FINAL REPORT
MONKFISH RSA 2008/2009

Report title: Influence of climate on the distribution and catch rates of monkfish, *Lophius americanus*
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Grant Number: NA08NMF4540433
Date: 7/28/2010

1. Abstract

The monkfish, *Lophius americanus* V., is an important commercial species in the Northwest Atlantic Ocean. The influence of climate on monkfish distribution and catch rates was investigated using two approaches. 1. Fishery-independent bottom trawl survey data, collected during autumn and spring from 1968 to 2008 by the NOAA Fisheries Science Center (NEFSC) in U.S. waters (Gulf of Maine, Georges Bank, Middle-Atlantic Bight), was used to 1) determine seasonal habitat associations with bottom temperature and depth, 2) evaluate thermal habitat availability based on habitat associations, and 3) determine if shifts in average centers of occurrence (latitude, longitude, depth, catch-temperature) have occurred over time in response to changes in bottom temperature. 2. VEMCO™ Minilog temperature and depth data loggers were distributed to seven commercial gillnet fishermen from Cape Cod, MA south to Chincoteague, VA to record bottom temperature and depth as well as catch rates and length information for monkfish over time. Results from the fishery independent data showed monkfish were strongly associated with temperature and depth distributions that differed significantly from those observed for sampling stations. Area of available thermal habitat varied by season and latitude with the greatest changes occurring during autumn in the southern portions of the survey region. Relationships between same-year and 5-year average water temperature and centers of monkfish occurrence revealed positive shifts over time in latitude and depth during spring, along with increased catch-temperature in both autumn and spring. VEMCO data collected from our industry collaborators showed bottom temperatures were warmest during summer and autumn and coolest during winter and spring. Relationships between monkfish catch numbers and bottom temperatures, depths and lunar cycle will require longer data collection to determine any trends.

2. Statement of Problem:

The American monkfish or goosefish (*Lophius americanus* V.) is a fast growing, benthic species belonging to the family Lophiidae (Steimle et al., 1999). It is found in the northwest Atlantic Ocean from the Grand Banks and northern Gulf of St. Lawrence, Canada to the east coast of Florida (Steimle et al., 1999). Although the species range from Canada to Florida, it is most commonly found north of Cape Hatteras, North Carolina in shallow coastal waters to over 800 m (Armstrong et al., 1992).

Once considered a commercially unimportant species in the United States, *L. americanus* has become one of the highest valued finfish species in the northeast. Historically, *L.*

americanus was often taken as a bycatch species in the groundfish and scallop fisheries (Armstrong et al. 1992). The popularity of monkfish as a food fish began to grow following a decline of traditional groundfish species in the 1970s and 1980s (Armstrong et al. 1992). Since then, the demand for monkfish has increased dramatically and the species may face overfishing in certain parts of its range. However, some aspects of monkfish biology and life history are not well known. One such aspect is the effects of thermal conditions on the distribution and abundance of monkfish within their geographic range. Currently, little information exists about the influence of changing sea water temperatures on the movement and behavior of monkfish. Previous findings suggest that sea water temperature shifts may have an effect on seasonal onshore-offshore movements and influence inshore spawning migrations. Sea water temperature changes could potentially affect the distribution and abundance of adults and juveniles, the timing and locations for spawning, the successful development of larvae, and may also help regulate the movement and availability of important prey species. Acquiring knowledge about the influence of thermal conditions on monkfish behavior is important because it would offer us a better understanding of the biology and life history and provide information to aid in the management of the fishery in the northwest Atlantic. Further, improving the present knowledge of thermal influences may provide a basis for assessing the effects of climate change on monkfish movements and behavior in the future.

Project Objectives

The overall objective of this study is to provide information on the biology of monkfish that can be used to enhance the management of this species.

Part A. NEFSC bottom trawl survey data
Objective 1: *Determine seasonal habitat associations for monkfish with bottom temperature and depth over time*
Objective 2*:* *Evaluate thermal habitat availability for monkfish based on seasonal habitat associations*
Objective 3: *Determine if shifts in average centers of occurrence (abundance-weighted latitude, longitude, depth, and catch-temperature) for monkfish have occurred in response to changes in bottom temperature*

Part B. Commercial gillnet Minilog data collection
Objective 1: *The influence of bottom temperature on monkfish gillnet catch rates*
Objective 2: *The relationship between the seasonal size distributions of monkfish caught by gillnets and bottom temperature and depth*
Objective 3: *The influence of lunar cycle on monkfish gillnet catch rates*

3. Methods

Part A. NEFSC bottom trawl survey data
Monkfish catch, bottom temperature, and depth data were collected during NEFSC annual bottom trawl surveys for autumn (1963-2007) and spring (1968-2008). These

surveys covered the northwest Atlantic continental shelf from Nova Scotia south to Cape Hatteras, North Carolina (approximately 44˚ 47’ N - 66 28’ W to 35˚ 31’ N - 75 08’ W) and were divided into offshore (≥27 m) and inshore (≤26 m) components (Figure 1 and 2). Offshore surveys covered areas including the Gulf of Maine, Georges Bank, western Scotian Shelf, and Mid Atlantic Bight (MAB) while inshore surveys covered coastal areas from the Gulf of Maine south to Cape Hatteras (Figure 2) (Azarovitz, 1989; Reid et al., 1999).

NEFSC bottom trawl surveys incorporate a stratified random sampling design with strata defined by latitude and bathymetry (Fogarty et al., 2008; Figure 2). Surveys were conducted in depths of <9 – 365 m although greater depths were occasionally sampled. Offshore survey strata were defined by depth zones of 27-55 m, 56-110 m, 111-185 m, and 186-365 m while inshore strata were defined by zones of <9 m, 9-17 m, and 18-26 m (Azarovitz, 1989). Sampling methodology at each station included weighing and enumerating each species as well as recording data on length, maturity, and diet composition. Information on sea surface and bottom temperature, surface and bottom salinity, and bottom depth was also recorded at selected stations.

Habitat associations

To explore spatial patterns in monkfish distribution in relation to bottom temperature, data from NEFSC autumn and spring inshore and offshore bottom trawl surveys were partitioned into five distinct geographic shelf regions defined by survey strata and delineated by major geographic features (Fogarty and Keith, 2005; Townsend et al., 2006; Nye et al., 2009). The five regions were the Southern Mid-Atlantic Bight (SMAB; offshore strata 61 – 76; inshore strata: 15 – 44), Northern Mid-Atlantic Bight (NMAB; offshore strata: 1 – 12; inshore strata: 1 – 14, 45 – 55), Georges Bank (GB; offshore strata 13 – 23, 25), Gulf of Maine (GOM; offshore strata: 24, 26 – 30_36 – 40; inshore strata: 56 – 90), and the Scotian Shelf (SS; offshore strata: 31 – 35; Figure 1).

For each region, cumulative distribution functions (CDFs) were calculated to describe the association between monkfish distribution, and bottom temperature and depth. Cumulative distribution functions were determined for the observed distributions for bottom temperature and depth. Monkfish were associated with these distributions by weighting the CDFs by fish abundance (number of fish caught per survey tow). Additionally, the strength of the association was examined statistically using a non-parametric method developed by Perry and Smith (1994); a Kolmogorov-Smirnov type statistic was used to determine the maximum vertical difference between un-weighted and abundance-weighted CDFs.

Available thermal habitat

Cumulative distribution functions were used to examine changes in available thermal habitat for monkfish by identifying the distribution of the central 95% of all abundance-weighted or occupied temperatures from habitat associations. Five-year average portions of shelf area (stratified area; squared nautical miles; nmi^2) were identified where bottom temperature values were equal to, above, or below the preferred range of temperatures (˚C) for monkfish. For each region, a time series of seasonally preferred bottom

temperatures was determined for autumn (1968-2007) and spring (1968-2008) prior to identifying the portions of shelf area within, above or below that range. Portions of area were identified by multiplying the area of strata within a survey region by the percent of temperatures within, above or below the preferred range over time (e.g. SMAB = 17,133 nmi^2 * 67% within range = 11,507.5 nmi^2).

Distribution shifts

A general linear model approach was used to investigate whether latitudinal, longitudinal, or depth shifts in monkfish distribution had occurred over time in relation to bottom temperature. NEFSC autumn (1968-2007) and spring (1968-2008) surveys were used to determine yearly shelf-wide (continental shelf from western Scotian Shelf south to Cape Hatteras) abundance-weighted mean latitude, longitude, stratified catch-temperature, and stratified depth of occurrence for monkfish (size and sexes combined).

Part B. Commercial gillnet Minilog data

Sampling locations

Sampling for monkfish by commercial gillnet fishermen took place at various sites throughout the Northwest Atlantic from Cape Cod, MA south to Chincoteague, VA (Table 1; Figure 3). Data sampling and collection occurred during the winter/spring and summer/autumn monkfish fishing seasons depending on location. In areas north of the New Jersey coast, sampling generally occurred from April to August and October to February. Sampling in areas off the coast of Maryland and Virginia generally occurred from April/May to June and November to February.

Sampling locations were considered fixed sites though on rare occasions, conflicts with other fishing gear or nuisance species (e.g. isopod "sea-lice") or low catches forced fishermen to move their nets to new locations. Since it was not possible to insure that sampling gear would remain in the exact location of deployment, locations were considered fixed unless changes in position were identifiable through the data.

