	Point Judith, RI	3		
non-RSA	10919390	Martha Porter	John Stolgitis	5/21/2007	Point Judith, RI	2	2553.10	
0.63	10919391	Martha Porter	John Stolgitis	5/23/2007	Point Judith, RI	2	2460.40	1152.00
0.63	10919393	Martha Porter	John Stolgitis	5/27/2007	Point Judith, RI	2	2242.40	
0.63	10919395	Martha Porter	John Stolgitis	5/29/2007	Point Judith, RI	1	2336.20	1052.00
0.63	10919397	Martha Porter	John Stolgitis	6/2/2007	Point Judith, RI	2	2344.10	539.00
0.63	10919400	Martha Porter	John Stolgitis	6/7/2007	Point Judith, RI	2	2428.60	
0.63	11079052	Martha Porter	John Stolgitis	6/9/2007	Point Judith, RI	2	2596.10	
0.63	11079053	Martha Porter	John Stolgitis	6/10/2007	Point Judith, RI	2	2246.00	1672.00
0.63	11079055	Martha Porter	John Stolgitis	6/16/2007	Point Judith, RI	2	2496.10	
non-RSA	11079056	Martha Porter	John Stolgitis	6/17/2007	Point Judith, RI	2		
0.63	11079057	Martha Porter	John Stolgitis	6/18/2007	Point Judith, RI	1	2593.60	
0.63	11079058	Martha Porter	John Stolgitis	6/19/2007	Point Judith, RI	0	2144.00	1663.00
non-RSA	11079059	Martha Porter	John Stolgitis	6/21/2007	Point Judith, RI	2	2342.31	538.00
0.63	11079060	Martha Porter	John Stolgitis	6/23/2007	Point Judith, RI	0		
non-RSA	11079061	Martha Porter	John Stolgitis	6/25/2007	Point Judith, RI	2		
non-RSA	11079062	Martha Porter	John Stolgitis	6/29/2007	Point Judith, RI	3		
non-RSA	11079063	Martha Porter	John Stolgitis	6/30/2007	Point Judith, RI	1		
0.63	11079064	Martha Porter	John Stolgitis	7/1/2007	Point Judith, RI	2	2509.20	
0.63	11079066	Martha Porter	John Stolgitis	7/2/2007	Point Judith, RI	2	2277.10	
0.63	11079067	Martha Porter	John Stolgitis	7/4/2007	Point Judith, RI	2	2248.20	1620.00
0.63	11079068	Martha Porter	John Stolgitis	7/28/2007	Point Judith, RI	0	1606.30	
0.63	11079069	Martha Porter	John Stolgitis	7/31/2007	Point Judith, RI	0	797.00	550.00
0.63	11079070	Martha Porter	John Stolgitis	8/2/2007	Point Judith, RI	0		
0.63	11079079	Martha Porter	John Stolgitis	10/18/2007	Point Judith, RI	0		
0.63	11079080	Martha Porter	John Stolgitis	10/22/2007	Point Judith, RI	2	2844.59	625.00
0.63	11079082	Martha Porter	John Stolgitis	10/25/2007	Point Judith, RI	2	2568.00	550.00
non-RSA	11079084	Martha Porter	John Stolgitis	11/5/2007	Point Judith, RI	3	3639.56	730.00
non-RSA	11079086	Martha Porter	John Stolgitis	11/18/2007	Point Judith, RI	2		
non-RSA	11079088	Martha Porter	John Stolgitis	11/20/2007	Point Judith, RI	1		
non-RSA	11079089	Martha Porter	John Stolgitis	11/24/2007	Point Judith, RI	1		
non-RSA	11079090	Martha Porter	John Stolgitis	11/26/2007	Point Judith, RI	2		
non-RSA	11079091	Martha Porter	John Stolgitis	12/1/2007	Point Judith, RI	1		
non-RSA	11079094	Martha Porter	John Stolgitis	12/10/2007	Point Judith, RI	1		
non-RSA		Martha Porter	John Stolgitis	1/24/2007	Point Judith, RI	1		
0.63		Martha Porter	John Stolgitis	4/15/2008	Point Judith, RI	0		
15.12						**60**	52459.56	11867.00

