A. MONKFISH (GOOSEFISH) STOCK ASSESSMENT FOR 2010

SAW50 Editor's Note: The SAW Chair has added comments to this monkfish assessment report, all of which use bold italicized text. These comments are included to present some opinions and decisions of the SARC50 peer review panel. The comments inserted here do not replace and are not a substitute for the complete set of reviewer reports that are available online from the SAW/SARC website (http://www.nefsc.noaa.gov/nefsc/saw/ in the SAW50 section).

Southern Demersal Working Group (WG)

The Southern Demersal Working Group prepared the stock assessment. The WG met during April 12-15, 2010 at the Northeast Fisheries Science Center, Woods Hole. MA, USA, with the following participants:

Larry Alade	NMFS NEFSC
Crista Bank	UMASS SMAST
Eleanor Bochenek	Rutgers University
Steve Cadrin	NMFS NEFSC/NEFMC SSC; via Webex
Trisha DeGraaf	Maine DNR
Phil Haring	NEFMC
Jason Link	NMFS NEFSC
J -J Maguire	Halieutikos, Inc., Monkfish Defense Fund, NEFMC SSC; via Webex
Allison McHale	NMFS NERO
Paul Nitschke	NMFS NEFSC (SCALE model)
Mike Palmer	NMFS NEFSC
Paul Rago	NEFSC NMFS
Anne Richards	NMFS NEFSC (assessment lead)
Fred Serchuk	NMFS NEFSC
Katherine Sosebee	NMFS NEFSC
Nils Stolpe	Monkfish Defense Fund; via Webex
Sandy Sutherland	NMFS NEFSC
Mark Terceiro	NMFS NEFSC (WG chair)
Michele Traver	NMFS NEFSC
Vidar Wespestad	Monkfish Defense Fund

SARC 50 Monkfish Terms of Reference

1. Characterize the commercial catch including landings, effort, LPUE and discards. Describe the uncertainty in these sources of data.
2. Report results of 2009 cooperative monkfish survey and describe sources of uncertainty in the data and results.
3. Characterize other survey data that are being used in the assessment (e.g., regional indices of abundance, recruitment, length data, state surveys). Describe the uncertainty in these sources of data.
4. Estimate annual fishing mortality, recruitment and stock biomass (both total and spawning stock) for the time series, and characterize the uncertainty of those estimates.
5. Update or redefine biological reference points (BRPs; estimates or proxies for B_{MSY}, $B_{THRESHOLD}$, and $F_{MSY;}$ and estimates of their uncertainty). Comment on the scientific adequacy of existing and redefined BRPs.
6. Evaluate stock status with respect to the existing BRPs, as well as with respect to updated or redefined BRPs (from TOR 5).
7. Evaluate monkfish diet composition data and its implications for population level consumption by monkfish.
8. Develop and apply analytical approaches and data that can be used for conducting single and multi-year stock projections and for computing candidate ABCs (Acceptable Biological Catch; see Appendix to the TORs).
    a. Provide numerical short-term projections (through 2016). Each projection should estimate and report annual probabilities of exceeding threshold BRPs for F, and probabilities of falling below threshold BRPs for biomass. In carrying out projections, consider a range of assumptions to examine important sources of uncertainty in the assessment.
    b. Comment on which projections seem most realistic, taking into consideration uncertainties in the assessment.
    c. Describe this stock's vulnerability to becoming overfished, and how this could affect the choice of ABC.
9. Review, evaluate and report on the status of the SARC and Working Group research recommendations listed in recent SARC reviewed assessments and review panel reports. Identify new research recommendations.

Executive Summary

The Southern Demersal Working Group (SDWG) met in April 2010 to develop stock assessments for the northern, southern and combined management areas of the U.S. fishery resource. The SDWG met within the process of Northeast SAW 50 and addressed 10 terms of reference, as follows.

1. Characterize the commercial catch including landings, effort, LPUE and discards. Describe the uncertainty in these sources of data.

Reported total landings (live weight) increased from an average of 2,500 mt in the 1970s to 8,700 mt in the 1980s, 23,000 mt in the 1990s, 22,000 mt from 2000-2005 and 11,600 mt during 2006-2009. Total landings have declined since 2003 due to management regulations including TACs during 2007-2009 of 5,000 mt in the northern area and 5,100 mt in the southern area. Landings in 2009 were 3,255 mt in the northern area and 5,302 mt in the southern area.

Estimated total discards of monkfish during 1989-2009 have ranged between 1,600 mt (1992) and 7,500 mt (2001) per year, with a long-term discard/kept ratio of 0.15 (northern and southern areas combined). Discard rates have been highest in the scallop dredge fisheries in the southern area, and lowest in gillnets in both areas. Discard ratios and discard levels (mt) increased in both areas after 2000, and have since declined somewhat (overall discard/kept ratio for 2000-2004 =0.20; for 2005-2009=0.17).

Length composition of landings was fairly stable during 2002-2009, with modal lengths ~52 cm in the north, ~65 cm in the south and few fish larger than 85 cm in either area. Recent decreases in landings have not resulted in a broadening of the size composition of landings.

Evaluating trends in effort or catch rates in the monkfish fishery is difficult because much of the catch is taken in multi-species fisheries, and defining targeted monkfish trips is problematic. Furthermore, programmatic changes from port interviews (1980-1993) and logbooks (1994-2006) make temporal comparison of effort statistics difficult. CPUE estimated from observed tows has declined in the north since 2003-2005 and remained stable or declined since 2004 in the south; however estimates of CPUE have a high variance and may not be reliable.

Estimation of total catch for monkfish has several sources of uncertainty. Before 1980, fishery removals were primarily bycatch, but most were unreported. Therefore, evaluation of fishery development is difficult, leading to problems interpreting the state of the resource in the early years of the marketed fishery. Since 1980, the quality of landings estimates generally increased, but the series includes under-reporting and difficulties converting landed products to live weight. Historical under-reporting of landings should be considered in the interpretation of this series.

There is no information on the magnitude of discards prior to 1989. The SDWG assumed that discard rates before 1989 were similar to discard: kept ratios observed in later years; this may be problematic if discard rates were lower in later years because markets had developed. The quality of discard data generally increased in the 1989-2009 observer time series, as a result of increasingly greater coverage of fleets and improved protocols, but there were some unsampled portions of the fishery (e.g., some half-year periods in which entire gear-types were not sampled).

Characterizing size and age composition of the catch also has considerable sources of uncertainty. Length sampling by fishery observers started earlier in the time series than sampling of landings in ports (1989 vs. 1996) and was more comprehensive (NEFSC 2007a); however, sampling intensity in most years is adequate only for estimation on a half-year basis. Age samples from at-sea observers have not been processed and are on hold until the ageing method is validated.

2. Report results of 2009 cooperative monkfish survey and describe sources of uncertainty in the data and results.

A cooperative monkfish survey was conducted during Feb-Apr 2009 using two industry trawlers and 3 nets (2 flat, 1 rockhopper). The survey design differed slightly from previous cooperative surveys (in 2001, 2004) because sampling effort was allocated in proportion to stratum area rather than to spatial patterns of fishing effort. The estimates of area swept population size and biomass for 2009 are lower than those estimated from earlier cooperative monkfish surveys (2001, 2004). The estimated population length composition was similar among cooperative surveys with a mode around 34 cm in the NMA and a bimodal distribution (~32 cm and ~52 cm) in the SMA. Length frequency composition data from the 2009 cooperative survey were input into the final SCALE assessment model. Major sources of uncertainty include timing of the survey with respect to spring onshore migrations and accuracy of net efficiency estimates from depletion experiments.

3. Characterize other survey data that are being used in the assessment (e.g., regional indices of abundance, recruitment, length data, state surveys). Describe the uncertainty in these sources of data.

Several surveys sample monkfish and provide time series of relative abundance. However, no single survey (with the exception of the new NEFSC survey on the FSV Bigelow) catches large numbers of monkfish throughout either management area. The NEFSC spring and autumn bottom trawl surveys provide long-term series that sample the entire continental shelf to 300m depth, but they only catch approximately 100 monkfish in each management area per year. The NEFSC winter bottom trawl survey and scallop survey, the ASMFC shrimp survey, and the ME/NH inshore survey catch considerably more monkfish, but are shorter series, and sample only a portion of either management area.

Within the northern management area, broad trends in stock size are consistent among the five surveys conducted there. Biomass fluctuated without trend from 1963 to the early 1980s, but declined thereafter to near historic lows during the 1990's when landings reached their peak. Biomass indices increased from 2000 to 2004, but have generally decreased since then. Abundance indices in the north fluctuated without trend during 1963-1998 but spiked during 2000-2002, reflecting a strong 1999 year class.

General trends in stock size in the southern area are also consistent among surveys. Survey biomass and abundance indices were high during the mid-1960s, fluctuated around an intermediate level during the 1970s and mid-1980s, then declined to low levels since the late 1980s. Biomass indices increased slightly around 2002 but have returned to lower levels since then.

Size-based indices of abundance indicate relatively strong recruitment in the northern area during the 1990s and variable but stable recruitment in the south. Length distributions gradually truncated from the 1960s to1990, and the median size of monkfish in survey catches has remained fairly constant since the early 1990s.

4. Estimate annual fishing mortality, recruitment and stock biomass (both total and spawning stock) for the time series, and characterize the uncertainty of those estimates.

Fishing mortality rates, recruitment and stock sizes were estimated using the SCALE statistical catch-at-length model. Estimated F in 2009 was 0.10 in the north and 0.07 in the south (0.05 combined areas). Estimated total biomass in 2009 was 66,062 mt in the north and 131,218 mt in the south (255,326 mt, combined areas). In the north, the strongest year classes were produced in 1997-1999; recruitment was generally below average in the 1980s, and has been about average since 2001. In the south, the strongest year classes were produced in 1992, 1997, and 2002; recruitment has been below average since 2004. Based on the combined-areas model, the strongest year classes were produced in 1997-1999 and recruitment has been below average since 2004.

Uncertainty in the estimates of stock size, recruitment and F stems from poorly known input data, including under-reported landings and unknown discards during the 1980s, and incomplete understanding of key biological parameters such as age and growth, longevity, natural mortality, sex ratios and stock structure, and the relatively short reference time frame (1980-2006) of the model. Further, the population models for all areas exhibit retrospective patterns that are strongest for the 2002-2006 terminal years and weaker for the 2007-2008 terminal years. The retrospective patterns are strongest for the northern area, weakest for the southern area, and intermediate for the model of combined areas.

SAW50 Editor's note: In view of the short time available for the review, the SARC50 panel declined to review the combined-areas model as it addressed a Research Recommendation rather than a Term of Reference, and because management is based on the two-areas model.

The SARC50 panel acknowledged the high degree of uncertainty in estimates from the SCALE model due to data limitations, poorly understood monkfish biology (growth, natural mortality, stock structure), and the strong retrospective pattern in the northern area.

5. Update or redefine biological reference points (BRPs; estimates or proxies for B_{MSY}, $B_{THRESHOLD}$, and $F_{MSY;}$ and estimates of their uncertainty). Comment on the scientific adequacy of existing and redefined BRPs.

The 2007 NEFSC assessment recommended new reference points based on a revised yield-per-recruit analysis (using M=0.3) and on the results of the SCALE length-tuned model that incorporated multiple survey indices and catch data. The new reference biomass levels were based on long term trends in biomass from the SCALE model, and were adopted in Framework 5 (April 2008). The current assessment updates the SCALE model and estimates new reference points based on the methods adopted in NEFSC (2007a) and using the method applied in the New England groundfish stock complex based on projections of B_{max} at F_{max}. The BRPs all use output from the SCALE model, which is subject to high levels of uncertainty as discussed under TOR 4, therefore the BRPs are also highly uncertain.