Sample collection

Bottom temperature (˚C) and depth (m) were recorded at each sampling site and during each gillnet deployment. Temperature and depth (pressure) loggers, VEMCO TDR 8-bit Minilog (temperature range: -4-20˚C, 0.1˚C resolution, ±0.2˚C accuracy; Depth range: 204 m, 1.2 m resolution; VEMCO Limited, 100 Osprey Drive, Shad Bay, N.S. Canada B3T 2C1; http://www.vemco.com) were distributed to seven gillnet fishermen who attached them to the outer bottom edge of one panel of each gillnet with cable wire ties; one logger was utilized per net. The data loggers recorded temperature and depth information hourly during the time period that gillnets were deployed; average gillnet soak time was ~2-4 days (48-96 hrs). During sampling, each fisherman also recorded data regarding the date and time of net deployment and retrieval, location (latitude and longitude), number of fish, total weight of catch, depth, and presence or absence of residual currents and their direction.

Data evaluation
Temperature, depth, and catch data (rough measure of CPUE = # fish caught/24 hour period) in numbers collected at each sampling location were examined separately. Relationships among these variables were explored graphically. Time-series plots of daily average bottom temperature and depth at sampling sites were constructed to examine general trends. Spikes in the data (jumps in temperature and depth reading) associated with the haul back of the fishing gear were removed prior to examining the data. Further, the data were examined for evidence of thermal or tidal fronts or zones with distinct horizontal gradients or fluctuations in bottom temperature between water masses with different densities. Relationships between monkfish catch and lunar cycle or moon phase information (obtained on-line: http://aa.usno.navy.mil/data/docs/MoonPhase.php) were also explored graphically to examine whether lunar cycle had an influence on catch rates. Monkfish total length measurements taken at selected sampling sites were examined graphically for patterns by plotting mean, minimum and maximum values for each time-series.

4. Results and Conclusions

Part A. NEFSC bottom trawl survey data

Habitat associations
Shelf-wide temperature and depth associations for monkfish were variable by season and significantly different from those of the sampling stations (Figure 4). Generally, monkfish occupied warmer shelf-wide temperatures and shallower depths in autumn than during the spring. In autumn, the central 95% of monkfish were caught between 6.1-13.5˚C and 37-319 m and occupied temperatures and depths between 4.0-13.8˚C and 14-340 m in spring, respectively. Compared to the temperature and depth distributions of the sampling stations, monkfish were associated with cooler temperatures and deeper depths in autumn and warmer temperatures and deeper depths in spring.

In general habitat associations varied by latitude and season for all survey regions. For example, in the GOM region, weighted CDFs indicated that monkfish were significantly ($P < 0.05$) associated with temperatures and depths that mirrored those of the sampling stations for both seasons (Figure 5a & b). Habitat associations for SMAB (Figure 5c & d) were similar with monkfish occupying cooler temperatures and deeper depths in autumn and warmer temperatures and deeper depths in spring than those observed for the sampling stations. Significant ($P < 0.05$) temperature and depth distributions were observed for the SMAB during both seasons. Overall, monkfish occupied the coolest temperatures in the SS and GOM and the warmest in the NMAB and SMAB regions (Figure 6).

Available thermal habitat
Preferred autumn and spring temperature ranges for monkfish were similar for all survey regions (Figure 7a & b). In general, area of habitat within the preferred temperature ranges for monkfish varied by season and latitude with the greatest changes occurring

during autumn in the southern portions of the survey region. For example, area within the favored autumn (5.0-11.1˚C) and spring (3.5-8.7˚C) temperature ranges in the GOM decreased from 20,897 nmi^2 in 1972 to 18,073 nmi^2 in 1997 and 19,986 nmi^2 in 1972 to 17,208 nmi^2 in 1997, respectively (Figure 7a & b). Compared to the GOM, area within the favored autumn (7.4-16˚C) temperature range in the SMAB decreased from 11,507 nmi^2 to 4,204 nmi^2 from 1972 to 2007 (Figure 7a). For the spring trawl survey, area of preferred temperatures (5.6-15.5˚C) fluctuated with marked decreases from 15,019 nmi^2 to 13,136 nmi^2 from 1977 to 1982 and 15,114 nmi^2 to 12,438 nmi^2 from 2002 to 2007 and increases from 13,500 nmi^2 to 14,570 nmi^2 from 1987 to 1992 and 12,467 nmi^2 to 15,114 nmi^2 from 1997 to 2002 (Figure 7b).

In summary, portions of area within the preferred temperature distributions were variable by region and season with the largest changes occurring during autumn and in the southern most regions (GB, NMAB and SMAB) where substantial decreases occurred.

Distribution shifts

During spring, monkfish showed a significant ($P < 0.05$) positive relationship between 5-year average bottom temperature and mean catch-temperature, mean latitude, and mean depth of occurrence. The significant relationship between catch-temperature and 5-year average bottom temperature suggests that monkfish are compensating for changes in temperature by shifting their average latitude by 0.58 (˚N y^{-1}) and depth by 14.14 (m y^{-1}). These results suggest that monkfish may shift their distribution northward to higher latitudes and to deeper depths in response to climate warming.

Conclusions

Based on habitat associations, monkfish occupy cooler temperatures and shallower depths in autumn than during spring. This suggests that monkfish move to different depths to find preferred temperatures. Differences in patterns for occupied temperatures and depths by latitude suggest that conditions in northern areas such as the GOM reflect preferred habitat preferences for monkfish. Therefore, selection for habitat is more important in southern areas such as the SMAB.

Preferred area of available thermal habitat for monkfish in NEFSC survey regions differed by season and latitude. Although changes in thermal habitat were not measured directly, the observed results indicate that monkfish could face losses of habitat within the survey area during autumn if water temperatures increase. Since trends observed for decadal habitat associations suggested that temperature conditions in the SS and GOM regions may be more favorable for monkfish, movement of the population from lower latitudes into these areas could happen if habitat losses occur.

Observed distribution shifts for monkfish during spring suggested that monkfish may have shifted their average latitude northward and depth of occurrence to deeper waters in response to increasing 5-year running mean bottom temperature. Though the effects of fishing on distribution could not be measured, changes in abundance may have contributed to changes in the abundance-weighted variables. Fishing may have impaired

the ability of monkfish stocks to compensate for environmental change during the study period.

Part B. Commercial gillnet Minilog data

Data evaluation

Bottom temperature and catch time series plots for data collected by Peter Krasowski off the coast of Pt. Pleasant, NJ and John Stolgitis off the coast of Pt. Judith, RI during autumn 2008 and winter 2009 are presented in Figures 8a and 9a. Both figures show a general cooling trend over time with the warmest temperatures occurring during the autumn months. Patterns in monkfish catch (# of fish/day) showed fluctuations over time with little relation to changes in bottom temperature, suggesting that other factors in addition to temperature may be affecting catch rates. Further, graphical representation of new and full lunar phases (Figures 8b, 9b, 10 and 11) with temperature and catch time series did not indicate discernable relationships among the variables.

In general, total length (TL) measurements taken for monkfish sampled from all locations ranged from ≈ 48 to 96 cm with an average of 76 cm (Figure 12). However, during some sampling trips, monkfish size may show varying patterns such as those caught during February off the coast of Pt. Judith, RI (Figure 12a). Here the minimum and maximum sizes of monkfish caught ranged from 26 to 36 cm with a mean of 30.7 cm. Plots of TL against bottom temperature do not reveal any visible relationships between the two variables.

Conclusions

Collection of bottom temperature and depth data by monkfish gillnetters was successful using the Minilog data loggers. Regardless of location, patterns for temperature showed warming trends during late spring to early autumn and cooling trends during late autumn to early spring. Relationships between depth, temperature, lunar cycle, and monkfish catch were difficult to discern for all sampling locations. Due to the size selectivity of gillnets used by the fishermen, monkfish caught were generally larger than 40 cm TL and averaged 76 cm.

Benefits and/or contributions to management decision making: Acquiring knowledge about the influence of thermal conditions on monkfish behavior is important because it would offer us a better understanding of the biology and life history and provide information to aid in the management of the fishery in the northwest Atlantic. The observed habitat preferences with regard to temperature and depth can aid fisheries managers in their assessment of monkfish. Changes in available thermal habitat and distribution shifts observed during this study suggest that losses in habitat may be occurring. Further, improving the present knowledge of thermal influences may provide a basis for assessing the effects of climate change on monkfish movements and behavior in the future. This information can be used to help predict the response of monkfish to current and future climate change. Finally, collecting gillnet catch rate and temperature information provides a way to monitor environmental conditions experienced by monkfish throughout the year.

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**
   Minilog data loggers were distributed and temperature, depth, and monkfish catch information was collected and processed by Dr. Johnson and Mr. Daniel Cullen.
2. **Northeast Fisheries Science Center**
   Fishery independent research vessel bottom trawl survey data was collected and provided by NEFSC. All data were analyzed by Dr. Johnson and Mr. Daniel Cullen in collaboration with Dr. Anne Richards from NEFSC.
3. **Monkfish gillnetters**
   Data and sample collection by gillnetters occurred at seven sites along the coast of New England and the Mid-Atlantic region. A total of 95.68 DAS were used by our industry collaborators from May 2008 to April 2009.

6. Financial Report

A total of $47,846.86 was received from sale of monkfish by gillnetters participating in the RSA (see Table 2). A total of $39,006 was spent during this funding period.