0.97	10910607	Misty Marie	John Roberts	4/11/2008	Cape Cod, MA	0	1511.05	226.66
1.14	10910608	Misty Marie	John Roberts	4/17/2008	Cape Cod, MA	0	2113.85	317.07
1.05	10910609	Misty Marie	John Roberts	4/23/2008	Cape Cod, MA	0	3954.10	593.12
1.28	10910610	Misty Marie	John Roberts	4/30/2008	Cape Cod, MA	0	3571.90	535.79
4.44						**0**	11150.90	1672.64
1	10546382	Sharon E	Scott Eshenfelder	7/7/2007	New London, CT	2	3757.00	749.00
0.63	10946316	Sharon E	Scott Eshenfelder	7/9/2007	New London, CT	1	3615.00	831.00
1.01	10946311	Sharon E	Scott Eshenfelder	7/12/2007	New London, CT	2	3084.00	709.00
1.02		Sharon E	Scott Eshenfelder	7/13/2007	New London, CT	0	3711.00	853.00
1	10946309	Sharon E	Scott Eshenfelder	7/19/2007	New London, CT	3	3607.00	829.00
0.63	10946308	Sharon E	Scott Eshenfelder	7/20/2007	New London, CT	1	1344.00	309.00
non-RSA		Sharon E	Scott Eshenfelder	7/21/2007	New London, CT	0		
1		Sharon E	Scott Eshenfelder	7/26/2007	New London, CT	0		
1	10946306	Sharon E	Scott Eshenfelder	8/1/2007	New London, CT	2		
1.01	10946307	Sharon E	Scott Eshenfelder	8/9/2007	New London, CT	2		
0.63	10951951	Sharon E	Scott Eshenfelder	8/12/2007	New London, CT	2		
0.83		Sharon E	Scott Eshenfelder	8/17/2007	New London, CT	0		
9.76						**15**	19118.00	4280.00
non-RSA	10930555	Wooley Bulley	Roger Wooleyhan	5/17/2007	Ocean City, MD	3	3863.90	
non-RSA	10930556	Wooley Bulley	Roger Wooleyhan	5/19/2007	Ocean City, MD	6	1255.00	
1.02	10930557	Wooley Bulley	Roger Wooleyhan	5/22/2007	Ocean City, MD	7	3444.65	792.26
non-RSA	10930560	Wooley Bulley	Roger Wooleyhan	5/25/2007	Ocean City, MD	2	3630.95	
1.02	10930562	Wooley Bulley	Roger Wooleyhan	5/30/2007	Ocean City, MD	5	3920.10	
non-RSA	10930566	Wooley Bulley	Roger Wooleyhan	5/31/2007	Ocean City, MD	30	3787.85	871.21
non-RSA	10930567	Wooley Bulley	Roger Wooleyhan	6/1/2007	Ocean City, MD	4		
1.04	11012575	Wooley Bulley	Roger Wooleyhan	11/18/2007	Ocean City, MD	5	1601.30	202.49
1.05	11012580	Wooley Bulley	Roger Wooleyhan	11/29/2007	Ocean City, MD	5	4503.00	869.89
1.01	11012583	Wooley Bulley	Roger Wooleyhan	12/6/2007	Ocean City, MD	5	3060.80	538.18
1.01	11012586	Wooley Bulley	Roger Wooleyhan	12/11/2007	Ocean City, MD	5	3805.60	709.49
0.87		Wooley Bulley	Roger Wooleyhan	12/20/2007	Ocean City, MD	0	2019.80	298.75
1.03		Wooley Bulley	Roger Wooleyhan	1/12/2008	Ocean City, MD	0	4537.00	1043.56
1.01		Wooley Bulley	Roger Wooleyhan	1/31/2008	Ocean City, MD	1	4696.00	1080.00
1.01	10562460	Wooley Bulley	Roger Wooleyhan	2/4/2008	Ocean City, MD	3	3000.00	690.00
non-RSA	10562461	Wooley Bulley	Roger Wooleyhan	2/12/2008	Ocean City, MD	1		
1.17	10562464	Wooley Bulley	Roger Wooleyhan	3/23/2008	Ocean City, MD	1	1345.60	309.40
0.63	10562465	Wooley Bulley	Roger Wooleyhan	3/25/2008	Ocean City, MD	0	broke down	250.00
1.03	10562466	Wooley Bulley	Roger Wooleyhan	3/27/2008	Ocean City, MD	1	3821.15	878.86
1.1	10562467	Wooley Bulley	Roger Wooleyhan	3/31/2008	Ocean City, MD	0	3029.30	696.74
1.04	10562468	Wooley Bulley	Roger Wooleyhan	4/4/2008	Ocean City, MD	0	3240.35	745.28
1.1		Wooley Bulley	Roger Wooleyhan	4/11/2008	Ocean City, MD	0	2478.10	569.96
1.01	10562469	Wooley Bulley	Roger Wooleyhan	4/13/2008	Ocean City, MD	1	3916.65	900.83
1.01	10562470	Wooley Bulley	Roger Wooleyhan	4/15/2008	Ocean City, MD	2	4342.00	998.66
1.03	10562477	Wooley Bulley	Roger Wooleyhan	4/29/2008	Ocean City, MD	5	2905.25	668.20
19.19						**92**	72204.35	13113.76
74.17					**Grand Total**	**268**	207985.45	42344.48