The following table summarizes the estimates for each management area and combined areas. Adjusted refers to estimates adjusted for retrospective patterns.

Management Areas	Biomass BRPs in metric tons			
North	BRP	Basis	DPSWG 2007	SDWG 2010
	Fmax	YPR	0.31	0.43
	Bthreshold	Bloss 1980-2006	65,200	
	Bthreshold	Bloss 1980-2009		41,238
	Bthreshold	0.5*Bmax Projected		26,465
	Bthreshold	0.5*Bmax Proj Adjust		20,643
	Btarget	Bavg 1980-2006	92,200	62,371
	Btarget	Bavg 1980-2009		61,991
	Btarget	Bmax Projected		52,930
	Btarget	Bmax Proj Adjust		41,286
	MSY	Fmax Projected		10,745
South	BRP	Basis	DPSWG 2007	SDWG 2010
	Fmax	YPR	0.40	0.46
	Bthreshold	Bloss 1980-2006	96,400	
	Bthreshold	Bloss 1980-2009		99,181
	Bthreshold	0.5*Bmax Projected		37,245
	Bthreshold	0.5*Bmax Proj Adjust		28,461
	Btarget	Bavg 1980-2006	122,500	120,292
	Btarget	Bavg 1980-2009		121,313
	Btarget	Bmax Projected		74,490
	Btarget	Bmax Proj Adjust		56,922
	MSY	Fmax Projected		15,279
Combined	BRP	Basis	DPSWG 2007	SDWG 2010
	Fmax	YPR		0.37
	Bthreshold	Bloss 1980-2009		159,715
	Bthreshold	0.5*Bmax Projected		64,501
	Bthreshold	0.5*Bmax Proj Adjust		49,021
	Btarget	Bavg 1980-2009		208,190
	Btarget	Bmax Projected		129,002
	Btarget	Bmax Proj Adjust		98,041
	MSY	Fmax Projected		25,943

SAW50 Editor's note: The SARC50 panel recommended adoption of the biomass reference points based on "Bmax projected" for each management area. The word "adjust" in the table above refers to results that were adjusted for the retrospective pattern. Although the SARC50 panel did not recommend using the "adjusted" values directly, the panel was well aware and very concerned about the lack of model fit.

6. Evaluate stock status with respect to the existing BRPs, as well as with respect to updated or redefined BRPs (from TOR 5).

Estimates of total biomass for 2006 in both management areas (see table below) were greater than their respective biomass targets, therefore, based on those somewhat uncertain analyses, monkfish in both management areas were not overfished and overfishing was not occurring.

Estimates of total biomass for 2009 in both management areas and the combined area (see table below), were above $B_{threshold}$ and B_{target}, but with a smaller margin in the north than estimated in 2006. These estimates are subject to the same uncertainty as the assessment in 2006.

	Stock Biomass			F					
	North	South	N+S	North	South	N+S	Overfished	Overfishing	Bthreshold Basis
SCALE 2006	119,000	135,000	-	0.09	0.12		no	no	Bloss (1980-2006)
SCALE 2009	66,062	131,218	255,326	0.10	0.07	0.05	no	no	Bloss (1980-2009)

SAW50 Editor's note: The SARC50 panel acknowledged the high degree of uncertainty in estimates from the SCALE model due to data limitations, poorly understood monkfish biology (growth, natural mortality, stock structure), and the strong retrospective pattern in the northern area. This uncertainty affects not only the current estimates of biomass but the estimates of the BRPs as well.

7. Evaluate monkfish diet composition data and its implications for population level consumption by monkfish.

Diet composition, per capita consumption, total consumption, and the amount of prey removed by monkfish were calculated from basic monkfish food habits data. Based on recent energy budgets, the amount of food consumed by monkfish is 0.005-0.02% of all energy flows in the system, and monkfish account for 2-6% of the total consumption by all finfish in the ecosystem (1-4 % in the northern area, 2-8% in the southern area).

The total amount consumed and per capita consumption peaked in the early 1980s for both stocks, driven by larger fish. Monkfish consumption of mackerel and herring is potentially 20-50% of landings, about equal to landings for squids, and potentially greater than the landings of silver hake and skates. Monkfish is an important piscivore in the ecosystem.

8. Develop and apply analytical approaches and data that can be used for conducting single and multi-year stock projections and for computing candidate ABCs (Acceptable Biological Catch; see Appendix to the TORs).

   a. Provide numerical short-term projections (through 2016). Each projection should estimate and report annual probabilities of exceeding threshold BRPs for F, and probabilities of falling below threshold BRPs for biomass. In carrying out projections, consider a range of assumptions to examine important sources of uncertainty in the assessment.

   b. Comment on which projections seem most realistic, taking into consideration uncertainties in the assessment.

c. Describe this stock's vulnerability to becoming overfished, and how this could affect the choice of ABC.

SCALE model results and AGEPRO projections were used to evaluate stock trends during 2011-2016 with $F=F_{threshold}$ and at proposed ACTs and ABCs assuming stochastic long-term recruitment. The projections indicate that the northern area is the most vulnerable to overfishing or becoming overfished during 2011-2016 if total catches approach the proposed ABC, while the southern area is the least vulnerable.

Projections for the northern area (NMA) are the most likely to be unrealistic, given the uncertainty of stock status due mainly to the relatively strong retrospective observed since 2002. The southern area (SMA) projections are the most likely to be realistic, given the moderate retrospective observed for that area. The combined area projections are intermediate with respect to the current management areas, as the relative scaling of the two populations is maintained when the areas are combined in one model.

SAW50 Editor's note: The SARC50 panel acknowledged the high degree of uncertainty in the projections due to uncertainty in the starting conditions (output from the SCALE model).

9. Review, evaluate and report on the status of the SARC and Working Group research recommendations listed in recent SARC reviewed assessments and review panel reports. Identify new research recommendations.

A list of 26 research recommendations generated since SAW 34 in 2001 was reviewed and results summarized where available. Of these, 14 had either been addressed or were considered no longer relevant. One new recommendation was added by the SDWG in 2010.

Introduction

Life History

Monkfish (*Lophius americanus*), also called goosefish, are distributed in the Northwest Atlantic from the Grand Banks and northern Gulf of St. Lawrence south to Cape Hatteras, North Carolina (Collette and Klein-Macphee 2002). Monkfish may be found from inshore areas to depths of at least 900 m (500 fathoms). Seasonal onshore-offshore migrations occur and appear to be related to spawning and possibly food availability (Collette and Klein-MacPhee 2002).

Monkfish rest partially buried on soft bottom substrates and attract prey using a modified first dorsal fin ray that resembles a fishing pole and lure. Monkfish are piscivorous and commonly eat prey as large as themselves. Despite the behavior of monkfish as a demersal 'sit-and-wait' predator, recent information from electronic tagging suggests seasonal off-bottom movements (Rountree et al. 2006). Growth is rapid at about 10 cm per year, and is similar for both sexes up to age 6 and lengths of around 60 cm (Richards et al. 2008). Few males are found older than age 7, but females can live to 12-14 years or older. Monkfish as large as 138 cm have been captured in NEFSC bottom trawl surveys.

Female monkfish begin to mature at age 4 and 50% of females are mature by age 4.7 (about 41 cm). Males mature at slightly younger ages and smaller sizes (50% maturity at age 4.2 or 37 cm (NEFSC 2002; Richards et al. 2008). Spawning takes place from spring through early autumn, progressing from south to north, with most spawning occurring during the spring and early summer. Females lay a buoyant mucoid egg raft or veil which can be as large as 12 m long and 1.5 m wide and only a few mm thick. The eggs are arranged in a single layer in the veil, and the larvae hatch after about 1-3 weeks, depending on water temperature. The larvae and juveniles spend several months in a pelagic phase before settling to a benthic existence at a size of about 8 cm (Collette and Klein-MacPhee 2002).

Stock Identification

The Fishery Management Plan defines two management areas for monkfish (northern and southern), divided roughly by a line bisecting Georges Bank (Figure A1). The two assessment and management areas for monkfish were defined based on differences in temporal patterns of recruitment (estimated from NEFSC surveys), perceived differences in growth patterns, and differences in the contribution of fishing gear types (mainly trawl, gill net, and dredge) to the landings.

Genetic studies suggest a homogeneous population of monkfish off the U.S. east coast (Chikarmane et al. 2000). Monkfish larvae are distributed over deep (< 300 m) offshore waters of the Mid-Atlantic Bight in March-April, and across the continental shelf (30 to 90 m) later in the year, but relatively few larvae have been sampled in the northern management area (Steimle et al. 1999). NEFSC surveys continue to indicate different recruitment patterns in the two management units in recent years.

The perceived differences in growth were based on studies about 10 years apart and under different stock conditions (Armstrong et al. 1992: Georges Bank to Mid-Atlantic Bight, 1982-1985; Hartley 1995: Gulf of Maine, 1992-1993). Age, growth, and maturity information from the NEFSC surveys and the 2001, 2004 and 2009 cooperative monkfish surveys indicated only minor differences in age, growth, and maturity between the areas (Richards et al., 2008; Johnson et al., 2008). The recent biological evidence (growth, maturity, and genetic information) suggests that use of a single stock hypothesis in the assessment might be appropriate. However, substantial differences in the fisheries exist, and current management maintains separate regulatory areas to accommodate these differences.

The southern deepwater extent of the range of American monkfish (*L. americanus*) overlaps with the northern extent of the range of blackfin monkfish (*L. gastrophysus*; Caruso 1983). These two species are morphologically similar, which may create a problem in identification of survey catches and landings from the southern extent of the range of monkfish. The potential for a problem however is believed to be small. The NEFSC closely examined winter and spring 2000 survey catches for the presence of blackfin monkfish and found none. The cooperative monkfish survey conducted in 2001 caught only eight blackfin monkfish of a total of 6,364 monkfish captured in the southern management area.

Fisheries Management

Commercial fisheries for monkfish occur year-round using gillnets, trawls and scallop dredges. No significant recreational fishery exists. The primary monkfish products are tails, livers and whole gutted fish. Peak fishing activity occurs during November through June, and value of the catch is highest in the fall due to the high quality of livers during this season.

U.S. fisheries for monkfish are managed in the Exclusive Economic Zone (EEZ) through a joint New England Fishery Management Council - Mid-Atlantic Fishery Management Council Monkfish Fishery Management Plan (FMP). The primary goals of the Monkfish FMP are to end and prevent overfishing and to optimize yield and economic benefits to various fishing sectors involved with the monkfish fisheries (NEFMC and MAFMC 1998; Haring and Maguire 2008).

Current regulatory measures vary with type of permit but include limited access, limitations on days at sea, mesh size restrictions, trip limits, minimum size limits and other measures (Tables A1 and A2).

Biological reference points for monkfish were established in the original Fishery Management Plan (FMP), but were revised according to the conclusions of SAW 34 (NEFSC 2002) and again by the Data Poor Stocks Working Group (DPSWG) in 2007 (NEFSC 2007a). The overfishing definition is F_{max}. Prior to 2007, $B_{threshold}$ was defined as one-half of the median of the 1965-1981 3-year average NEFSC autumn trawl survey catch (kg) per tow). After acceptance of an analytical assessment in 2007 (NEFSC 2007a), B_{target} was redefined as the average of total biomass for the model time period (1980-2006) and $B_{threshold}$ as the lowest observed value in the total biomass time series from which the stock has then increased (termed "B_{Loss}"). According to the earlier (survey index-based) reference points, monkfish were overfished and overfishing status could not be determined (NEFSC 2005); however, with adoption of the analytical assessment in 2007, monkfish status was no longer overfished and overfishing was not occurring.