RESEARCH BUDGET			
GRANTEE:	Project Title:	Influence of climate on the distribution and catch rates of monkfish, *Lophius americanus*	
A. SALARIES AND WAGES			
1. SENIOR PERSONNEL		Total Time (Mo	Expenditures
a. Principal Investigator:	Andrea Johnson	3	
b. Graduate Student:	Daniel Cullen	12	
c. Undergraduate Students (2):			$14,385
Total Salaries and Wages			$14,385
B. PERMANENT EQUIPMENT			
C. EXPENDABLE SUPPLIES AND EQUIPMENT			$13,874
D. TRAVEL			$10,747
E. PUBLICATIONS AND DOCUMENTATION COSTS			
F. OTHER COSTS			
TOTAL DIRECT COSTS			$39,006

7. Evaluation

1. 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.

Part A. NEFSC bottom trawl survey data

Objectives 1, 2, and 3 were attained. No modifications were made to the objectives.

Objective 1: Seasonal habitat associations for monkfish with respect to bottom temperature and depth were obtained for all survey regions. Differences in occupied temperature and depth were observed by latitude and season.
Objective 2: Available thermal habitat was evaluated from seasonal habitat associations. Changes in area of preferred thermal habitat depended on latitude and season with the declines occurring in the southern most regions and during autumn.
Objective 3: Shifts in distribution or abundance-weighted centers of occurrence were observed for latitude and depth during the spring survey. Distribution shifts may be used as models to predict the response of monkfish to current and future climate change.

Part B. Commercial gillnet Minilog data
Objective 1: The influence of bottom temperature on monkfish catch rates was difficult to elucidate since relationships between these two variables were unclear. This process may require the collection of more years of data before these relationships can be revealed.
Objective 2: The relationship between the seasonal size distributions of monkfish caught by gillnets and bottom temperature and depth was not attained. Gillnets used to catch monkfish incorporate 12-inch stretch mesh panels that selectively sample fish larger than 40 cm. The mean, maximum, and minimum lengths of monkfish did not change considerably during the sampling period at all locations.
Objective 3: The influence of lunar cycle on monkfish catch rates will require more data collection since other variables may have contributed to the observed patterns in monkfish catch rates.
B. If significant problems developed which resulted in less than satisfactory or negative results, they should be discussed.

Significant problems did not develop despite the inability to attain all the objectives for the Minilog portion of the study. One problem that did arise for the gillnet fishermen involved conflicts with other fishing gear where gillnets with attached data probes were dragged away by trawlers. In these instances, the data probes were not recovered and the data was lost.

2. Dissemination of project results:
Explain, in detail, how the project's results have been, and will be disseminated.

This research provided partial fulfillment of the requirements for a Master of Science for Mr. Daniel Cullen, a graduate student at UMES.

A manuscript of the results of this study is being prepared and will be submitted for publication to the ICES Journal of Marine Science.

The results have been presented at the following scientific conferences below:

1. "Temperature and Depth Associations of Monkfish (*Lophius americanus*)" NOAA 5th Annual Education and Science Forum, Howard University,

Washington D.C. (November 12 to 14, 2009). Oral presentation by Daniel Cullen (UMES M.S. student)

2. "Temperature and Depth Associations of Monkfish (*Lophius americanus*)" American Fisheries Society 139th Annual Meeting, Nashville, Tennessee (August 30 to September 3, 2009). Oral presentation by Daniel Cullen (UMES M.S. student)
3. **"**The Influence of Temperature on Monkfish (*Lophius americanus*) Distribution: Research in Progress" American Fisheries Society 138th Annual Meeting, Ottawa, Canada (August 17 to 22, 2008). Poster presentation by Daniel Cullen (UMES M.S. student)

8. References

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Table 1. Data collection for monkfish gillnetters from May 2008-April 2009.

Monkfish Gillnetters	Location & Vessel	Position	Dates of Data Collection	Sample Collection
Brian Roche	Cape Cod, MA F/V Lady Irene	Lat: 42° 00' 00" N Long: 69° 15' 00" W	February 1 to April 30	Length Composition
John Stolgitis	Pt. Judith, RI F/V Martha Porter	Lat: 40° 56' 41" N Lon: 71° 45' 16" W	October 1 to February 6 May 14 to August 1	Length Composition
Chris Hickman	Chincoteague, VA F/V Bout Time	Lat: 37° 56' 00" N Long: 74° 58' 00" W	December 12 to February 1 May 5 to May 26	Length Composition
Roger Wooleyhan	Ocean City, MD F/V Wooley Bully	Lat: 38° 03' 21" N Long: 74° 49' 56" W	October 10 to February 14 April 10 to May 29	Length Composition
Peter Krasowski	Pt. Pleasant NJ F/V Critical	Lat: 40° 12' 00" N Long: 73° 44' 00" W	November 20 to February 14 May 22 to July 29	Length Composition
Ted Platz	Pt. Judith RI F/V Gertrude H.	Lat: 41° 02' 59" N Long: 71° 04' 32" W	May 14 to August 1	Length Composition
Tim Caldwell	Pt. Judith RI F/V Griswold	Lat: 41° 05' 15" N Long: 71° 26' 43" W	May 14 to August 1	

Table 2. Monkfish landings information collected from June 2008 to May 2009

DAS	VTR	F/V	Fishermen	Date Landed	Port Landed	Amt. Sold ($)	Research Funds ($)
1	11191085	Martha Porter	John Stolgitis	6/12/2008	Point Judith, RI	$4,548.40	
1	11191086	Martha Porter	John Stolgitis	6/14/2008	Point Judith, RI	$4,615.00	$1,832.00
1	11191088	Martha Porter	John Stolgitis	6/20/2008	Point Judith, RI	$4,792.10	
0.63	11191089	Martha Porter	John Stolgitis	6/22/2008	Point Judith, RI	$2,506.80	$1,460.00
0.63	11191042	Martha Porter	John Stolgitis	6/28/2008	Point Judith, RI	$2,656.20	
0.63	11191041	Martha Porter	John Stolgitis	7/1/2008	Point Judith, RI	$2,417.20	$1,014.00
0.63	11191093	Martha Porter	John Stolgitis	7/2/2008	Point Judith, RI	$1,841.00	
0.63	11191094	Martha Porter	John Stolgitis	7/6/2008	Point Judith, RI	$2,351.20	$810.00
0.63	11191096	Martha Porter	John Stolgitis	7/10/2008	Point Judith, RI	$2,368.00	
0.63	11191097	Martha Porter	John Stolgitis	7/12/2008	Point Judith, RI	$2,276.20	$925.00
1	11191099	Martha Porter	John Stolgitis	7/20/2008	Point Judith, RI	$4,494.06	
0.63	11284401	Martha Porter	John Stolgitis	7/22/2008	Point Judith, RI	$2,228.30	$1,340.00
0.63	11191100	Martha Porter	John Stolgitis	8/1/2008	Point Judith, RI	$1,868.00	$325.00
0.63	Set-day	Martha Porter	John Stolgitis	9/29/2008	Point Judith, RI	$0.00	$0.00
0.63	11284403	Martha Porter	John Stolgitis	10/1/2008	Point Judith, RI	$3,619.10	
0.63	11284404	Martha Porter	John Stolgitis	10/4/2008	Point Judith, RI	$3,368.75	
0.63	11284405	Martha Porter	John Stolgitis	10/5/2008	Point Judith, RI	$3,101.25	$720.00
1	11284407	Martha Porter	John Stolgitis	10/10/2008	Point Judith, RI	$5,290.11	$1,300.00
1	11284408	Martha Porter	John Stolgitis	10/12/2008	Point Judith, RI	$4,412.35	$1,940.00
1.03	11284410	Martha Porter	John Stolgitis	10/21/2008	Point Judith, RI	$2,102.92	$420.00
0.63	11284411	Martha Porter	John Stolgitis	10/24/2008	Point Judith, RI	$3041.30	$608