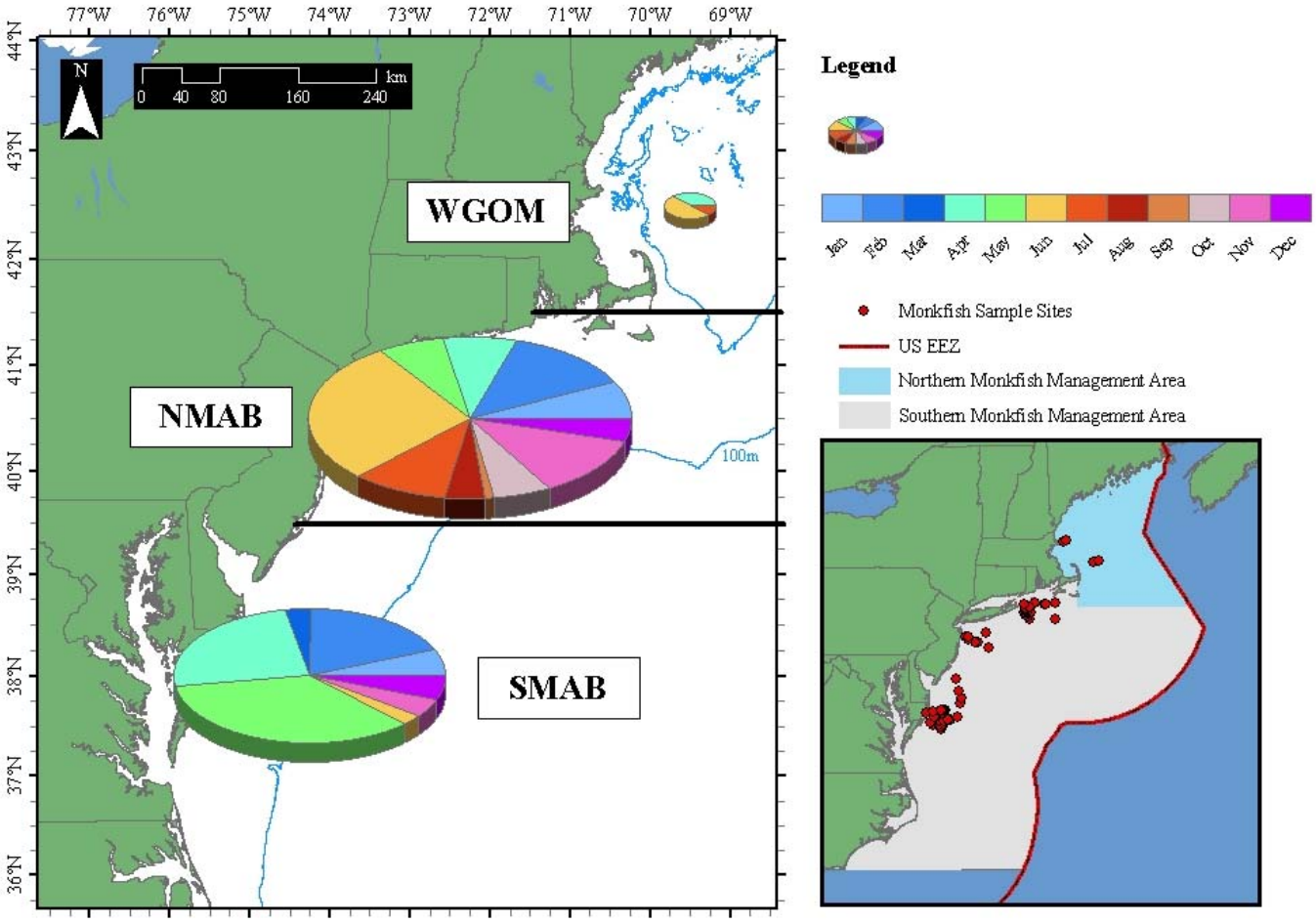


Figure 1. Sampling locations of large *L. americanus* collected by commercial gillnetters between January 2006 and April 2008 in the Northwest Atlantic Ocean. The size of the pie charts is proportional to the number of monkfish samples per site (Table 1).