2007 DPSWG Assessment

The DPSWG accepted a length-tuned analytical model (SCALE) for monkfish assessment and status determination, and adopted a value of M=0.3 (vs. M=0.2). However, the WG emphasized that the assessment was highly uncertain due to under-reported landings, unknown discards during the 1980s, incomplete understanding of key biological parameters such as age and growth, longevity, natural mortality and stock structure, the shorter reference time frame (1980-2006) than in previous assessments (1963-2006), and the relatively recent development of the assessment model. The WG concluded that uncertainties in historical catch data precluded application of long-term models that rely on episodes of depletion and recovery to estimate stock size.

2010 SAW 50 Assessment

The 2010 Southern Demersal Working Group (SDWG) updated the SCALE model to assess the status of monkfish using data through 2009. Further developments included examination of retrospective patterns in the SCALE estimates, and development of short-term stochastic age-based projections. Data from a cooperative monkfish survey conducted during winter/spring of 2009 were analyzed and included in the assessment model, along with data collected on the new NEFSC survey vessel, starting in spring 2009, which was adjusted using calibration coefficients developed for monkfish. Length frequency composition data from the 2009 cooperative survey were input into the final SCALE assessment model.

SAW50 Editor's note: The SARC50 panel discussed the relative merits of adjusting for retrospective patterns and decided against making a direct adjustment for the pattern in the current assessment.

TOR 1. Characterize the Commercial Catch including landings, effort, LPUE and discards. Describe the uncertainty in these sources of data.

Landings

Landings statistics for monkfish are sensitive to conversion from landed weight to live weight, because a substantial fraction of the landings occur as tails only (or other parts). The conversion of landed weight of tails to live weight of monkfish in the NEFSC weigh-out database is made by multiplying landed tail weight by a factor of 3.32. Recently concerns have been raised that monkfish landings reported as ‘round’ (no conversion) may actually be ’head-on, gutted’, which has a conversion factor of 1.14, in which case live weight of landings would be underestimated. Assuming all landings classified as ‘round’ are actually ‘head-on, gutted’, the difference in live weight landings would be less than 0.8% on average since the ‘round’ category appeared in 1989. The working group concluded that this was not likely an important source of error in the assessment.

Early catch statistics are uncertain, because many of the monkfish caught were sold outside of the dealer system or used for personal consumption until the mid-1970s. For 1964 through 1989, there are two potential sources of landings information for monkfish; the NEFSC ‘weigh-out’ database, which consists of fish dealer reports of landings, and the ‘general canvass’ database, which contains landings data collected by NMFS port agents (for ports not included in the weigh-out system) or reported by states not included in the weigh-out system (Table A3). All landings of monkfish are reported in the general canvass data as ‘unclassified tails.’ Consequently, some landed weight attributable to livers or whole fish in the canvass data may be inappropriately converted to live weight. This is not an issue for 1964-1981 when only tails were recorded in both databases. For 1982-1989, the weigh-out database contains market category information which allows for improved conversions from landed to live weight. The two data sources produce the same trends in landings, with general canvass landings slightly greater than weigh-out landings. It is not known which of the two measures more accurately reflects landings, but the additional data sources suggest that the general canvass is most reliable for 1964-1981 landings, whereas the availability of market category details suggest that the weigh-out database is most reliable for 1982-1989.

Beginning in 1990, most of the extra sources of landings in the general canvass database were incorporated into the NEFSC weigh-out database. However, North Carolina reported landings of monkfish to the Southeast Fisheries Science Center and until 1997 these landings were not added to the NEFSC general canvass database. Since these landings most likely come from the southern management area, they have been added to the weigh-out data for the southern management area for 1977-1997 for the landings statistics used for stock assessment.

Beginning in July 1994, the NEFSC commercial landings data collection system was redesigned to consist of vessel trip reports (VTR) and dealer weigh-out records. The VTRs include area fished for each trip which is used to apportion dealer-reported landings to statistical areas. The northern management area includes statistical areas 511-515, 521-523 and 561; and the southern management area includes areas 525-526, 562, 537-543 and 611-636 (Figure A1). Each VTR trip should have a direct match in the dealer data base, but this is not always true. VTR records with no matching dealer landings were excluded, but dealer landings with no matching VTR were included in landings statistics, apportioning the unmatched landings to management area using proportions calculated from matched trips pooled over gear, state and quarter.

Total U.S. landings (live weight) remained at low levels until the middle 1970s, increasing less than 1,000 mt to around 6,000 mt in 1978 (Table A3, Figure A2). Annual landings remained stable at between 8,000 and 10,000 mt until the late 1980s. Landings increased from the late 1980s to over 20,000 mt per year 1992-2004, peaking at 28,500 mt in 1997. Landings have declined steadily since 2003, to 8,600 mt in 2009. By region, landings began to increase in the north in the mid-1970s, and began to increase in the south in the late

1970s. Most of the increase in landings during the late 1980s through mid-1990s was from the southern area. Historical under-reporting of landings shold be considered in the interpretation of this series.

Trawls, scallop dredges and gill nets are the primary gear types that land monkfish (Table A4, Figure A3). Trawls have contributed approximately half of the landings. Prior to 1994, gillnets contributed less than 10% of total landings, but landings from gillnets generally increased to account for >35% of the recent fishery, with an associated decrease in monkfish landings from the scallop dredge fishery.

Until the late 1990s, total landings were dominated by landings of monkfish tails. From 1964 to 1980 landings of tails rose from 19mt to 2,302mt, and peaked at 7,191mt in 1997 (Table A5). Landings of tails declined after 1997, but are still an important component of the landings. Landings of gutted whole fish have increased steadily since the early 1990s and are now the largest market category on a landed-weight basis. On a regional basis, more tails were landed from the northern area than the southern area prior to the late 1970s (Tables A6 and A7). From 1979 to 1989, landings of tails were about equal from both areas. In the 1990's, landings of tails from the south predominated, but since 2000, landings of tails have been greater in the north.

Beginning in 1982, several market categories were added to the system (Table A5). Tails were broken down into large (> 2.0 lbs), small (0.5 to 2.0 lbs), and unclassified categories and the liver market category was added. In 1989, unclassified round fish were added, in 1991 peewee tails (<0.5 lbs) and cheeks, in 1992 belly flaps, and in 1993 whole gutted fish were added. Monkfish livers have become a very valuable product. Landings of livers increased from 10mt in 1982 to an average of over 600mt during 1998 - 2000. During 1982-1994, ex-vessel prices for livers rose from an average of $0.97/lb to over $5.00/lb, with seasonal variations as high as $19.00/lb. Landings of unclassified round (whole) or gutted whole fish jumped in 1994 to 2,045mt and 1,454mt, respectively; landings of gutted fish continued to increase through 2003. The tonnage of peewee tails landed increased through 1995 to 364mt and then declined to 153mt in 1999 and 4mt in 2000 when the category was essentially eliminated by regulations.

Foreign Landings

Landings (live wt) from NAFO areas 5 and 6 by countries other than the US are shown in Table A3 and Figure A2. Reported landings were high but variable in the 1960s and 1970s with a peak in 1973 of 6,818mt. Landings were low but variable in the 1980s, declined in the early 1990s, and have generally been below 300mt in recent years.

Discard Estimates

Catch data from the fishery observer and VTR databases were used to investigate discarding frequencies and rates. The number of trips with monkfish discards available for analysis varied widely among management areas and gear types (Table A8). In the previous assessment (NEFSC 2007a), three methods were considered for the estimation of discards: 1) observed discard-per-kept-monkfish expanded to total discards using total monkfish landings; 2) observed discard-per-all-kept-catch expanded to total discards using total landings (Rago et al. 2005, Wigley et al. 2007); and 3) observed discard-per-days-absent expanded to total discards using total days-absent (Rago et al. 2005, Wigley et al. 2007). All three methods were done on a gear, half-year and management area basis. The effort-based method (#3) was considered inappropriate, because much of the monkfish is bycatch taken incidentally or targeted on a tow-by-tow basis rather than on a trip basis. Predicting discards using kept catch assumes a linear relationship between kept and discarded catch and no discarding when there is no catch (i.e., the linear relationship passes through the origin). Inspection of the relationship between observed monkfish discards and monkfish kept (method #1) and total catch (method #2) by gear and year indicated weak correlation in general, but the relationships between kept and discarded monkfish (method #1) for trawls and gillnets conformed to the statistical assumptions best (NEFSC 2007a). Therefore, discard estimates were based on discard-to-kept-monkfish for trawls and gillnets but were based on discard-per-all-kept-catch for shrimp trawls and dredges, which do not currently target monkfish. This method, (NEFSC 2007a) was continued in the current assessment.

Discards for 1980-1988 (before observer sampling) were estimated by applying average discard ratios by management area and gear type (trawl, shrimp trawl, gillnet, dredge) from 1989-1991 to landings for 1980-1988. If insufficient samples were available, additional years of observer data were included until a sample size (number of trips) of at least 20 was reached. The resulting time periods entering the 1980-1988 discard ratio estimates were as follows:

Area	**Shrimp Trawls**	**Trawls**	**Gillnets**	**Dredges**
North				
Years included	1989-1991	1989-1991	1989-1991	1992-1997
Number of trips	124	180	852	20
South				
Years included	n/a	1989-1991	1991-1992	1991-1993
Number of trips		231	103	30

The overall annual discard ratio (discarded monk / kept monk) decreased in the northern area, from an average of 16% of total catch in the 1980s to an annual average of 8% during 2002-2006, but was slightly higher on average (~10%) during 2007-2009 (Table A9, Figure A4). The proportion of discards in the southern area generally increased since 1980, with an annual average of 23% during 2002-2006, but a slight decrease during 2007-2009 (to ~14%) (Table A9, Figure A5). Gill nets consistently have had the lowest discard ratios. Some of the trends in discarding may reflect imposition of size limits starting in 2000 and decreased trip limits in the south starting in 2002. The DPSWG (NEFSC 2007a) noted a potential bias in discard estimates due to increased observer sampling in the multispecies groundfish fishery. Monkfish discard rates may differ between the directed monkfish fisheries and bycatch fisheries. The most frequent discard reasons were that fish were too small for regulations or the market. The estimates of total catch for 1980-2009 are shown in Figure A6 and Table A10.

Size and Age Composition of U.S. Catch

Tail lengths were converted to total lengths using relations developed by Almeida et. al.(1995). As in NEFSC (2007a), length composition of landings and discard were estimated from fishery observer samples by management area, year, gear-type (trawls, dredges and gillnets) and catch disposition (kept or discarded; Figures A7 – A13). Observer sampling data for December 2009 were not yet available, so the sample set for 2009 is incomplete. Landings in unknown gear categories were allocated proportionately to the 3 major gear types before assigning lengths. The stratification used for assigning lengths within area and gear type for

2007-2009 is shown in Table A11. Discards were generally between 20-40 cm, while kept fish were greater than 40 cm; however, there were some exceptions to this pattern in recent years.

Age composition of the catch was not estimated for 2007-2009 due to uncertainties in the aging method that were highlighted during the previous assessment (NEFSC 2007a) and because the operational model for monkfish (SCALE) is length-based.