0.63	11284412	Martha Porter	John Stolgitis	10/27/2008	Point Judith, RI	$1780.70	$352
0.63	11284413	Martha Porter	John Stolgitis	11/1/2008	Point Judith, RI	$3,086.72	$615.00
0.63	11284415	Martha Porter	John Stolgitis	11/5/2008	Point Judith, RI	$1,665.05	$333.00
0.63	11284416	Martha Porter	John Stolgitis	11/8/2008	Point Judith, RI	$3,274.60	$653.00
0.63	11284417	Martha Porter	John Stolgitis	11/12/2008	Point Judith, RI	$2,998.30	$599.00
0.63	11284418	Martha Porter	John Stolgitis	11/13/2008	Point Judith, RI	$3,063.78	$612.00
0.63	11284419	Martha Porter	John Stolgitis	11/14/2008	Point Judith, RI	$2,845.70	$568.00
1.16	11284421	Martha Porter	John Stolgitis	11/20/2008	Point Judith, RI	$5,289.35	$1,058.00
1	11284422	Martha Porter	John Stolgitis	11/24/2008	Point Judith, RI	$5,536.25	$1,112.00
1.01	11284423	Martha Porter	John Stolgitis	11/29/2008	Point Judith, RI	$3,069.75	$610.00
0.97	11284424	Martha Porter	John Stolgitis	12/3/2008	Point Judith, RI	$2,266.70	$450.00
0.94	11284425	Martha Porter	John Stolgitis	12/6/2008	Point Judith, RI	$3,051.25	$610.00
0.63	11284426	Martha Porter	John Stolgitis	12/9/2008	Point Judith, RI	$3,824.90	$650.00
1	11284428	Martha Porter	John Stolgitis	12/18/2008	Point Judith, RI	$5,175.35	$1,020.00
0.63	11284429	Martha Porter	John Stolgitis	12/26/2008	Point Judith, RI	$1,979.00	$400.00
0.63	11284430	Martha Porter	John Stolgitis	1/5/2009	Point Judith, RI	$2,860.50	$565.00
0.63	11284431	Martha Porter	John Stolgitis	1/10/2009	Point Judith, RI	$2,649.85	$397.00
0.63	11284432	Martha Porter	John Stolgitis	1/12/2009	Point Judith, RI	$2,358.10	$353.00
0.63	11284433	Martha Porter	John Stolgitis	1/19/2009	Point Judith, RI	$1,501.10	$228.00
0.63	11284434	Martha Porter	John Stolgitis	1/23/2009	Point Judith, RI	$1,694.65	$255.00
0.63	11284435	Martha Porter	John Stolgitis	1/26/2009	Point Judith, RI	$1,577.50	$237.00
0.63	11284436	Martha Porter	John Stolgitis	1/30/2009	Point Judith, RI	$1,399.60	$210.00
0.63	11284437	Martha Porter	John Stolgitis	2/2/2009	Point Judith, RI	$576.00	$85.00
0.63	11284438	Martha Porter	John Stolgitis	2/6/2009	Point Judith, RI	$342.50	$50.00
0.63	Set net	Martha Porter	John Stolgitis	4/18/2009	Point Judith, RI		
	11284440	Martha Porter	John Stolgitis	4/24/2009	Point Judith, RI	$1,369.35	$205.00
0.93	11284441	Martha Porter	John Stolgitis	4/27/2009	Point Judith, RI	$1,682.00	$250.00
34.83						**$130,816.79**	**$25,171**
1.08	11230116	Last Fling	Ted Platz	39630	Newport, RI		
1.08							
0.63	Set net	Sea Otter VI	Joel Lizza	4/19/2009	New London,CT		
1.09	11457702	Sea Otter VI	Joel Lizza	4/24/2009	New London,CT	$4,834.45	$749.12
1.08	11457703	Sea Otter VI	Joel Lizza	4/26/2009	New London,CT	$4,994.25	$725.18
2.8						**$9,828.70**	**$1,474.30**
1.12	11214716	Bout Time	Chris Hickman	1/4/2009	Pt. Pleasant, NJ	$3,362.33	$672.47
1.09	11214735	Bout Time	Chris Hickman	1/10/2009	Pt. Pleasant, NJ	$1,113.47	$222.69
0.66	set net	Bout Time	Chris Hickman	1/17/2009	Pt. Pleasant, NJ		
1.01	11214738	Bout Time	Chris Hickman	1/18/2009	Pt. Pleasant, NJ	$3,265.42	$510.99
1.06	11214740	Bout Time	Chris Hickman	1/22/2009	Pt. Pleasant, NJ	$3,339.38	$525.79

4.94						**$11,080.60**	**$1,931.94**
0.78	11279477	Wooley Bulley	Roger Wooleyan	11/17/2008	Ocean City, MD	$529.30	$105.86
1.1	11279480	Wooley Bulley	Roger Wooleyan	11/24/2008	Ocean City, MD	$665.05	$133.01
0.82	11279483	Wooley Bulley	Roger Wooleyan	11/29/2008	Ocean City, MD	$1,794.60	$358.92
1	11279487	Wooley Bulley	Roger Wooleyan	12/10/2008	Ocean City, MD	$3,311.10	$662.22
1.02	11279489	Wooley Bulley	Roger Wooleyan	12/16/2008	Ocean City, MD	$6,444.00	$1,288.80
1.01	11279490	Wooley Bulley	Roger Wooleyan	12/19/2008	Ocean City, MD	$4,411.15	$882.23
1.01	11279406	Wooley Bulley	Roger Wooleyan	12/30/2008	Ocean City, MD	$2,962.70	$592.54
1.01	11279413	Wooley Bulley	Roger Wooleyan	1/19/2009	Ocean City, MD	$2,701.60	$405.24
1.01	11279414	Wooley Bulley	Roger Wooleyan	1/22/2009	Ocean City, MD	$4,163.20	$624.48
1.02	11279416	Wooley Bulley	Roger Wooleyan	1/27/2009	Ocean City, MD	$2,249.65	$337.44
1.07	11279418	Wooley Bulley	Roger Wooleyan	2/2/2009	Ocean City, MD	$2,447.50	$367.12
1.06	11279419	Wooley Bulley	Roger Wooleyan	2/6/2009	Ocean City, MD	$1,946.85	$292.02
0.93	11279420	Wooley Bulley	Roger Wooleyan	2/10/2009	Ocean City, MD	$1,596.45	$239.46
0.74	11279421	Wooley Bulley	Roger Wooleyan	2/14/2009	Ocean City, MD	$485.45	$72.81
0.63	11279423	Wooley Bulley	Roger Wooleyan	3/20/2009	Ocean City, MD	$363.25	$54.48
1.01	11279426	Wooley Bulley	Roger Wooleyan	4/6/2009	Ocean City, MD	$3,797.50	$569.62
1.11	11279427	Wooley Bulley	Roger Wooleyan	4/9/2009	Ocean City, MD	$3,787.10	$568.06
1.02	11279428	Wooley Bulley	Roger Wooleyan	4/11/2009	Ocean City, MD	$3,333.00	$499.95
1.84	11279429	Wooley Bulley	Roger Wooleyan	4/13/2009	Ocean City, MD	$2,562.30	$384.34
1.14	11279431	Wooley Bulley	Roger Wooleyan	4/22/2009	Ocean City, MD	$1,866.75	$280.01
0.73	11279432	Wooley Bulley	Roger Wooleyan	4/23/2009	Ocean City, MD	$1,080.00	$162.00
0.91	11279433	Wooley Bulley	Roger Wooleyan	4/26/2009	Ocean City, MD	$1,534.60	$230.19
0.8	11279434	Wooley Bulley	Roger Wooleyan	4/27/2009	Ocean City, MD	$754.25	$113.14
22.77						**$54,787.35**	**$9,223.94**
1.42	11197315	Reginas Pride	Brian Roche	3/6/2009	New Bedford, MA	$1,225.90	$183.89

1.55	11197316	Reginas Pride	Brian Roche	3/9/2009	New Bedford, MA	$1,332.40	$199.86
1.35	11197317	Reginas Pride	Brian Roche	3/14/2009	New Bedford, MA	$1,418.05	$212.71
1.42	11197318	Reginas Pride	Brian Roche	3/19/2009	New Bedford, MA	$3,980.85	$597.13
1.51	11197319	Reginas Pride	Brian Roche	3/23/2009	New Bedford, MA	$2,139.30	$320.90
1.6	11197320	Reginas Pride	Brian Roche	3/27/2009	New Bedford, MA	$4,204.60	$630.69
1.52	11197321	Reginas Pride	Brian Roche	4/2/2009	New Bedford, MA	$4,483.70	$672.56
2.17	11197322	Reginas Pride	Brian Roche	4/11/2009	New Bedford, MA	$6,865.00	$1,120.60
2.12	11197323	Reginas Pride	Brian Roche	4/15/2009	New Bedford, MA	$8,903.25	$1,233.52
1.21	11197324	Reginas Pride	Brian Roche	4/19/2009	New Bedford, MA	$4,847.10	$727.07
2.03	11197325	Reginas Pride	Brian Roche	4/26/2009	New Bedford, MA	$7,130.50	$1,069.58
1.31	11197326	Reginas Pride	Brian Roche	5/1/2009	New Bedford, MA	$4,329.50	$629.70
19.21						**$50,860.15**	**$7,598.19**
2.04	11254954	Gulf Voyager	Brian Roche	4/11/2009	New Bedford, MA	$5,794.40	$869.16
1.74	11254955	Gulf Voyager	Brian Roche	4/15/2009	New Bedford, MA	$4,538.45	$608.57
2.35	11254956	Gulf Voyager	Brian Roche	4/20/2009	New Bedford, MA	$3,352.80	$451.98
2.1	11254957	Gulf Voyager	Brian Roche	4/26/2009	New Bedford, MA	$3,533.63	$161.25
1.82	11254959	Gulf Voyager	Brian Roche	5/1/2009	New Bedford, MA	$2,435.10	$356.53
10.05						**$19,654.38**	**$2,447.49**
95.68						**$277,027.97**	**$47,846.86**