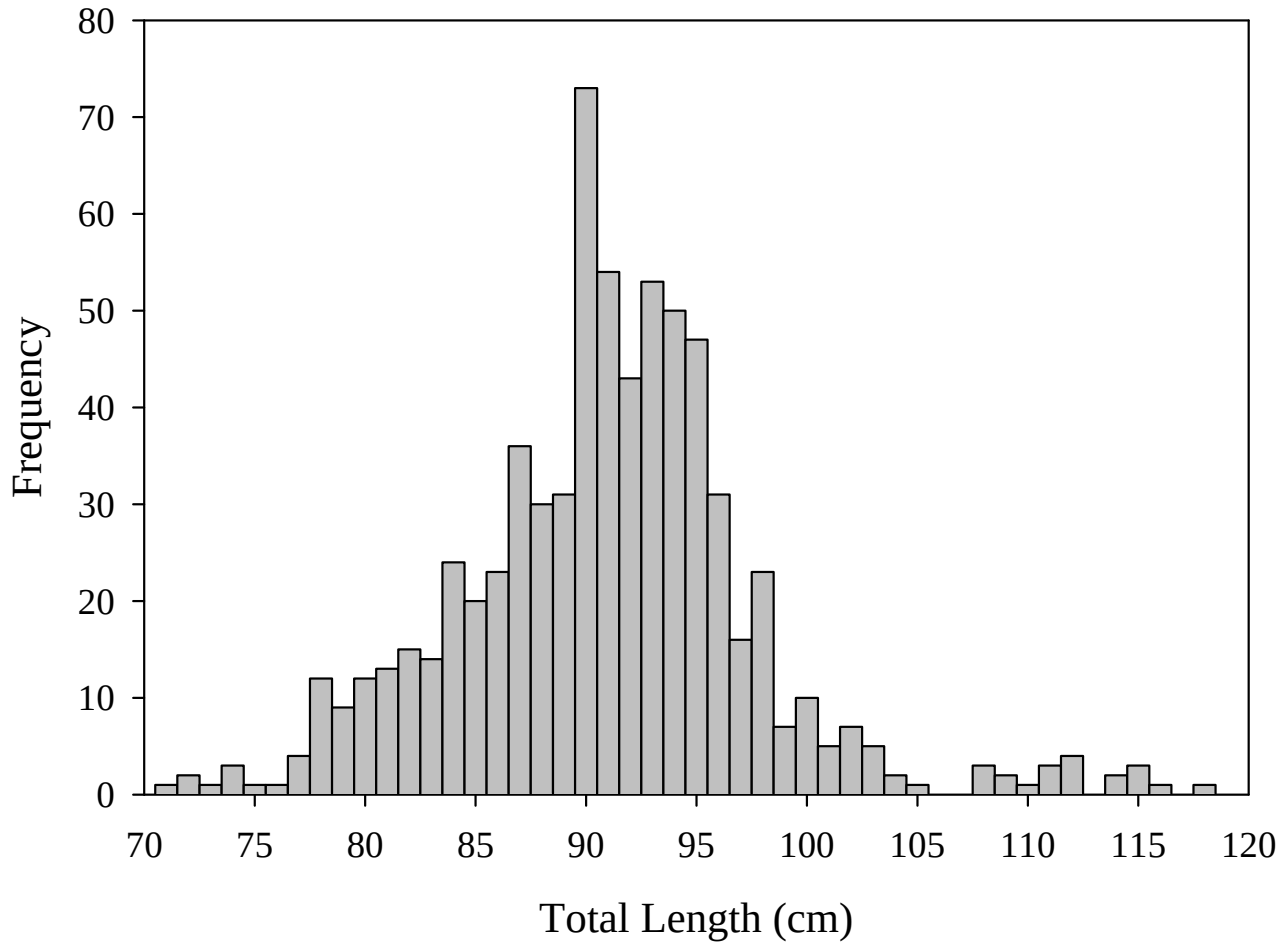


Figure 2. Length composition of large *L. americanus* collected between January 2006 and April 2008. Modal length = 90 cm TL (n = 699).

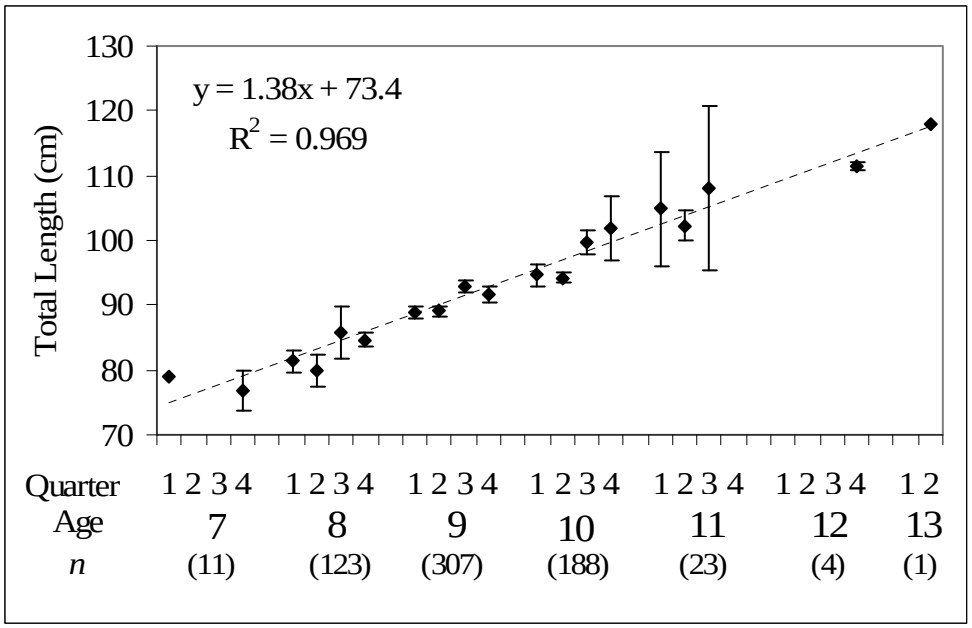


Figure 3. Age–length relationship for *L. americanus* by quarter of the year. Error bars are 95% confidence intervals.