Effort and CPUE

Evaluating trends in effort or catch rates in the monkfish fishery is difficult for several reasons. Much of the catch is taken in multi-species fisheries, and defining targeted monkfish trips is difficult. There have been programmatic changes in data collection from port interviews (1980-1993) to logbooks (1994-2009), and comparison of effort statistics among programs is difficult. Catch rates may not reflect patterns of abundance, because they have been affected by regulatory changes (e.g., 1994 closed areas, 2000 trip limits, 2006 reductions in trip limits). However, evaluation of catch rates (kept + discarded) from observed tows that caught monkfish in the NFMA showed a peak in 2003 in the trawl fishery and in 2005 in the gillnet fishery, probably reflecting the strong 1999 yearclass. CPUE has since declined in the north (Figure A14). In the SFMA, CPUE indices have been relatively flat in the trawl and dredge fisheries for the past decade; however, gillnet indices increased steadily during 1999-2004, and have since held steady or declined slightly (Figure A14).

TOR 2. Report results of 2009 cooperative monkfish survey and describe sources of uncertainty in the data and results.

Methods - 2009 Monkfish Cooperative Survey

Survey Design and Protocols

The survey used a stratified random design with allocation proportional to stratum area (n=175 planned tows). An additional 35 tows (~17% of the total) were randomly selected in strata selected by industry members. In previous monkfish cooperative surveys (2001, 2004), sampling effort was allocated according to fishing effort patterns; however, this led to problems with interpretation of the 2004 survey which experienced extensive weather delays. Allocation of sampling effort using stratum area in 2009 addressed this concern and provided a basis for more direct comparison with the NEFSC 2009 spring survey conducted on the *FSV Henry Bigelow*.

Standard operating procedures were used on each vessel, including 30 minute tows (from time winches locked to time winches re-engaged for haul back) at 2.5 knots designated speed. Tow paths followed the depth contour. If pre-determined locations could not be sampled (due to fixed gear, bad bottom, etc.), stations were relocated as close as possible at a similar depth. A standard scope ratio of 2* tow depth plus 25 fathoms of wire was used for all nets.

The location of successful survey tows is shown in Figure A15. All survey tows were completed during Feb. 10 – Apr 26, 2010.

Ships and Gear

Two monkfish trawl vessels were contracted for the survey, both out of New Bedford. The *FV Endurance* (“ER”, 107 ft. stern trawler) sampled primarily the northern monkfish management area (U.S. waters of the Gulf of Maine and northern portion of Georges Bank) using two nets, one fitted with a cookie sweep for soft bottom, and one with roller gear for hard bottom (Figures A16 and A17). Both nets had a tickler chain (38 m of 3/8” chain). The *FV Mary*

K ("MK", 96 ft. stern trawler) sampled in the southern management area (southern portion of Georges Bank and middle Atlantic Bight) using a net with a cookie sweep (Figure A18).

Sensor packages (Furuno on *Endurance*, NorthStar on *Mary K*) collected streams of data during each tow which included course over ground, speed over ground, GPS location (latitude, longitude), wingspread, bottom contact, depth and temperature. All types of data were not successfully collected for each tow. The number of tows with each type of sensor data is shown in Table A12 for each net type. Due to difficulties with obtaining wingspread measurements on the *Mary K* net, a set of dedicated mensuration tows were conducted to develop depth-wingspread relationships for the *Mary K*.

Analysis

Monkfish population estimates (biomass, numbers) were developed by estimating area swept during sampling in each stratum, converting this to monkfish density (kg, number caught per area swept), multiplying density by stratum area for each stratum, and summing over strata to derive total biomass and population size of monkfish in the two monkfish management areas. Population estimates were made using winch lock and winch re-engage to define tow duration ("nominal tow") or using sensor data to define tow duration ("sensor tow"). Nominal and sensor tow population estimates were generated under different assumptions of net capture efficiency.

Area Swept Population Estimates

Area swept by each tow was calculated as

$$AS = TDis * WS$$

where

$$TDis = TDur * \overline{SOG}$$

and

AS = area swept (nmi^2)

$TDis$ = distance covered by each tow in nmi

WS = wing spread in nmi

$TDur$ = tow duration (nominal or sensor)

SOG = speed over ground during tow

To estimate population biomass and number, we calculated monkfish densities in each stratum as the sum of the numbers caught divided by the sum of the area swept. Biomass in each stratum was estimated as the product of number of fish and mean weight of fish in the stratum. Biomass and numbers were summed over strata to arrive at minimum biomass and population size. Biomass and population size were also estimated under two assumptions regarding net efficiencies.

$$N = \sum_h n_h$$

$$B = \sum_h n_h * \overline{w}_h$$

where

$$n_h = \left(\sum (n_i / c_j) / \sum a_i\right) * A_h$$

and

N= population size
B= biomass
n_h= number in stratum h
$\overline{w}_h$ = mean weight in stratum
i=tow number
c_j=efficiency of net j (proportion retained)
a_i=area swept during tow i
A_h=total area of stratum h

We used tows that had good quality sensor data to develop estimates of sensor tow data from nominal tow data, as follows:

To develop wingspread estimates for MK cookie, we applied a regression of wingspread against tow depth (Figure A19) developed from the mensuration experiments. Bottom contact readings were used to define the start of the tow, and winch re-engage (nominal stop time) was used to define the end of the tow; this generally coincided with tow end defined by bottom contact indicators because of the use of a separate winch engine on the Mary K. The deepest station for which we had wingspread measurements was 271 m. Approximately 13 % of stations were deeper than this (max. 480 m). Therefore we assumed a wingspread at 400 m equal to the average for tows greater than 200 m (n=4); this caused the predicted wingspread to decline at greater depths as would be expected (Weinberg and Kotwicki 2008).

A similar approach was used for ER tows that had no wingspread readings, except that bottom contact data were used to define the end of the tow as well as the beginning. For ER cookie, there were only 4 tows with both bottom contact and wingspread measurements, therefore we used wingspread during the nominal tow time to develop the depth-wingspread relationship (Figure A20). We used senor tow durations for the ER roller net, however, the relationship with depth was very similar to that derived from nominal tow times (Figure A20).

To develop tow duration for tows with no bottom contact sensor data, we adjusted tow duration according to relationships between depth and the relative difference between nominal and senor-defined tow durations (Figure A21). This relationship was relatively tight for the MK cookie sweep (r2=0.80), but much weaker and of smaller magnitude for the ER roller gear. Too few tows were available for the ER cookie sweep to estimate a relationship between nominal and sensor tow durations, so we applied the relationship for ER roller to ER cookie. The reason for the negative slope for MK cookie was that most sensor start times were after nominal start times, but sensor end times coincided with nominal end times, so sensor tows were generally shorter than nominal tows. For the ER, sensor start and end were both generally after nominal start and end (Appendix A2).

The following table summarizes the corrections applied to derive sensor tow durations and wingspread estimates for tows lacking sensor data.

Net	Wingspread predicted from	Sensor tow duration predicted from
MK Cookie	depth-wspread relation - MK cookie sensor data	depth-% difference relation - MK cookie sensor data
ER Cookie	depth-wspread relation - ER cookie nominal data	depth-% difference relation - ER roller sensor data
ER Roller	depth-wspread relation - ER roller sensor data	depth-% difference relation - ER roller sensor data

An additional adjustment was made to average tow speed for tows with no bottom contact data using relationships between nominal tow speed and tow speed during the sensor-defined tow period (Figure A22). This resulted in slower average tow speed during sensor-defined tows on the Endurance because speed dropped abruptly after winch lock, but bottom contact continued for a short period, thus bringing down the average speed for sensor tows. This pattern was not seen on the *Mary K*, which has an independent winch engine, thus nominal and sensor tow end occurred at the same time.

Net Efficiency

Depletion experiments were used to estimate efficiency of the 3 nets in capturing monkfish. The experiments were done by repeatedly towing over the same tow path, always in the same direction, until the monkfish catch approached zero. Eight depletion experiments were completed (4 for the *Mary K* cookie sweep, and 2 for each of the Endurance nets). The method used for data analysis is described in Rago et al. (2006). The location of the depletion experiments is shown in Figure A23.

Results

A total of 204 survey stations were successfully completed, and an additional 91 tows were made for depletion experiments and mensuration studies (Table A13). Figures A24-A26 show nominal catch rates (kg per tow, # per tow) for the survey stations. Figure A27 shows the depth distribution of sampling locations for survey tows.

Net Efficiency

The efficiency estimates derived from the depletion experiments are summarized in Table 14. For detailed description of the net efficiency analysis and results, see Appendix A1.
For three of the efficiency experiments, the estimation procedure was not successful (Appendix A.1) and the results were excluded from further analysis. Net efficiencies used to estimate population biomass and numbers were the average of experiments 1, 3, and 4 for the *Mary K* cookie sweep and experiments 5 and 7 for the *Endurance* cookie sweep. For the *Endurance* roller sweep, there were no successful experiments, so the results of experiments conducted during the 2001 cooperative survey comparing roller and cookie sweeps were used. These experiments found that the roller was 92% as efficient as the cookie sweep. We therefore used the average efficiency of the *Endurance* cookie sweep 0.249 * 0.92 = 0.229 as the efficiency of the 2009 net with roller gear. The efficiency estimates, called 'intermediate' in this report to correspond with earlier cooperative survey reports which additionally reported estimates based on a range (low and high) of efficiency estimates.

Population Estimates

Swept-area population point estimates are shown in Table A15 and Figure A29, and were on the order of 114-116 thousand mt (60-62 million fish) for the entire survey area assuming intermediate net efficiencies. Minimum estimates showed approximately 30% of the stock in the northern management area (which contains 42% of the survey area).

Differences between estimates derived from sensor tow durations were slightly higher (~8 %) than nominal estimates in the north and slightly lower (~6%) in the south (Table A15). In the north, the differences can be attributed to slower average speeds and shorter tow durations for sensor tows, which reduced the estimate of area swept and increased the estimate of density (Figure A28). In the south, adjustments to average speed and tow duration essentially cancelled each other, resulting in little difference in tow distance between nominal and senor estimates. Sensor-derived monkfish densities were lower than nominal densities because wingspread estimates were higher in sensor tows, thus increasing area swept and decreasing the density estimate (Figure A28).

The point estimates of area swept population size and biomass for 2009 are lower than those estimated from the 2001 survey (Table A15, Figure A29), with the exception of the south for efficiency-corrected and sensor-based estimates. (The 2004 survey is difficult to interpret due to extensive delays in completing the survey due to weather, but the 2001 survey is more comparable to the 2009 survey in that the two management areas were sampled simultaneously and the survey completed during Feb-April). The lower estimates for 2009 are driven by consistently lower densities (nominal # per nominal nmi swept) in the NFMA (Figure A30), which could be related to earlier start dates in that area than in 2001 (Table A15). In the south, there is no consistent difference between stratum densities in 2001 and 2009; however, the overall density is slightly lower in 2009 (Figure A31). Densities in the mid-Atlantic Bight (Hudson Canyon area and south) are higher in the deep water strata (greater than 200 fa) in 2009 than in the previous two surveys, suggesting that more monkfish may have been in deep water at the time of the 2009 cooperative survey.

In addition to density differences among years, the proportion of zero tows is higher in 2009 than in the earlier surveys (Table A15). This may be due in part to the change in allocation of sampling effort in 2009 (Figure A32).

The coefficient of variation developed by bootstrapping for the 2009 area swept population estimates was very low (Figure A33). This likely underestimates the true variance because of the relatively small number of tows in each stratum (and thus a small number to be drawn from in the bootstrapping).