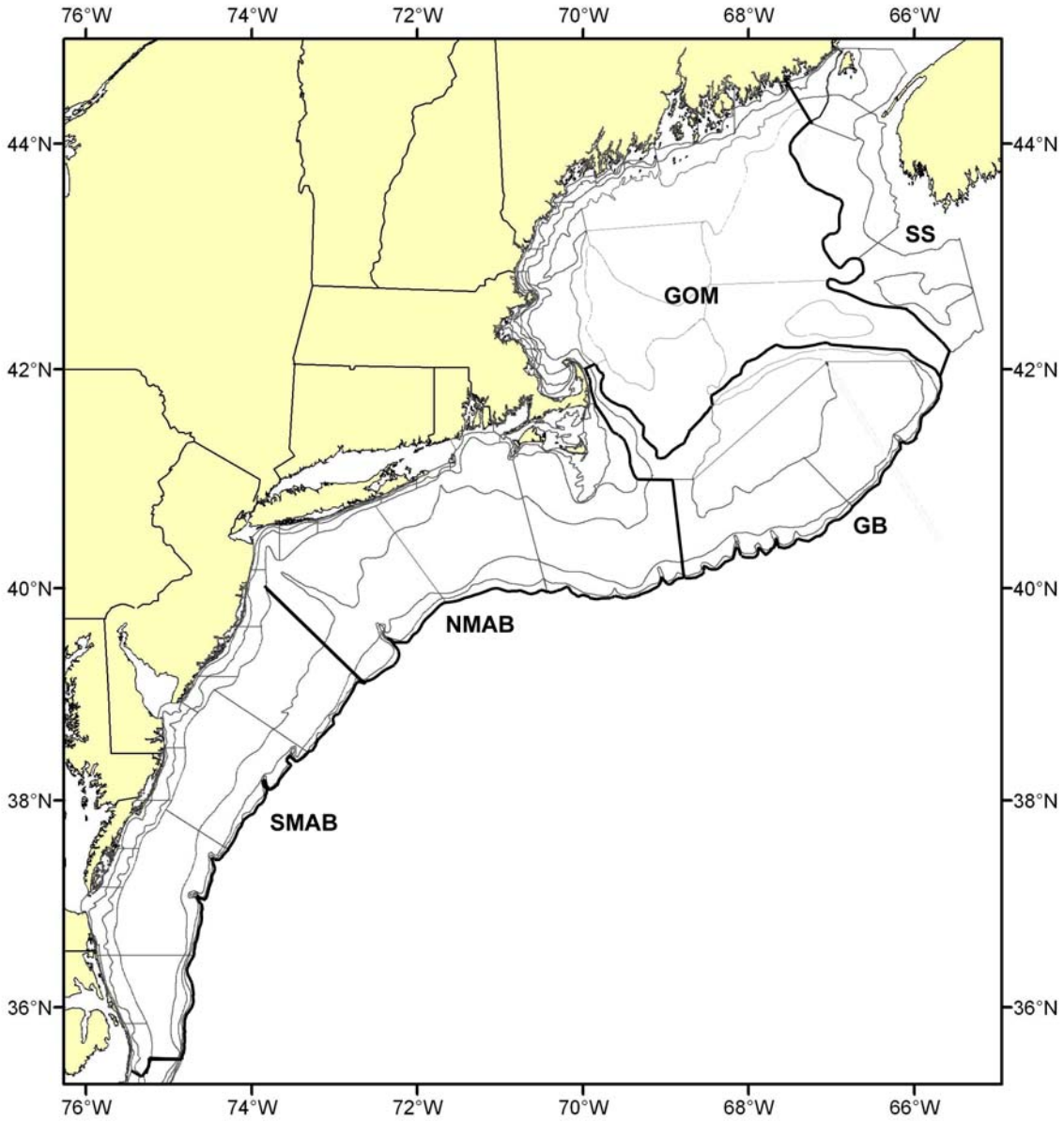

Figure 1. Map showing the five regions sampled during NEFSC annual autumn and spring bottom trawl surveys defined by survey strata. Stratified regions referred to in the text are labeled as SS = Scotian Shelf; GOM = Gulf of Mane; GB = Georges Bank; NMAB = northern Mid-Atlantic Bight; SMAB = southern Mid-Atlantic Bight.

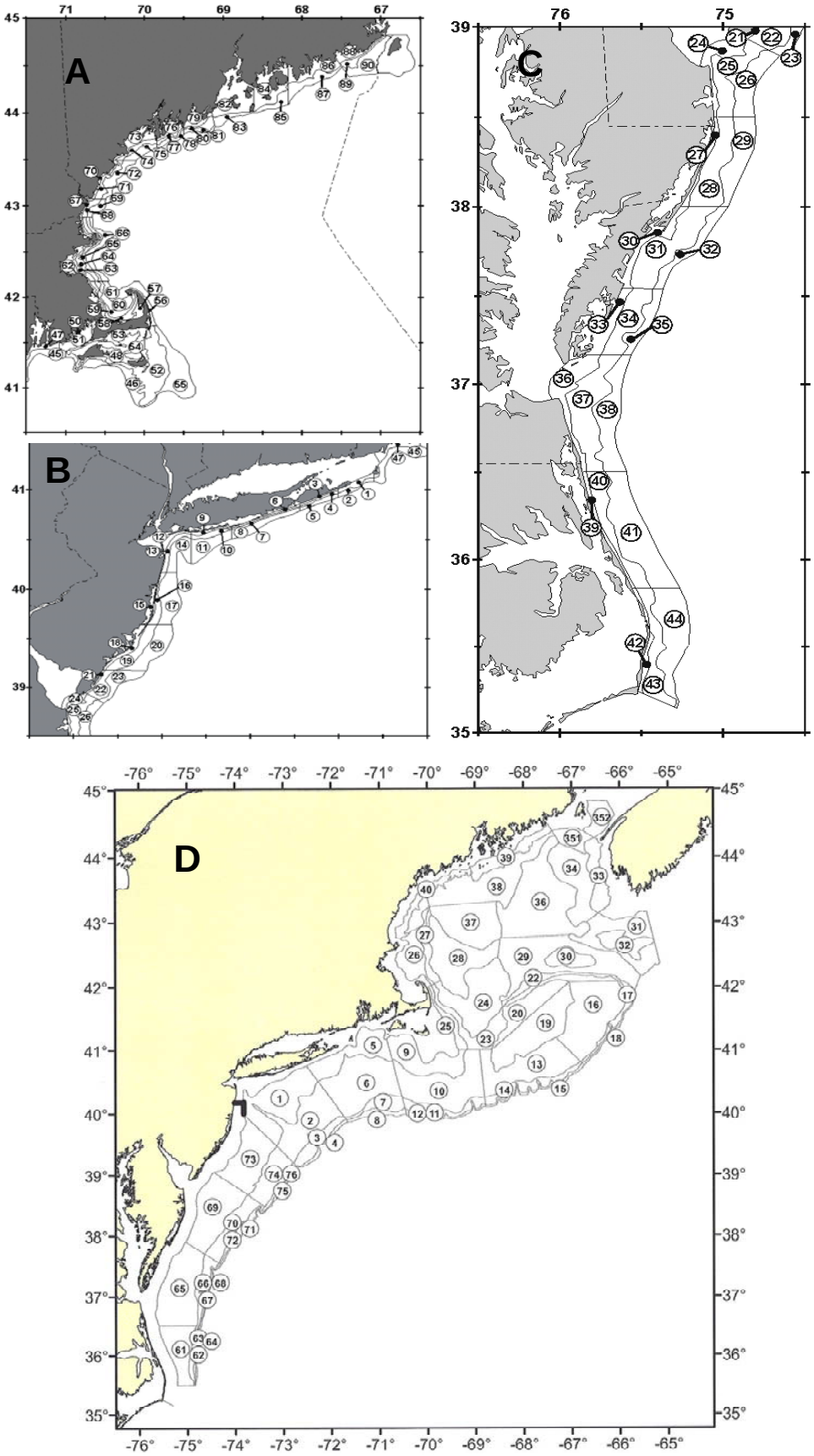

Figure 2. Maps of NEFSC strata sampled during annual bottom trawl surveys. A-C: Inshore (<9-26 m); D: Offshore (27-365 m). Strata 61-76 (SMAB) were not sampled prior to 1967. Courtesy of NOAA Northeast Fisheries Science Center.

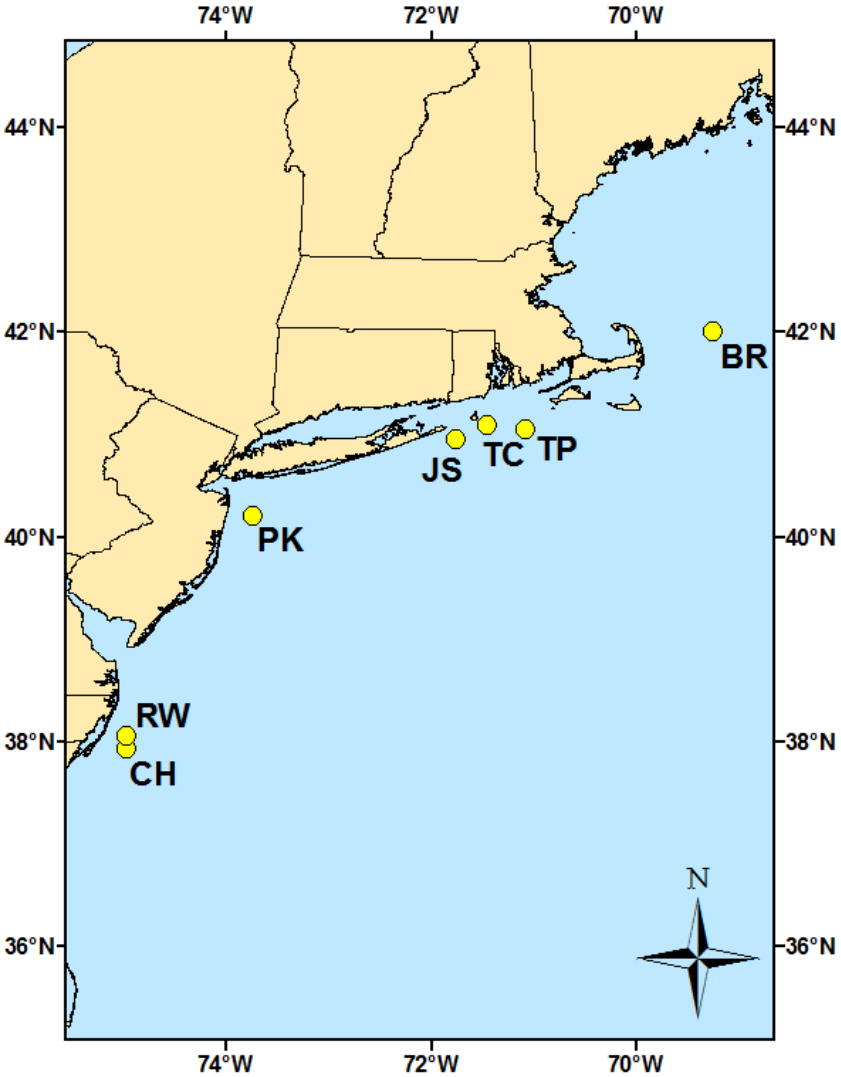

Figure 3. Sampling locations for monkfish gillnetters from May 2008 to April 2009 (BR = Brian Roche, TP = Ted Platz, TC = Ted Caldwell, JS = John Stolgitis, RW = Roger Wooleyhan, PK = Peter Krasowski, CH = Chris Hickman).