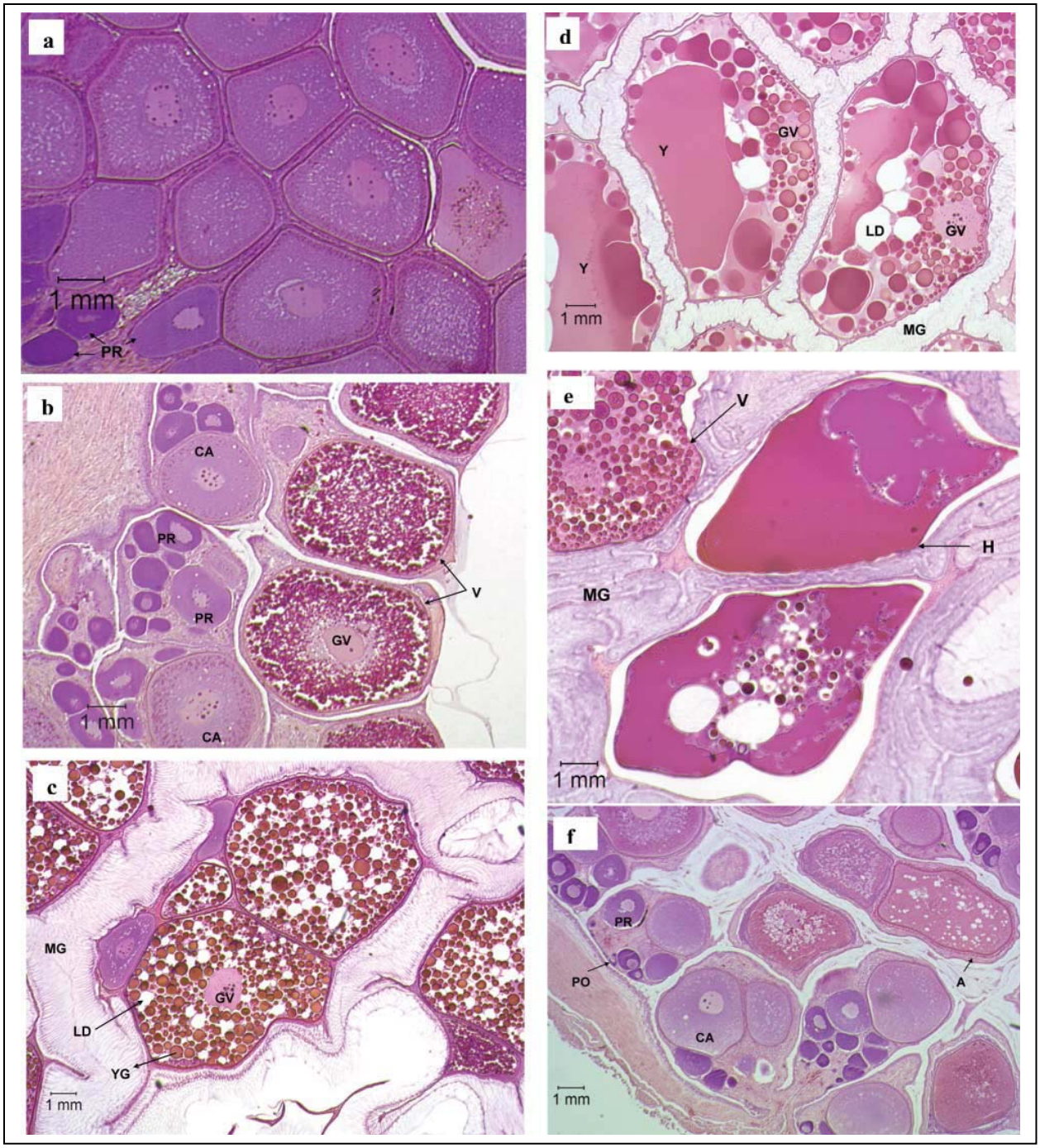


Figure 4. Photomicrographs of transverse sections of the ovaries of *L. americanus* stained with H&E. (a) Female caught in January with mainly cortical alveoli stage oocytes. A few perinucleolar stage oocytes were also observed in the ovary. (b) Female caught in January showing oocytes at different stages of maturation (perinucleolar, cortical alveoli and vitellogenic). (c) Vitellogenic oocytes from a female caught in February. Mucogelatinous material can be found outside the germinal compartment of the developing oocytes. (d) A female caught in May showing germinal vesicle migration, fusion of lipid droplets, and coalesced yolk globules (protein yolk) forming a homogeneous mass of yolk. (e) Ripe female with hydrated and vitellogenic oocytes. (f) Degeneration of vitellogenic oocytes and an increase in primary chromatin nucleolar and perinucleolar stage oocytes in a female caught in May. PO, primary chromatin nucleolar; PR, perinucleolar; CA, cortical alveoli; V, vitellogenic; H, hydrated; A, atretic; GV, germinal vesicle; LD, lipid droplet; YG, yolk globule; MG, mucogelatinous material; Y, yolk.