Further bootstrapping analyses were used to compute the sampling distribution of biomass estimates in each management area from the 2001, 2004 and 2009 cooperative surveys using each of the valid depletion experiments within each year. Average monkfish density by management area was estimated from 1000 bootstrap samples. The distribution of efficiency estimates for each experiment was developed from 1000 bootstrap samples of the 95% confidence interval for the mean efficiency for each experiment. Each bootstrapped realization of density was divided by the corresponding bootstrapped efficiency estimate to develop 1000 estimates of population number, from which the mean and confidence intervals for each year, management area and experiment were derived. The estimated population numbers were converted to biomass using the mean fish weight for each year and management area. The resulting estimates are shown in Table A16.

Length, Age, Maturity

Expanded length frequencies from the cooperative survey (Figure A34) suggest a unimodal distribution in the north with the mode at around 35cm, and a bimodal distribution in the south with modes around 33 and 57 cm.

Samples were collected for aging studies but were not processed for this assessment due to uncertainty concerning validity of the aging method (NEFSC 2007a). However, a small number (n=25) of monkfish $\geq$ 80 cm were aged using the vertebral method for comparison with earlier samples (Figure A35).

Length-weight relationships for males and females from each management area are shown in Figure A36 and the parameters are listed in Table A17 along with parameters estimated from earlier studies. Maturation ogives are shown in Figure A37 and the parameters listed in Table A18 with estimates from earlier studies.

Comparison with NEFSC 2009 Spring Survey

The NEFSC spring survey was conducted during March 4 – May 8, 2010, generally proceeding from south to north. The spatial distribution of catches in the NEFSC survey was similar to catches from the cooperative surveys (Figure A38). Length frequencies from the NEFSC survey (Figure A39) reflect the gear's greater retention of smaller monkfish and lower overall catch rates (NEFSC total number of monkfish caught = 638, cooperative survey = 3,050). However, nominal minimum area swept estimates of biomass and population size were very similar for the northern area from the two surveys (Table A19). In the south, the estimates from the cooperative survey were approximately double those from the NEFSC survey for both biomass and population numbers.

Finding differences between results from the two surveys is not surprising because a number of operational characteristics differ. The NEFSC survey net has a codend liner with 1" mesh, while the cooperative survey nets used 6" mesh in the codend with no liner, thus the NEFSC survey captures smaller fish. The average tow speed was 3.1 kt during 20 minute tows (NEFSC) vs. 2.6 kt during 30-minute tows (Coop). Differences in net efficiency likely result from differences in the configuration of the net sweeps. In particular, the NEFSC survey net used roller gear for all tows whereas the cooperative survey net in the south used a cookie sweep which would be expected to tend bottom more closely and thus capture a higher proportion of the monkfish encountered. This may be important in the difference between surveys in estimates in the south. Finally, the cooperative survey sampled the southern Mid-Atlantic Bight in February, when monkfish are present across the shelf, while the Bigelow started a month later when monkfish have begun moving out of that area (Figure A40).

TOR 3. Characterize other survey data that are being used in the assessment (e.g., regional indices of abundance, recruitment, length data, state surveys). Describe the uncertainty in these sources of data.

Additional resource surveys used in the assessment include 2001 and 2004 cooperative monkfish surveys, NEFSC winter, spring and autumn offshore surveys, NEFSC scallop surveys (SFMA only), Northern Shrimp Technical Committee (NSTC) shrimp surveys (NFMA only), and ME/NH inshore surveys.

The NEFSC survey strata used to define the northern and southern management areas are:

Survey	Northern Area	Southern Area
NEFSC Offshore bottom trawl	20-30, 34-40	1-19, 61-76
NSTC Shrimp	1,3,5-8	
Shellfish		6,7,10,11,14,15,18,19,22-31,33-35,46,47,55,58-

NEFSC spring and autumn bottom trawl survey indices were standardized to adjust for statistically significant effects of trawl type (Sissenwine and Bowman 1977) on catch rates. The trawl conversion coefficients apply only to the spring survey during 1973-1981.

NEFSC indices derived from surveys on the FSV Henry Bigelow (starting spring 2009) were adjusted using calibration coefficients estimated during experimental work (Miller et al. 2009). The FSV *Henry B. Bigelow*, which became the main platform for NEFSC research surveys in spring 2009, has significantly different size, towing power, and fishing gear characteristics than the previous survey platform (*Albatross IV)*, resulting in different fishing power and catchability for most species. Calibration experiments to estimate these differences were conducted during 2008 (Brown 2009, NEFSC 2007b), and were peer reviewed by a Panel of three non-NMFS scientists during the summer of 2009 (Anonymous 2009). The objective was to develop specific protocols for guidance in the selection and use of appropriate estimators based on the amount of data available and the relative performance of two candidate estimators. The Panel developed general guidance on which estimator to use given sample sizes for each species. Following these guidelines, monkfish catches were converted using a simple ratio estimator without a seasonal (spring vs. fall) correction. The coefficients for monkfish were 7.1295 for numbers and 8.0618 for weight (kg) (Anonymous 2009; Miller et al. 2009).

Geographic distributions of survey catches are shown in Figures A40 to A42.

Northern Area

Indices from NEFSC autumn research trawl surveys indicate that biomass fluctuated without trend between 1963 and 1975, appears to have increased briefly in the late 1970's, but declined thereafter to near historic lows during the 1990's (Table A20, Figures A43 – A44). From 2000 to 2003, the index was greater than 2 kg/tow, but decreased to less than 1 kg/tow by 2008. Indices from the NEFSC spring research trawl surveys reflect similar trends of relatively high biomass levels in the mid 1970s (but with possible declines in the late 1970s), a declining trend from the early 1980s to the lowest values in the time series in 1998 an increase to relatively high biomass from 2001 to 2005, and somewhat lower levels since then (Table A21, Figures A43 and A45).

Abundance indices declined during the early 1960s, and then fluctuated without trend until the late 1980s. Abundance increased steadily from the late 1980s to a peak in 1994, declined during the late 1990s, and then peaked in 2000, reflecting a relatively strong 1999 yearclass. Abundance has declined steadily since 2000, but remains high relative to the earlier part of the time series.

Length distributions have become increasingly runcated over time (Figure A48). By 1990, fish greater than 60 cm long were uncommon in length frequency distributions. The minimum, median and maximum lengths in the trawl surveys declined steadily from the early 1980s until around 2000, when they began to increase again (Figure A49). Several modes potentially representing strong yearclasses have appeared consistently in survey distributions in recent years (Figures A48, A50).

Abundance indices were estimated for monkfish of lengths corresponding to ages 1 and 2 to help identify potential recruitment patterns (Figure A51). To the extent that these indices reflect recruitment, recruitment in the northern area has increased in the past decade. Relatively strong yearclasses were produced in 1993 and 1999. Survey abundance at age data (available since the mid 1990s) corroborates the suggestion of relatively strong 1993 and 1999 yearclasses in the northern area. Survey age data are available for 1993-2006 from the autumn trawl survey and for 1995-2006 for the spring trawl survey (NEFSC 2007a). Within the range of ages observed in the surveys, growth is essentially linear and there are no obvious differences with gender or management area. Other surveys which catch monkfish in the northern area include the ASMFC shrimp survey, the Massachusetts Division of Marine Fisheries fall and spring surveys, and ME/NH inshore surveys. These surveys sample only a portion of the stock area and may be affected by inconsistent coverage over time.

The shrimp survey samples the western Gulf of Maine during summer and caught more monkfish than the spring or fall surveys prior to 2009 (when the FSV Bigelow survey series began) (Table A22, Figures A43 and A46). Patterns of abundance and biomass have been relatively consistent among the spring, fall and shrimp surveys (NEFSC 2007a). The Massachusetts surveys catch few monkfish and were not considered to reflect patterns of abundance for the entire management area; therefore are not reported in the assessment (NEFSC 2007a). ME/NH inshore surveys began in 2000 and are conducted in spring and fall (Figure A47). Indices show similar trends to those from NEFSC and shrimp surveys (Table A23, Figure A43 and A.46).

Southern Area

Biomass indices from the NEFSC autumn research survey were high during the mid-1960s, fluctuated around an intermediate level during the 1970s-mid 1980s, then declined to consistently low levels since the late 1980s (Table A24, Figures A52 and A53). The biomass index increased slightly above the existing biomass threshold in 2001 and has been relatively stable, or declining slightly since then. NEFSC spring surveys reflect similar trends as the autumn series: biomass remained fairly high during the mid 1970s - early 1980s, but fluctuated around lower levels thereafter (Table A25, Figures A52 and A54). A spike in biomass was observed in 2003, but subsequent indices have returned to lower values. Biomass and abundance indices based on the NEFSC winter flatfish survey (conducted during 1992-2007) fluctuated without trend (Table A26, Figures A52 and A55). Although the winter survey series had a short duration, the gear used in the winter survey was more effective for capturing monkfish than the gear used in autumn or spring surveys. Abundance indices based on the NEFSC sea scallop survey show an increasing trend during 1984-1994 followed by a rapid decline from 1994-1998 and fluctuations around a relatively level during 2006-200 (Table A27, Figure A56).

Inconsistent geographic coverage should be considered in the interpretation of southern survey indices. For example the fall survey did not sample southern strata until 1967. The winter survey sampled Georges Bank inconsistently and did not sample deep strata before 1998. The scallop survey does not currently sample the entire southern management area.

Abundance (numbers per tow) shows trends similar to biomass, with a spike in 1972, fluctuations around a relatively low level since the mid-1970s, a slight increase in 2002 and 2003 followed by a return to lower levels. Length distributions from the southern area showed increasing truncation over time, but the size distribution appears to have stabilized in recent years (Figure A57). Maximum lengths declined by approximately 20 cm or more over the time series (Figure A58). As in the northern area, fish greater than 60 cm have been rare since the 1980s, especially when compared to the 1960s. Any recent strong recruitment does not appear to survive long enough to contribute substantially to increased stock biomass. Survey age data are available for 1993-2006 from the autumn trawl survey, 1995-2006 for the spring trawl survey and 1997-2007 for the winter trawl survey (NEFSC 2007a). Age samples collected since the 2006 survey have not been processed due to uncertainties regarding validity of the aging method (NEFSC 2007a).

Combined Management Areas

Survey indices for combined management areas for spring and fall are shown in Table A28 and A29, and Figures A59 – A61. Length composition trends are shown in Figures A62-A63.

TOR 4. Estimate annual fishing mortality, recruitment and stock biomass (both total and spawning stock) for the time series, and characterize the uncertainty of those estimates.

Several candidate modeling approaches were investigated by the Data Poort Stocks Working Group (NEFSC 2007a), but the only one considered suitable was a relatively new approach called SCALE (for Statistical Catch-At-Length Analysis). Results from this model were used in 2007 to estimate fishing mortality, recruitment and stock biomass and to redefine reference points. The SCALE model was updated and serves as the primary basis for the current assessment.

Monkfish SCALE Model

Introduction

Incomplete or lacking age-specific catch data and survey indices often limit the application of a full age-structured assessment (e.g. Virtual Population Analysis and many forward projecting age-structured models). Stock assessments often rely on the simpler size/age aggregated models (e.g. surplus production models) when age-specific information is lacking. However these models may not utilize all of the available information for a stock assessment. Knowledge of a species growth and lifespan, along with total catch data, size composition of the removals, recruitment indices and indices on numbers and size composition of the recruited fish in a survey can provide insights on population status using a simple model framework.

The Statistical Catch At Length (SCALE) model, is a forward projecting age-structured model tuned with total catch (mt), catch at length or proportional catch at length, recruitment at a specified age (usually estimated from first length mode in the survey), survey indices of abundance of the larger/older fish (usually adult fish) and the survey length frequency distributions. The SCALE model was developed in the AD model builder framework. The model parameter estimates are fishing mortality and recruitment in each year, fishing mortality to produce the initial population (Fstart), logistic selectivity parameters for each year or blocks of years and Qs for each survey index.