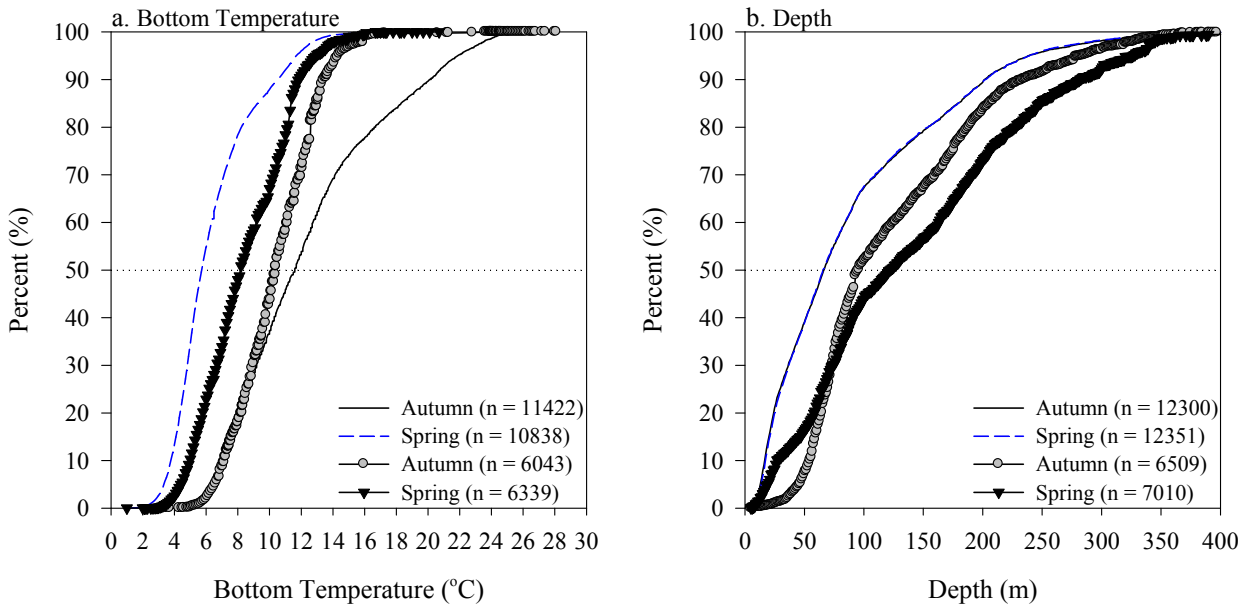

Figure 4. U.S. continental shelf-wide (including SS region) a) bottom temperature (˚C) and b) depth (m) associations for monkfish caught during NEFSC autumn and spring inshore and offshore trawl surveys. Solid lines represent the distribution of the sampled temperatures and depths, while the lines with symbols show the distribution of abundance-weighted (number of fish caught per survey tow) temperatures and depths (n = sample size).

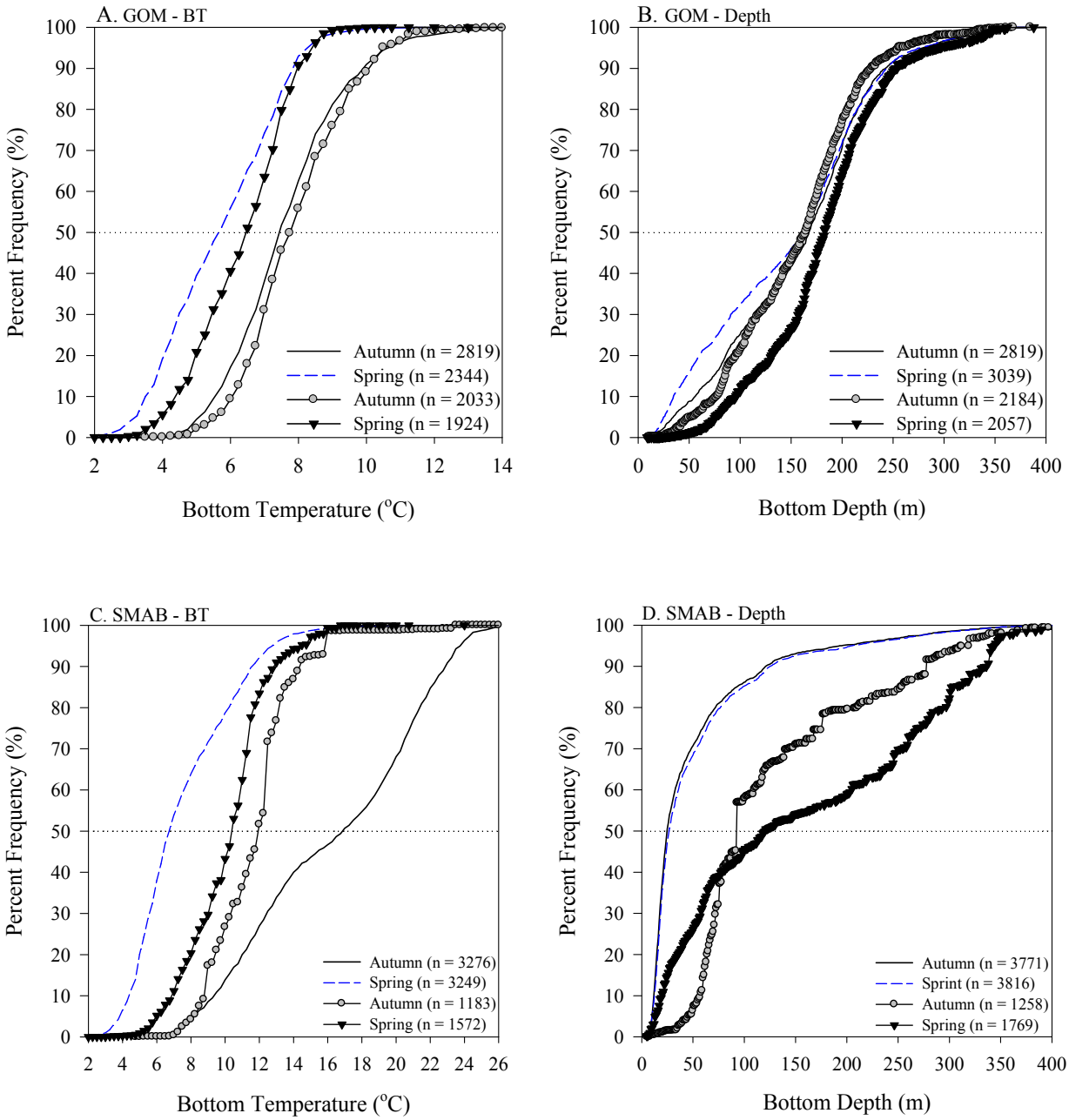

Figure 5. Cumulative distribution functions of bottom temperature (˚C) and depth (m) for the NEFSC GOM (plots A & B) SMAB region (plots C & D). Solid lines represent the distribution of the sampled temperatures and depths, while the lines with symbols show the distribution of abundance-weighted (number of fish caught per survey tow) temperatures and depths (n = sample size).

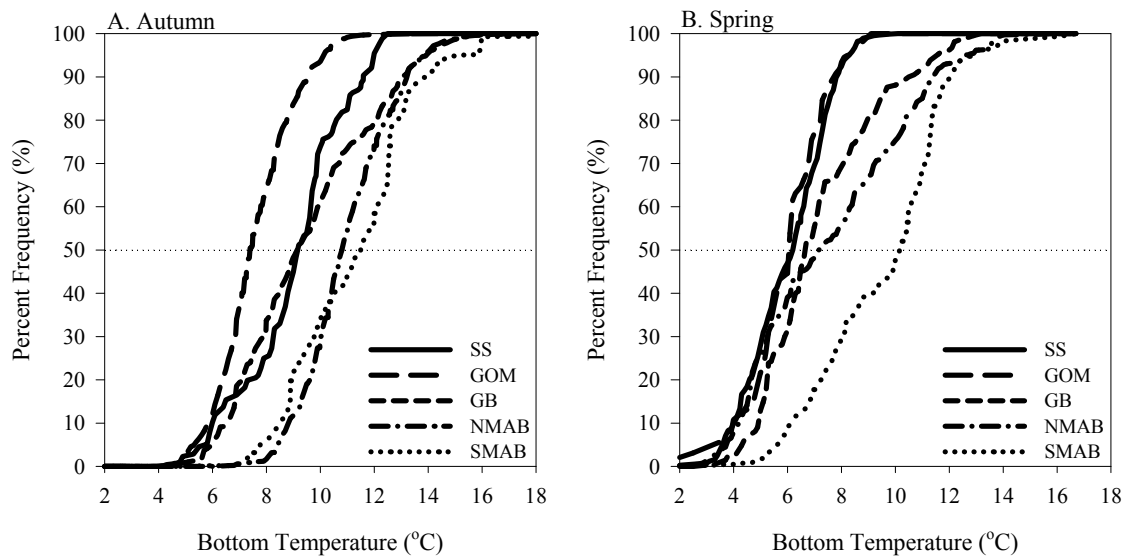

Figure 6. Comparison of abundance-weighted (number of fish caught per survey tow) bottom temperature (˚C) and depth (m) for the five NEFSC sub-regions (SS, GOM, GB, NMAB, SMAB) sampled during autumn (plot A) and spring (plot B) inshore and offshore trawl surveys.