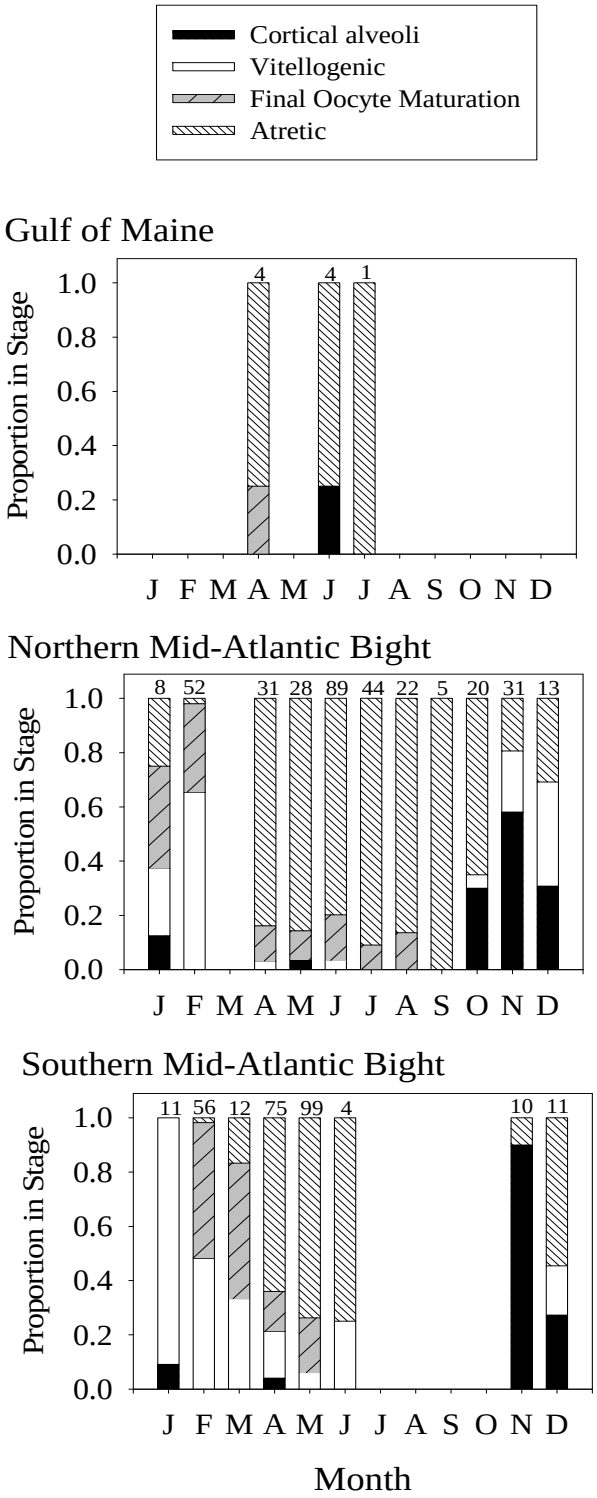


Figure 5. Proportion of mature female *L. americanus* at different ovarian stages (cortical alveoli, vitellogenic, FOM, and atretic) collected by month in the WGOM, NMAB, and SMAB. The numbers above each bar represent the number of fish sampled per month.

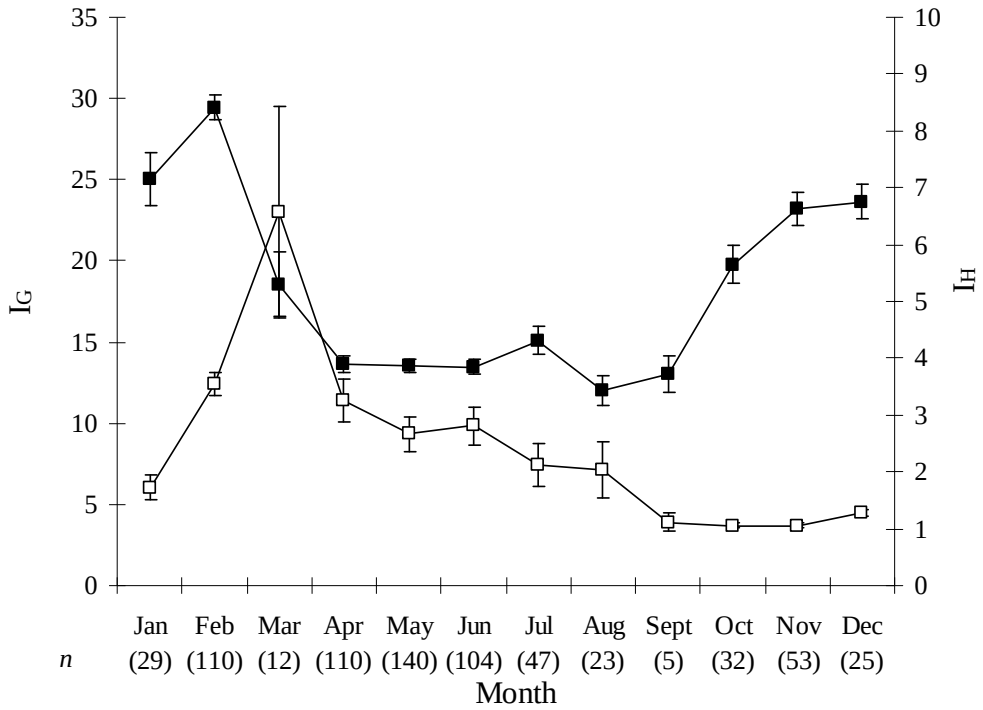


Figure 6. Monthly variations in mean GSI (I_G, white boxes) and HSI (I_H, black boxes) values for female *L. americanus* caught off the east coast of the US between January 2006 and April 2008. Numbers below months are sample size (*n*).