The SCALE model was developed as an age-structured model that does not rely on age-specific information on a yearly basis. The model is designed to fit length information, abundance indices, and recruitment at age which can be estimated by using survey length slicing. However the model does require an accurate representation of the average overall growth of the population which is input to the model as mean lengths at age. Growth can be modeled as sex-specific growth and natural mortality or growth and natural mortality can be modeled with the sexes combined. The SCALE model will allow for missing data.

Model Configuration

The SCALE model assumes growth follows the mean input length at age with predetermined input error in length at age. Therefore a growth model or estimates of the average mean length at age is essential for reliable results. The model assumes static growth and therefore population mean length/weight at age are assumed constant over time.

The SCALE model estimates logistic parameters for a flattop selectivity curve at length in each time block specified by the user for the calculation of population and catch age-length matrices or the user can input fixed logistic selectivity parameters. Presently the SCALE model cannot accommodate a dome shaped selectivity pattern.

The SCALE model computes an initial age-length population matrix in year one of the model as follows. First the estimated populations numbers at age starting with age-1 recruitment are normally distributed at 1 cm length intervals using mean length at age with the assumed standard deviation. Next the initial population numbers at age are calculated from the previous age at length abundance using the survival equation. An estimated fishing mortality (Fstart) is also used to produce the initial population. This F can be thought of as the average fishing mortality that occurred before the first year in the model. Now the process repeats itself with the total estimated abundance at age being redistributed according to the mean length at age and standard deviation in the next age (age+1).

This two step process is used to incorporate the effects of length specific selectivities and fishing mortality. The initial population length and age distribution is constructed by assuming population equilibrium with an initial value of F, called F_{start}. Length specific mortality is estimated as a two step process in which the population is first decremented for the length specific effects of mortality as follows:

$$N^*_{a,len,y_1} = N_{a-1,len,y_1} e^{-\left(PR_{len}F_{start}+M\right)}$$

In the second step, the total population of survivors is then redistributed over the lengths at age *a* by assuming that the proportions of numbers at length at age *a* follow a normal distribution with a mean length derived from the input growth curve (mean lengths at age).

$$N_{a,len,y_1} = \pi_{len,a} \sum_{len=0}^{L_\infty} N^*_{a,len,y_1}$$

where

$$\pi_{len,a} = \Phi\left(len+1 \mid \mu_a, \sigma_a^2\right) - \Phi\left(len \mid \mu_a, \sigma_a^2\right)$$

where

$$\mu_a = L_\infty\left(1 - e^{-K(a-t_0)}\right)$$

Mean lengths at age can be calculated from a von Bertalanffy model from a prior study as shown in the equation above or mean lengths at age can be calculated directly from an age-length key. Variation in length at age a = $\bullet_s^2$ can often be approximated empirically from the growth study used for the estimation of mean lengths at age. If large differences in growth exist between the sexes then growth can be input as sex-specific growth with sex-specific natural mortality. However catch and survey data are still fitted with sexes combined.

This SCALE model formulation does not explicitly track the dynamics of length groups across age because the consequences of differential survival at length at age a do not alter the mean length of fish at age a+1. However, it does realistically account for the variations in age-specific partial recruitment patterns by incorporating the expected distribution of lengths at age.

In the next step the population numbers at age and length for years after the calculation of the initial population use the previous age and year for the estimate of abundance. Here the calculations are done on a cohort basis. As in the previous initial population survival equation, the partial recruitment is estimated on a length vector.

$$N^*_{a,len,y} = N_{a-1,len,y-1} e^{-\left(PR_{len} F_{y-1} + M\right)}$$

second stage

$$N_{a,len,y} = \pi_{len,a} \sum_{len=0}^{L_\infty} N^*_{a,len,y}$$

Constant M is assumed along with an estimated length-weight relationship to convert estimated catch in numbers to catch in weight. The standard Baranov=s catch equation is used to remove the catch from the population in estimating fishing mortality.

$$C_{y,a,len} = \frac{N_{y,a,len}\, F_y\, PR_{len}\left(1 - e^{-\left(F_y PR_{len} + M\right)}\right)}{(F_y \;\; PR_{len}) + M}$$

Catch is converted to yield by assuming a time invariant average weight at length.

$$Y_{y,a,len} = C_{y,a,len} W_{len}$$

The SCALE model results in the calculation of population and catch age-length matrices for the starting population and then for each year thereafter. The model is programmed to estimate recruitment in year 1 and estimate variation in recruitment relative to recruitment in year 1 for each year thereafter. Estimated recruitment in year one can be thought of as the estimated average long term recruitment in the population since it produces the initial population. The residual sum of squares of the variation in recruitment • $(Vrec)^2$ is then used as a component of the total objective function. The weight on the recruitment variation component of the objective function (Vrec) can be used to penalize the model for estimating large changes in recruitment relative to estimated recruitment in year one.

The model requires an age-1 recruitment index for tuning or the user can assume relatively constant recruitment over time by using a high weight on Vrec. Usually there is little overlap in ages at length for fish that are one and/or two years of age in a survey of abundance. The first mode in a survey can generally index age-1 recruitment using length slicing. In addition numbers and the length frequency of the larger fish (adult fish) in a survey where overlap in ages at a particular length occurs can be used for tuning population abundance. The model tunes to the catch and survey length frequency data using a multinomial distribution. The user specifies the minimum size (cm) for the model to fit. Different minimum sizes can be fit for the catch and survey data length frequencies.

The number of parameters estimated is equal to the number of years in estimating F and recruitment plus one for the F to produce the initial population (Fstart), logistic selectivity parameters for each year or blocks of years, and for each survey Q. The total likelihood function to be minimized is made up of likelihood components comprised of fits to the catch, catch length frequencies, the recruitment variation penalty, each recruitment index, each adult index, and adult survey length frequencies:

$$\mathrm{L_{catch}} = \sum_{years}\left(l\,\mathrm{n}(Y_{\mathrm{obs,y}} + 1) - \ln\left(\sum_{a}\sum_{len} \mathrm{Y_{pred,len,a,y}} + 1 \right)\right)^2$$

$$L_{catch\_lf} = -N_{eff} \sum_{y}\left(\sum_{inlen}^{L_\infty}\left(\left(C_{y,len}+1\right)\ln\left(1+\sum_{a} C_{pred,y,a,len}\right) - \ln\left(C_{y,len}+1\right)\right)\right)$$

$$\mathrm{L_{vrec}} = \sum_{y=2}^{Nyears}\left(Vrec_y\right)^2 = \sum_{y=2}^{Nyears}\left(R_1 - R_y\right)^2$$

$$\sum L_{rec} = \sum_{i=1}^{Nrec} \left[\sum_{y}^{Nyears} \left(\ln\left(I_{rec_i, inage_i, y}\right) - \ln\left(\sum_{len}^{L_\infty} N_{y, inage_i, len} * q_{rec\,i} \right) \right)^2 \right]$$

$$\sum L_{adult} = \sum_{i=1}^{Nadult} \left[\sum_{y}^{Nyears} \left(\ln\left(I_{adult_i, inlen+_i, y}\right) - \left(\sum_{a} \sum_{inlen_i}^{L_\infty} \ln\left(N_{pred, y, a, len} * q_{adult\,i}\right) \right) \right)^2 \right]$$

$$\sum L_{lf} = \sum_{i=1}^{Nlf} \left[-N_{eff} \sum_{y} \left(\sum_{inlen_i}^{L_\infty} \left(\left(I_{lf_i, y, len} + 1\right) \ln\left(1 + \sum_{a} N_{pred, y, a, len}\right) - \ln\left(I_{lf_i, y, len} + 1\right) \right) \right) \right]$$

In equation L_{catch_lf} calculation of the sum of length is made from the user input specified catch length to the maximum length for fitting the catch. Input user specified fits are indicated with the prefix “in” in the equations. LF indicates fits to length frequencies. In equation L_{rec} the input specified recruitment age and in L_{adult} and L_{lf} the input survey specified lengths up to the maximum length is used in the calculation.

$$Obj\ \ fcn = \sum_{i=1}^{N} \lambda_i L_i$$

Lambdas represent the weights to be set by the user for each likelihood component in the total objective function.

Monkfish SCALE Model Configuration and Results

No new information on growth and natural mortality exists for this assessment. Growth, variation in mean length at age, and natural mortality (M=0.3) did not change from the assumptions used in the 2007 assessment (NEFSC 2007a). Mean and variance in monkfish length at age were estimated from industry-based surveys (2001 and 2004), and NEFSC winter, spring, and fall surveys for management areas combined (Table A30). No significant differences in growth were observed between the management units in the 2001 and 2004 cooperative surveys. The standard deviation for age 1 was 2.9; for older ages a standard deviation of 4.5 was assumed. The overall standard deviation on mean lengths at age was estimated directly from the age data. The oldest aged fish from surveys and commercial samples was age 12. Mean lengths at age for the older fish (10-12) was supplemented with data collected from a study of large monkfish (Johnson et al. 2008).

Age modes in the predicted length frequencies are seen for most ages due to the linear nature of monkfish growth and the model structure that uses a single annual growth time step (Appendix A1). The absence of a decline in growth with age in monkfish produces this process error in the SCALE model fits. This can be concealed by increasing the variance on mean lengths at age by increasing the assumed variance on the mean lengths at age. However, as in the 2007 assessment, an increase in the variance on the mean lengths at age beyond what is supported by the raw growth data was not done due to concerns on its effect on the estimated selectivity.

Relative abundance trends for recruits (ages 1, 2, and/or 3) and adults (40+ cm) in each management unit were updated and are shown in Figures A64 through A69. The length interval specific to each survey used as a proxy for the recruitment ages are shown in the plots. For both management units, the model was fit to spring, fall and industry-based survey length frequencies (30+ cm), 40+ cm adult indices, and recruitment indices at age. The northern area had additional inputs from a shrimp trawl survey (1991-2009) and the southern area used the NEFSC winter trawl (1992-2007) and NEFSC scallop dredge (1984-2009) surveys. Inputs from the fall inshore ME/NH trawl survey (2000-2009) were added to the northern management area in this assessment (Figures A70 and A71). The use of the Fall MDMF bottom trawl survey was also investigated in this assessment but was dropped as an index of abundance (Figure A72). The working group concluded that this index was unreliable for monkfish due to the low numbers of fish caught in the survey.

Indices at age and adult 40+ cm abundance indices were scaled using the approximate area (nm^2) of the survey divided by the average coverage of the survey's tow (Table A31). The survey catchability estimates from the model were used as a diagnostic check for the interpretation of survey efficiencies. Survey indices from the R/V Bigelow were converted to Albatross units for 2009 (numbers per tow / 7.2). An additional diagnostic run for each management area (north, south and combined) that included the absolute estimates of the cooperative monkfish 40+ cm estimates for all three years was investigated. An assumed 50 percent efficiently was used for the 2009 cooperative monkfish survey. The estimated q's from the model for the cooperative monkfish survey ranged from 0.68 to 1.18 but the model could not fit the large fluctuation in abundance between survey years (Figure A73).

There is no evidence of strong recruitment in the age-specific indices over the last three years (2007-2009). The 40+ cm indices also indicate a decline in abundance in comparison to the previous three years. There was little change in the survey and catch length frequency distributions since the 2007 assessment (Appendix A1).