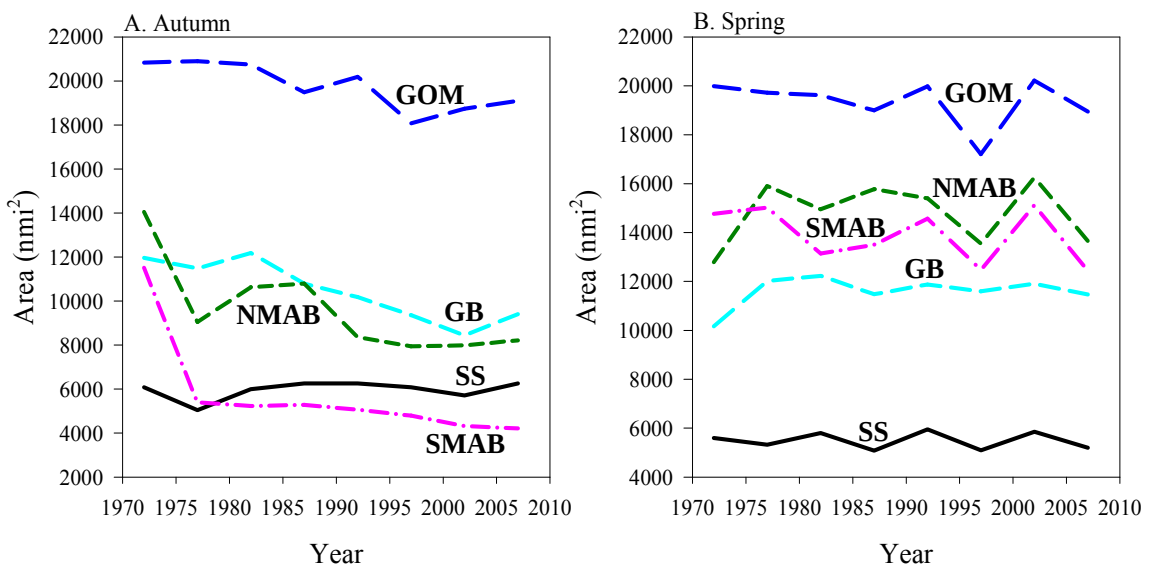

Figure 7. Area (nmi^2) of autumn (plot A) and spring (plot B) shelf waters for the NEFSC survey regions (SS, GOM, GB, NMAB, SMAB) where bottom temperatures (˚C) were within preferred range of temperatures for monkfish.

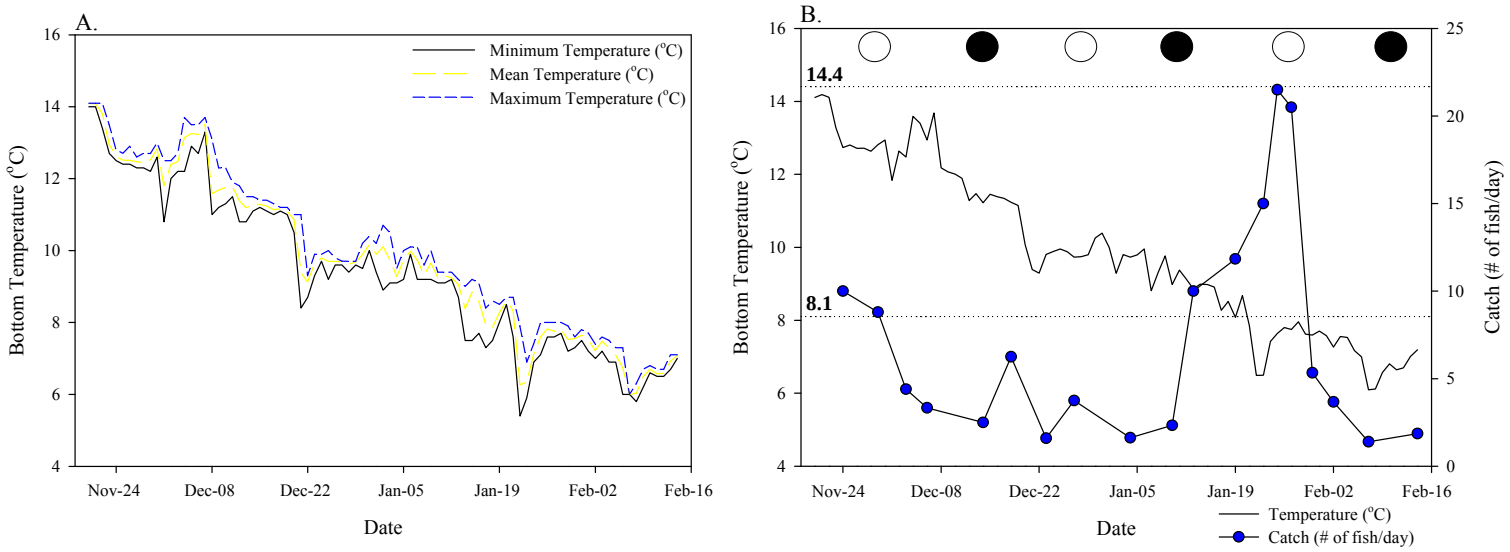

Figure 8. Minimum, maximum, and daily average temperature (A) and daily mean temperature and catch (B) collected by Peter Krasowski from November 2008 to February 2009 off the coast of Pt. Pleasant, NJ. Circles represent new (○) and full (●) lunar phases. Dotted lines represent the preferred temperature range (8.1-14.4°C) determined from CDFs of NEFSC trawl survey data.

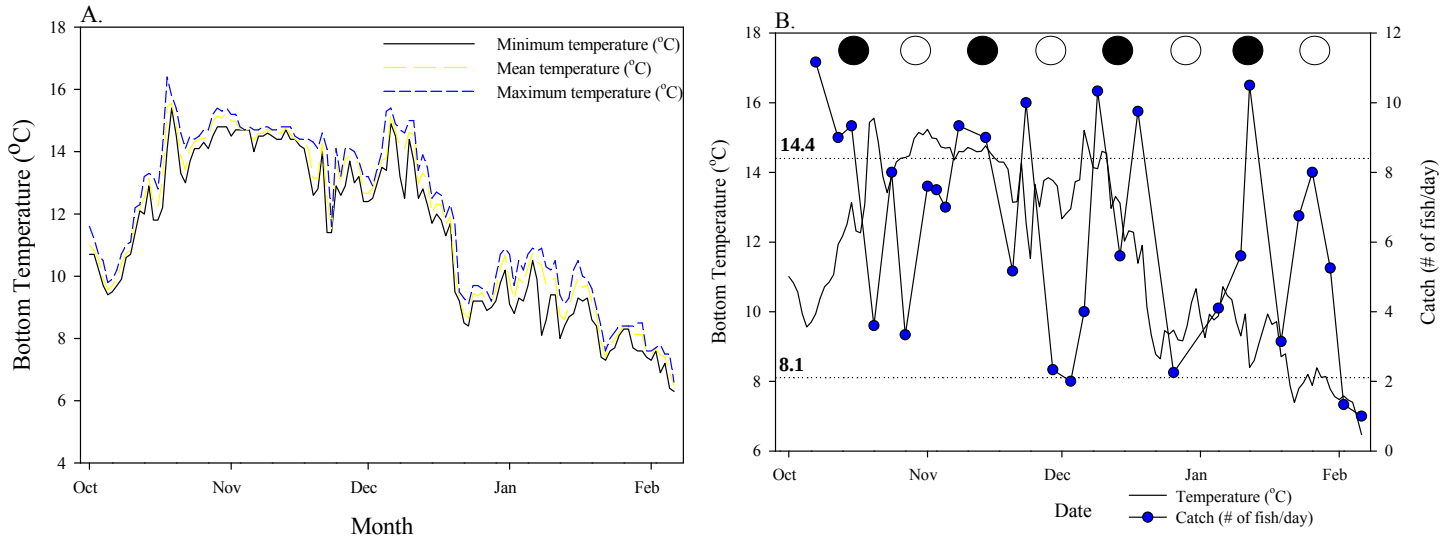

Figure 9. Minimum, maximum, and daily average temperature and daily mean temperature (A) and catch (B) collected by John Stolgitis from October 2008 to February 2009 off the coast of Pt. Judith, RI. Circles represent new (○) and full (●) lunar phases. Dotted lines represent the preferred temperature range (8.1-14.4°C) determined from CDFs of NEFSC trawl survey data.