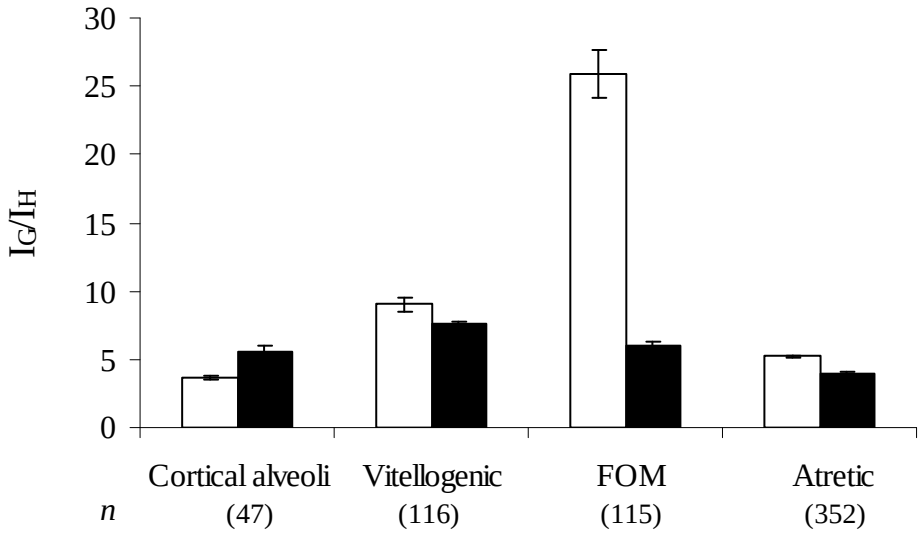
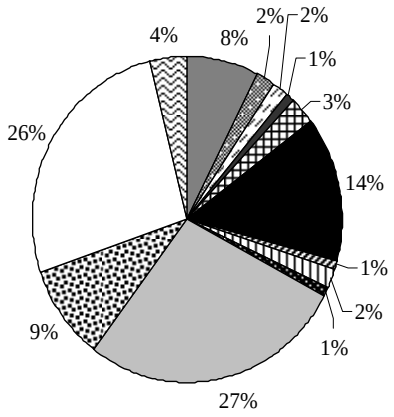
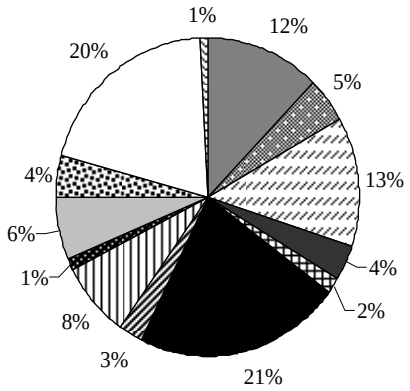


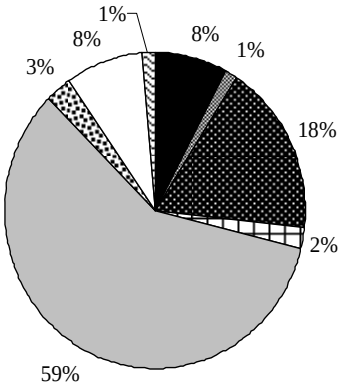
Figure 7. Variation in mean GSI (I_G, white bars) and HSI (I_H, black bars) values among females in successional stages of gonad development. Identical letters indicate mean HSI and GSI that are statistically non-significant. Numbers below gonad stages are sample sizes.

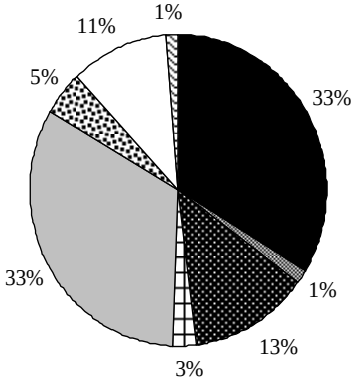
Northern Mid-Atlantic Bight





Southern Mid-Atlantic Bight





- *Atlantic cod, Gadus morhua*
- *Atlantic mackerel, Scomber scombrus*
- *Atlantic menhaden, Brevoortia tyrannus*
- *Clearnose skate, Raja eglanteria*
- *Little skate, Leucoraja erinacea*
- *Longfin squid, Loligo pealeii*
- *Monkfish, Lophius americanus*
- *Northern searobin, Prionotus carolinus*
- *Northern stargazer, Astroscopus guttatus*
- *Scup, Stenotomus chrysops*
- *Smooth dogfish, Mustelus canis*
- Unidentified Bony fish
- Unidentified Flatfish
- Unidentified Skate
- Other

Figure 8. Percentage number and weight of prey items in *L. americanus* stomachs. Prey species were placed in the "other" category if their frequency of occurrence was < 1%. *n* = 103 (NMAB), *n* =134 (SMAB).