In the 2007 assessment a single selectivity block (1980-2009) was estimated for the northern management unit and three selectivity blocks were estimated for the southern management unit. A single selectivity block for the north was retained for this assessment. Shifting the second selectivity block from 2003-2004 (2007 assessment) to 2001-2002 (current assessment) in the south provided a better fit to the catch length frequency data and corresponded better to the shift to gillnet gear in the fishery. The first selectivity block in the southern area (1980-1995) that was established in the 2007 assessment has only two years of length information and appears to produce unstable selectivity estimates in this assessment, therefore it was eliminated in the final southern run 8.

For the 2007 assessment a variety of conditions and assumptions were tested using sensitivity runs and a similar approach was taken for SARC 50. Comparisons of the configuration and results of the final and sensitivity SCALE runs for this assessment are shown in Tables A32 through A34 and Figures A74 through A80. The influence of three additional years of data to the final configuration of the 2007 assessment was determined in run 1 in both the north and southern management areas. In the north run 2 determined the influence of adding both the ME/NH survey and the MA DMF survey. In runs 3 and greater the MDMF survey was dropped from the model. The model was allowed to estimate Fstart in runs 4 to 7 and runs 6 and 7 were done to test sensitivity to the Vrec (recruitment variation) penalty weight. In the south, runs 2 to 7 allowed estimation of Fstart; runs 3 to 5 also tested alternative selectivity blocks.

Similar to the 2007 assessment, models for both the north and south had difficulty in fitting the catch length frequency data in the last few years. Fits to the catch length frequencies can be seen Appendix A1. A significant decline in the catch has occurred in the last three years of the model. However there is no evidence of an increase in the number of larger fish in the catch or in any of the survey length frequency distributions from 2007 to 2009. The model could not reconcile the effects of a decline in catch with the lack of a corresponding shift in the length distributions. Sensitivity run 5 in the north and runs 6 and 7 puts higher weight on the length distributions in the model. This resulted in a lack of fit to the catch (Figure A80).

The sensitivity runs of the SCALE model produced similar trends in F and biomass. As in the 2007 assessment the trade-off between shifts in the estimated selectivity and other weighting components of the model still exist.

Combining the northern and southern areas into a single assessment model was investigated in this assessment. In general the combined assessment model results were intermediate between the northern and southern model runs (Figure A79). Combined biomass estimates approximated the sum for the two area runs.

The final working group model runs retained for the 2007 assessment assumed fixed parameters for Fstart (North at 0.01, South at 0.2). The northern area results suggested there were at least two strong recruitment pulses during the 1990s that fueled subsequent increases in the catch (Figures A75 and A80). These strong recruitment events were not evident in the south (Figures A78 and A80). The final northern run estimated lower abundance with a shift in selectivity to larger fish relative to the 2007 assessment. The northern final model estimated much lower abundance in the terminal year than what was projected from the 2007 assessment; 144,000 tons in 2007 versus 66,000 tons in the current assessment (Figure A75). The final model for the southern area estimated relatively low recruitment in the last five years (2005-2009) of the model. However biomass and F predictions were similar to estimates from the 2007 assessment. Recruitment, biomass and fishing mortality estimates from the current assessment final runs are listed in Table A35.

The estimates of total biomass from the SCALE model fall within the confidence intervals (25^{th}-75^{th} percentile) of biomass estimates from the cooperative surveys for 2001 and 2004 (Table A16); however, the 2009 estimates from the SCALE model are approximately double the absolute biomass estimates from the cooperative survey for 2009. The effect of the retrospective pattern in the SCALE estimates has not been factored into these comparisons.

Monkfish SCALE model Uncertainty

Assessment of monkfish is difficult because of the often-poor quality of data available. Survey data provide a long-term picture, but there is high variability in the survey trends due to the low numbers of fish caught in many of the surveys. Landings were historically under-reported and discard data were not available until relatively recently. Age samples were not taken in surveys until 1994 and from landings until 2000, and the landings are sparsely sampled for age even at present because removing vertebrae compromises product quality. Important aspects of monkfish biology are poorly understood, including stock structure and movement patterns, growth rates and longevity. Ageing methods have not been validated using known-age individuals. Effects of the process error within the model due to the linear growth trend are unknown. There is uncertainty surrounding the lack of an explanation for the consistent sex ratio patterns that occur with size in multiple surveys (Richards et al., 2008).

Given the litany of data limitations, it is not surprising that most of the assessment approaches applied were not successful during the 2007 Data Poor Stocks Working Group assessment. The SCALE model was considered useful at that assessment because it integrated the available information and the resulting estimates appeared reasonable (e.g. biomass estimates consistent with empirically-estimated biomass from industry-based surveys). This is still true in the current assessment. However, in this assessment substantial uncertainty remains surrounding the lack of evidence for rebuilding of the size structure with the observed decline in the catch.

Retrospective analyses suggest there is higher uncertainty with the northern management model relative to the southern management assessment (Figures A81 and A82). The northern model exhibits strong retrospective patterns in fishing mortality and stock size. If the fishing mortality estimated for 2009 is adjusted upward to account for the average retrospective underestimation of -66% for the 2002-2008 terminal years, the estimate for 2009 changes from 0.10 to 0.17. If the total biomass estimated for 2009 is adjusted downward to account for the average retrospective overestimation of +108% for the 2002-2008 terminal years, the estimate for 2009 changes from 66,062 mt to 31,761 mt. The model for the southern area exhibits moderate retrospective patterns in fishing mortality and stock size. If the fishing mortality estimated for 2009 is adjusted upward to account for the average retrospective underestimation of -13% for the 2002-2008 terminal years, the estimate for 2009 changes from 0.07 to 0.08. If the total biomass estimated for 2009 is adjusted downward to account for the average retrospective overestimation of +16% for the 2002-2008 terminal years, the estimate for 2009 changes from 131,218 mt to 113,119 mt. The model for the combined area exhibits intermediate retrospective patterns in fishing mortality and stock size with respect to the separate areas (Figure A83). Age specific retrospective adjustments using seven peels are summarized in Table A36.

Potential explanations for the lack of fit and/or retrospective pattern in the SCALE model are summarized in Table A37. The explanations deemed most likely to cause underlying problems with the model were (1) the growth model is incorrect (ie. growth is not linear with age) and (2) setting M=0.3 is inappropriate (ie. monkfish longevity may be greater than currently assumed).

Improvements to the SCALE model allow for estimation of within model uncertainty on fishery selectivity and stock numbers through the MCMC procedure. However, uncertainty in F could not be estimated with the MCMC for monkfish because fishing mortality is set equal to model results in the MCMC. Therefore all of the within model uncertainty is not accounted for in the MCMC results. The high uncertainty surrounding this assessment will be largely underestimated by within model uncertainty estimates and probably should not be solely used for the determination of the uncertainty in setting ABCs. As in the 2007 assessment, the results are dependent on the input mean lengths at age as an appropriate approximation for monkfish growth.

Spawning biomass is not output directly by the SCALE model, but was estimated as the product of population numbers at length (SCALE), maturity at length (Richards et al. 2008), weight at length (SCALE) and fraction female at length (based on data in Richards et al. 2008). The fraction female at length was estimated two ways: (1) using observed patterns of proportion female vs. length in the south and north (e.g. Richards et al. 2008) and (2) assuming sex ratio=50:50 up to 70 cm, then 100% female for fish $\geq$ 70 cm. Ogives were averaged to develop estimates for the combined stock areas. Trends in spawning biomass are shown in Figure A84.

> ***SAW50 Editor's note: The SARC50 panel acknowledged the high degree of uncertainty in estimates from the SCALE model due to data limitations, poorly understood monkfish biology (growth, natural mortality, stock structure), and the strong retrospective pattern in the northern area. The panel did not favor directly adjusting for the retrospective pattern. Despite the high uncertainty, the model was accepted, but with strong precautionary caveats.***

TOR 5. Update or redefine biological reference points (BRPs; estimates or proxies for B_{MSY}, $B_{THRESHOLD}$, and F_{MSY}; and estimates of their uncertainty). Comment on the scientific adequacy of existing and redefined BRPs.

Overfishing Reference Points

SAW 34 (NEFSC 2002) and Framework 2 of the Monkfish FMP established the overfishing definition as F_{max} and estimated it be equal to 0.2 for both management areas (assuming M=0.2). NEFSC (2007a) examined length-based and age-based YPR models and concluded that the length-based approach was not appropriate as it assumes a von Bertalanffy growth model which does not fit currently understood monkfish growth patterns. NEFSC (2007a) used the age-based YPR model to update the value of Fmax assuming M=0.3 and the current assessment updates this model again using revised selectivity patterns output from SCALE. F_{target} was not defined in the original monkfish FMP or in Framework Adjustment 2. The DPSWG (NEFSC 2007a) recommended that $F_{40\%}$ be used to define F_{target}.

Age-based YPR was calculated for each management region using the approach of NEFSC (2007a). This assumed a constant natural mortality M=0.3 and applied selectivity at age approximated from SCALE output selectivity at length for each area. Mean weights at age for the catch and stock were from SCALE output, and maturity ogives were from 2001 Cooperative Monkfish Survey data (NEFSC 2002), which were very similar to other estimates of maturity (Table A18, Figure A85). The estimates from NEFSC (2007a) and the current assessment are shown in Table A38. The difference in estimates for the two areas reflects differing selectivity of gillnets and trawls; more monkfish are landed using gillnets in the south than in the north. The differences between years reflect the changes in selectivity patterns estimated by the SCALE model.

Biomass reference points

Biomass reference points were developed by NEFSC (2007a) using results of the SCALE model. The recommended $B_{threshold}$ was the lowest observed value in the total biomass time series (1980-present) from which the stock has then increased (termed "B_{Loss}"), estimated in 2006 to be 65,000 mt in the north and 96,000 mt in the south. The recommended B_{target} was the average of total biomass for the time period (1980-present), estimated in 2006 to be 92,000 mt in the north and 123,000 mt in the south.

The 2010 assessment updated biomass reference points developed by NEFSC (2007a) based on results of the 2009 SCALE population model (Table A39). Using the current FMP definitions, updated estimates of $B_{threshold}$ are 41,238 mt of total stock biomass in the northern area and 99,181 mt in the southern area. Estimates of B_{target} (average of 1980-2006 estimates) are 62,371 mt of total stock biomass in the northern area and 120,292 mt in the southern area. Biomass reference points for the combined areas approximated the sum for the two existing management areas (i.e., relative scaling persisted). Using the current FMP definitions, the combined area estimate of $B_{threshold}$ is 159,715 mt (average of 1980-2009 estimates) and the combined area estimate of B_{target} (average of 1980-2009 estimates) is 208,190 mt.

Biomass reference points for New England groundfish stocks have recently been based on the long-term projected biomass corresponding to F_{MSY} or its proxy, which for monkfish would be F_{max}. In keeping with this practice, proposed total biomass targets (i.e., B_{max} at F_{max}) and thresholds (0.5*B_{max}) were calculated for monkfish for the northern, southern and combined areas (Table A39). Using this approach, proposed estimates of B_{target} are 52,930 mt in the northern area and 74,490 mt in the southern area, and estimates of $B_{threshold}$ are 26,465 mt in the northern area and 37,245 mt in the southern area. The combined area estimate of B_{target} 129,002 mt and the estimate of $B_{threshold}$ is 64,501 mt. The total catch produced from the long-term Btarget at the respective values of F_{max} (i.e., proxy for F_{MSY}), is 10,745 mt for the northern area, 15,279 mt for the southern area, and 25,943 mt for the areas combined.