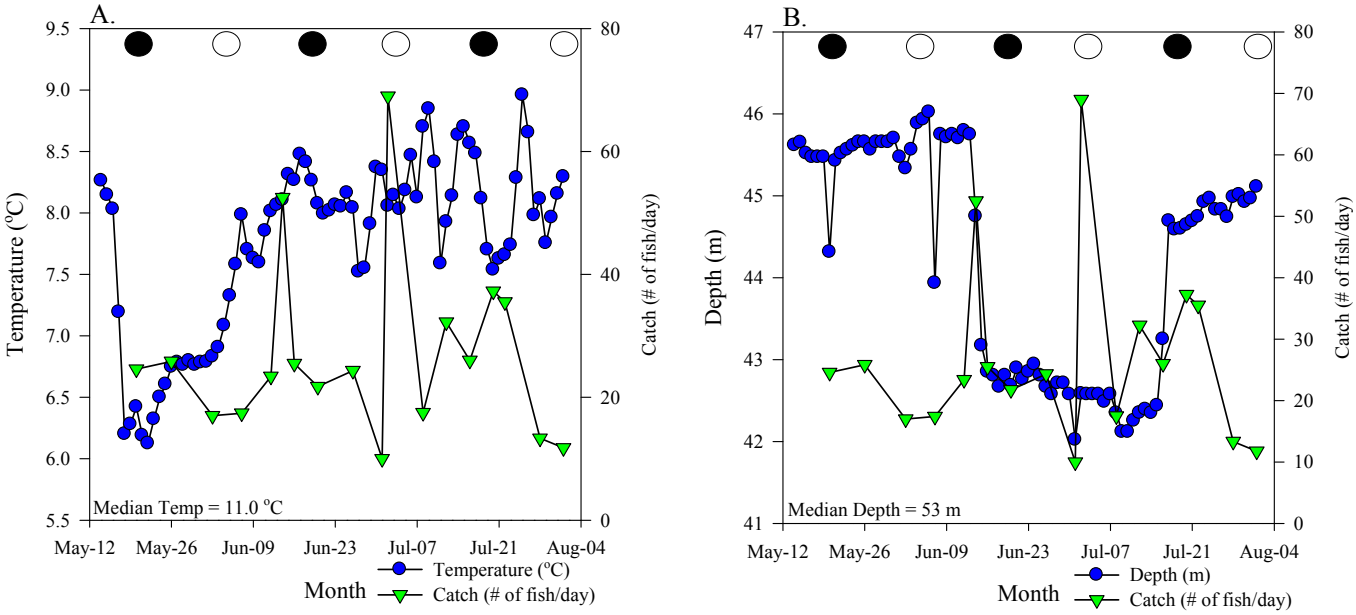

Figure 10. Time-series for the number of fish caught per day and bottom temperature (plot A) and depth (plot B) sampled by John Stolgitis from May to September 2008 off the coast of Pt. Judith, RI. Median preferred temperature and depth determined from CDFs of NEFSC trawl survey data are listed for comparison.

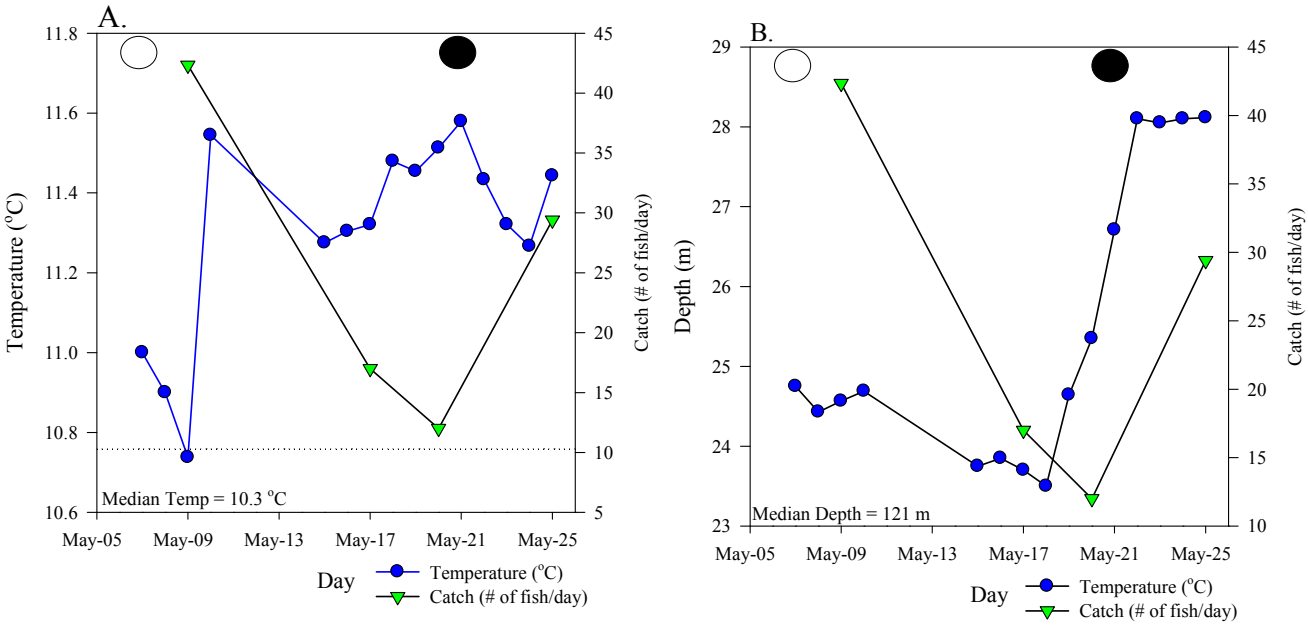

Figure 11. Time-series plots between the number of fish caught per day and A) bottom temperature and B) depth sampled by Chris Hickman during May 2008 off the coast of Chincoteague, VA.

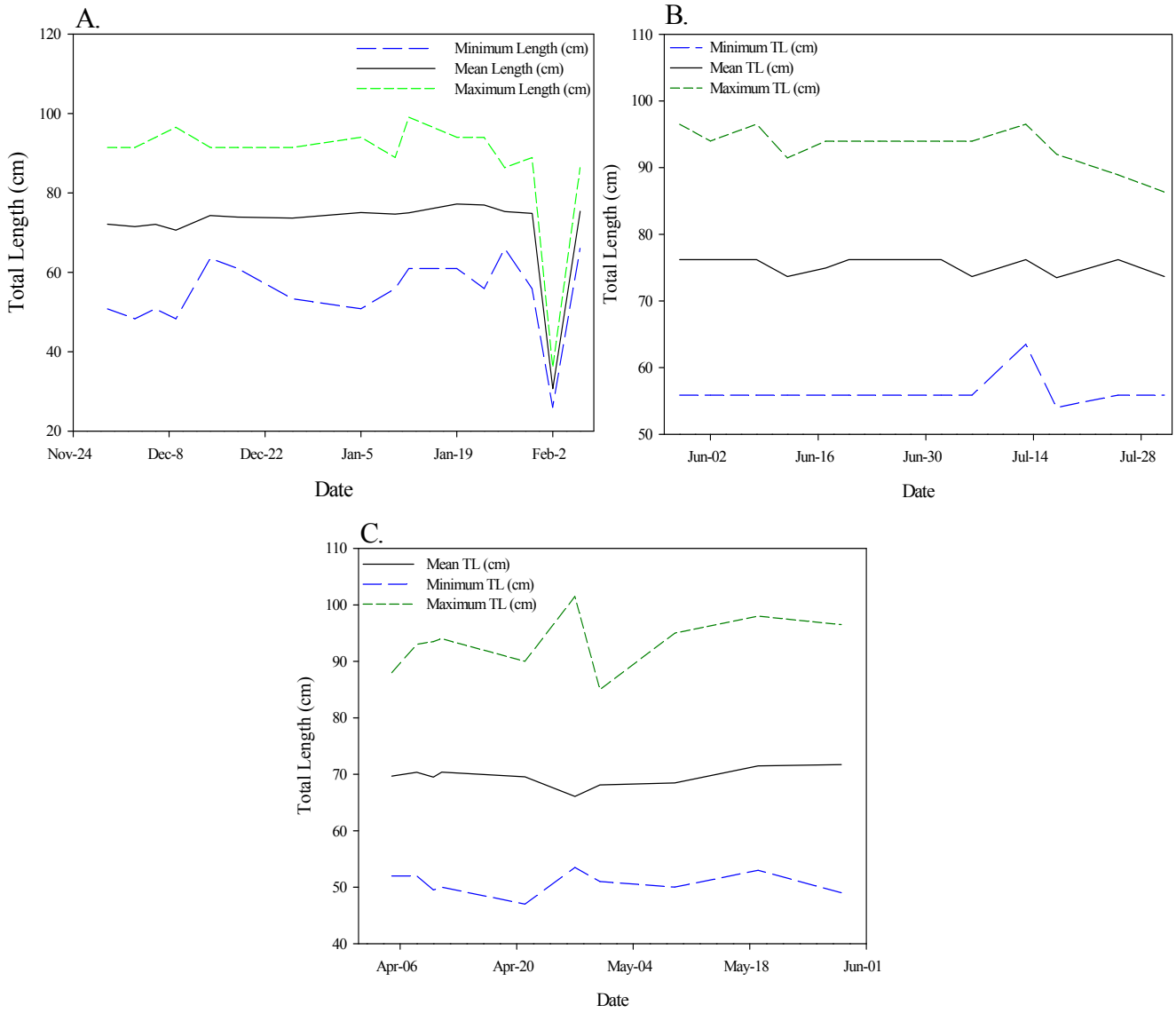

Figure 12. Mean, minimum, and maximum total lengths (cm) for monkfish sampled from A) November 2008 to February 2009 off the coast of Pt. Judith, RI, B) May to August 2008 off the coast of Pt. Pleasant, NJ, C) April to June 2008 off the coast of Ocean City, MD.

Andrea Johnson
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Date: 2010.07.28 17:16:29 -04'00'