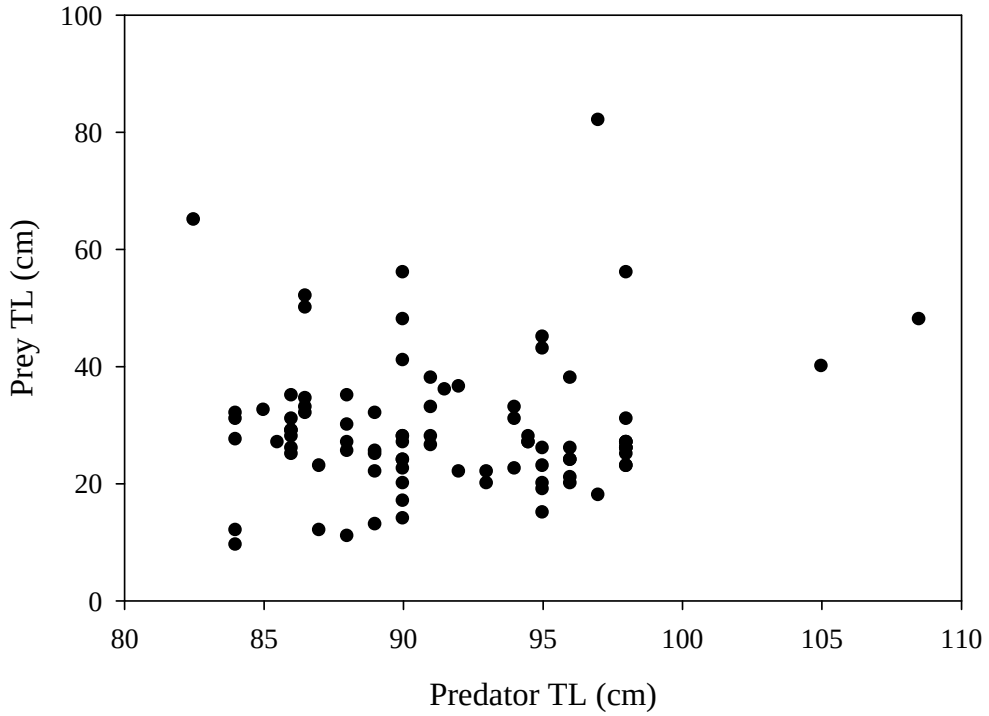


Figure 9. Relationship between prey length and predator (*L. americanus*) length. *n* = 88 prey items.

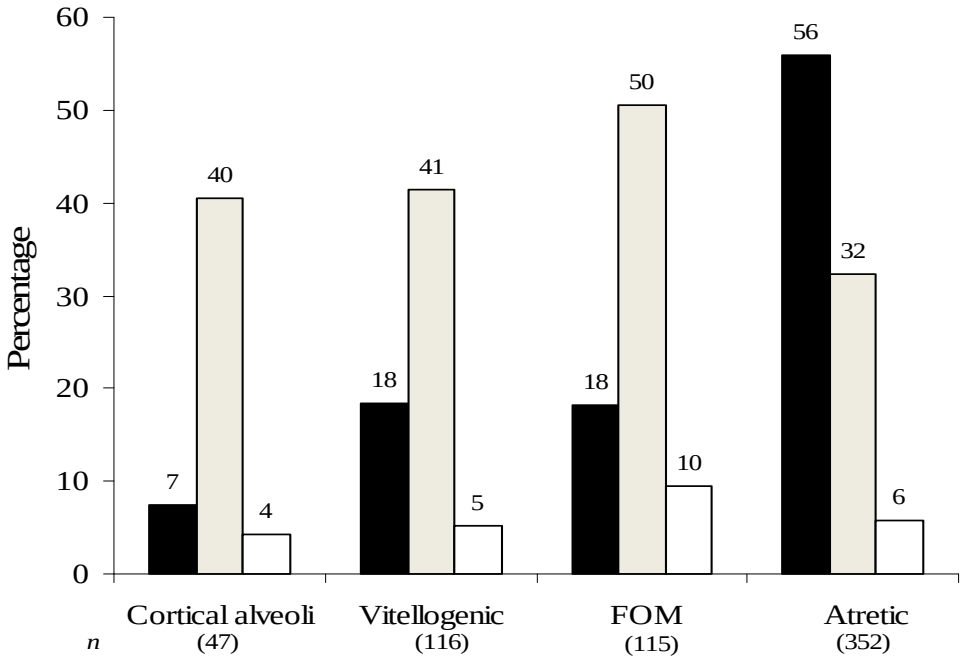


Figure 10. Relative frequency of feeding by microscopic gonad stage of development (*n* =630). Percentage of all specimens at each gonad stage (black bars); Percentage of specimens with prey in their stomachs at each gonad stage (grey bars); Percentage of specimens with stomachs containing *L. americanus* at each gonad stage (white bars).

Andrea Johnson
Digitally signed by Andrea Johnson
DN: cn=Andrea Johnson, o=UMES, ou=Natural Sciences, email=akjohnson@umes.edu, c=US
Date: 2008.10.01 14:10:50 -04'00'