All of the BRPs are based on results of the SCALE model (including F reference points from the YPR which uses selectivity curves estimated by SCALE), therefore the BRPs are subject to the same high level of uncertainty that surrounds the SCALE model results. The BRPs developed by NEFSC (2007a) were *ad hoc* and are problematic in that BRPs change with every update or modification of the model. Further, the results for the southern management area indicate that biomass approached overfished status in the mid-1990s even though F remained below F_{target}. This suggests that those BRPs were unreliable. The BRPs based on projected biomass at F_{max} are also subject to high uncertainty due to reliance on projections of SCALE model results and the high estimate of F_{max} due to the assumption of M=0.3 in the YPR model. The biomass reference points using the current method are much lower, which accounts for the more optimistic view of stock size relative to the biomass target and biomass threshold.

SAW50 Editor's note: The SARC50 panel recommended adoption of the biomass reference points based on "Bmax projected".

TOR 6. Evaluate stock status with respect to the existing BRPs, as well as with respect to updated or redefined BRPs (from TOR 5).

Based on the existing biological reference points from the 2007 stock assessment and the Monkfish Fishery Management Plan (FMP), monkfish would be considered not overfished with no overfishing occurring for both the northern and southern stock management areas (Figure A86, Table A39). In the northern area, the existing $B_{threshold}$ is 65,200 mt of total stock biomass and the existing $F_{threshold}$ is F_{max} = 0.31. The estimated 2009 northern area biomass is 66,062 mt, above the existing $B_{threshold}$; the estimated northern area F in 2009 is 0.10, below the existing $F_{threshold}$. In the southern area, the existing $B_{threshold}$ is 96,400 mt and the existing $F_{threshold}$ is F_{max} = 0.40. The estimated 2009 southern area biomass is 131,218 mt, above the existing $B_{threshold}$; the estimated southern area F in 2009 is 0.07, below the existing $F_{threshold}$.

The 2010 assessment has updated the biological reference points based on an updated yield-per-recruit analysis and the results of the SCALE length-tuned population model that incorporates multiple survey indices and catch data. Based on proposed reference points from these updated analyses, monkfish in both management areas are not overfished with no overfishing occurring (Figure A87). Using the current FMP definitions, updated estimates of

$B_{threshold}$ are 41,238 mt of total stock biomass in the northern area and 99,181 mt in the southern area. Estimates of B_{target} (average of 1980-2006 estimates) are 62,371 mt in the northern area and 120,292 mt in the southern area. Estimates of total biomass for 2009 are 66,062 mt in the northern area and 131,218 mt in the southern area, above B_{target} for both areas. The existing overfishing threshold is based on F_{max}, and this was retained in the 2010 assessment. The updated estimates of F_{max} are 0.43 per year in the northern area and 0.46 per year in the southern area. Estimates of current F (2009) are 0.10 per year in the northern area and 0.07 per year in the southern area, both less than the respective overfishing thresholds.

A combined stock area model was constructed to address a Research Recommendation from the 2007 assessment. Biomass reference points for the combined areas approximated the sum for the two existing management areas (i.e., relative scaling persisted). Using the current FMP definitions, the combined area estimate of $B_{threshold}$ is 159,715 mt of total stock biomass (average of 1980-2009 estimates) and the combined area estimate of B_{target} (average of 1980-2009 estimates) is 208,190 mt. The estimate of combined area total biomass for 2009 is 255,326 mt, above B_{target}. The combined area overfishing threshold based on F_{max} is 0.37. The combined area estimate of current F (2009) is 0.05, below the combined area overfishing threshold (Figure A88).

Biomass reference points for New England groundfish stocks have recently been based on the long-term projected biomass corresponding to F_{MSY} or its proxy, which for monkfish would be F_{max}. In keeping with this practice, proposed total biomass targets (i.e., B_{max} at F_{max}) and thresholds ($0.5*B_{max}$) were calculated for monkfish for the northern, southern and combined areas. Using this approach, proposed estimates of B_{target} are 52,930 mt in the northern area and 74,490 mt in the southern area, and estimates of $B_{threshold}$ are 26,465 mt in the northern area and 37,245 mt in the southern area (Table A39, Figure A89). The combined area estimate of B_{target} 129,002 mt and the estimate of $B_{threshold}$ is 64,501 mt. The total catch produced from the long-term B_{target} at the respective values of F_{max} (i.e., proxy for F_{MSY}), is 10,745 mt for the northern area, 15,279 mt for the southern area, and 25,943 mt for the areas combined.

The assessment results for monkfish continue to be uncertain due to likely under-reported landings and unknown discards during the 1980s and incomplete understanding of key biological parameters such as age and growth, longevity, natural mortality and stock structure. The population models for all areas exhibit retrospective patterns that are strongest for the 2002-2006 terminal years and weaker for the 2007-2008 terminal years. The retrospective patterns are strongest for the northern area, weakest for the southern area, and intermediate for the model of combined areas (Figures A81-A83). The BRPs are all based on output from the SCALE model, therefore the BRPs are also highly uncertain.

TOR 7. Evaluate monkfish diet composition data and its implications for population level consumption by monkfish.

Food habits were evaluated for monkfish as major a predator in the ecosystem. The total amount of food eaten and the type of food eaten were the primary food habits data examined. From these basic food habits data, diet composition, per capita consumption, total consumption, and the amount of prey removed by monkfish were calculated. Contrasts to total energy flows in the ecosystem and fishery removals of commercially targeted skate prey were conducted to fully address the Term of Reference.

Methods

To estimate mean stomach contents (S_i), the total amount of food eaten (as observed from food habits sampling) was calculated for each size class, temporal and/or spatial scheme. The denominator in the mean stomach contents (i.e., the number of stomachs sampled) was inclusive of empty stomachs. These means were weighted by the number of tows in a temporal and spatial scheme as part of a two-stage cluster design. Further background on food habits sampling protocols and these estimators can be found in Link and Almeida (2000). This sampling program was a part of the NEFSC bottom trawl survey program (Azarovitz 1981; NEFC 1988). Units are in g.

Estimates were calculated on an annual basis for each monkfish size class, temporal and spatial combination. The size classes were < and• 40 cm for Small (S) and Large (L) size classes, respectively and the areas were southern and northern management regions. Although the food habits data collections started quantitatively in 1973, collections for monkfish weren't initiated until 1977. Key diagnostics were the number of empty stomachs over time and mean length vs. mean stomach contents weight (with ± 95% CI), which were examined to identify any major outliers in the data and to ascertain any notable patterns in variance.

To estimate diet composition (D_{ij}), the amount of each prey item was summed across all monkfish stomachs. These estimates were then divided by the total amount of food eaten in a size class, temporal and spatial scheme, totaling 100%. These estimates are proportions and were only presented for those major prey comprising >85% of the total for each size class, temporal and spatial scheme.

The approach to calculating consumption followed previously established methods, using an evacuation rate model methodology. For further details, see Durbin et al. (1983), Ursin et al. (1985), Pennington (1985), Overholtz et al. (1991, 1999, 2000, 2008), Tsou & Collie (2001a, 2001b), Link & Garrison (2002), Link et al. (2002, 2006, 2008, 2009), Link & Sosebee (2008), Overholtz & Link (2007), Tyrrell et al. (2007, 2008), Link and Idoine (2009), Moustahfid et al. (2009a, 2009b), and NEFSC (2006, 2007a, 2007b, 2008). The main data inputs are mean stomach contents (S_i) for each monkfish size-time-space scheme i, diet composition (D_{ij}) where j is the specific prey of interest, and T is the bottom temperature taken from the bottom trawl surveys (Taylor et al. 2005). Estimates of variance about all input variables were calculated.

Using the evacuation rate model to calculate consumption requires two variables and two parameters. The per capita consumption rate, C_i is calculated as:

$$C_i = 24 \cdot E_i \cdot \overline{S_i}^{\gamma} \quad ,$$

where 24 is the number of hours in a day and the evacuation rate E_i is:

$$E_i = \alpha e^{\beta T} \quad ;$$

and is formulated such that estimates of mean stomach contents (S_i) and ambient temperature (T; here used as bottom temperature from the NEFSC bottom trawl surveys (Taylor et al. 2005)) are the only data required. The parameters • and • are set as values chosen from the literature (Tsou and Collie 2001a, 2001b, Overholtz 1999, 2000). The parameter • is a shape function is almost always set to 1. To estimate per capita consumption, the gastric evacuation rate method was used (Eggers 1977, Elliott and Persson 1978). The two main parameters, • and •, were set to 0.004 and 0.11 respectively based upon prior studies and sensitivity analyses (NEFSC 2007c, 2007d). From 1992 on (when individual weights were measured), a diagnostic of % daily ration was also calculated.

Once per capita consumption rates were estimated for each monkfish size class, temporal and spatial scheme, those estimates were then scaled up to an annual and stock wide basis, *C*:

$$C = 365 \cdot C_i \cdot N_i$$

where N_i is the estimate of abundance (from assessment results) for each monkfish size class, temporal and spatial scheme and 365 is the number of days in a year.

This total consumption was partitioned for the major prey items of monkfish by multiplying it by the diet composition of each prey (D_{ij}) to provide an estimate of prey removals. Both the total consumption and the amount of prey removed by each monkfish size class (and combined across sizes) are presented as metric tons year^{-1}. These were then summed for both areas.

To evaluate the consumptive demands of a monkfish and the predatory removals of monkfish in a broader ecosystem context, total consumption by monkfish was compared to the amount of energy flow for the entire ecosystem. The total energy flows were calculated in a recent energy budget (Link et al. 2006, 2008, 2009). Monkfish consumption is presented as a percentage of total energy flows in the ecosystem. In addition, the total amount of commercially targeted prey eaten by monkfish was compared to fishery landings to evaluate potential competition between monkfish and fisheries.

Results & Observations

- The amount of food consumed by monkfish was 0.005-0.02% of all energy flows in the system
- Monkfish comprised 2-6% of total consumption by all finfish in the ecosystem (1-4 % in N, 2-8% in S)
- Consumption by monkfish has changed over time, mainly as a function of abundance (Figure A90)
- Consumption has been more important at times, perhaps when other piscivore species were at lower abundances; monkfish has the potential to be one of the dominant piscivores in the ecosystem
- All diagnostics were within the normal range.

Summary

- Amount of food eaten and per capita consumption peaked in early 1980s in both management areas; this was due to the greater abundance of large monkfish in the population.
- Total, scaled consumption follows the peak in 1980s for both management areas and early 2000s for the northern stock
- Some subtle shifts in diet across size classes, decades and areas were observed, but this species is categorically piscivorous and is of the more notable piscivores in the ecosystem
- Monkfish is an ecologically important piscivore in the Northwest Atlantic ecosystem
- Lots of small, other fishes eaten by monkfish
- Monkfish consumption (C) was high relative to landings of some of its prey stocks (L):

- C ~ 20-50% of L: mackerel, herring, monkfish
- C ~ L: squids
- C > L: silver hake, skates

TOR 8. Develop and apply analytical approaches and data that can be used for conducting single and multi-year stock projections and for computing candidate ABCs.

a. Provide numerical short-term projections (through 2016). Each projection should estimate and report annual probabilities of exceeding threshold BRPs for F, and probabilities of falling below threshold BRPs for biomass. In carrying out projections, consider a range of assumptions to examine important sources of uncertainty in the assessment.

b. Comment on which projections seem most realistic, taking into consideration uncertainties in the assessment.

c. Describe this stock's vulnerability to becoming overfished, and how this could affect the choice of ABC.

SCALE model results and AGEPRO projections were used to evaluate stock trends during 2011-2016 fishing at Fthreshold and at proposed ACTs and ABCs assuming stochastic long-term recruitment. Projections assumed that F in 2010 would equal the estimated F in 2009 from the SCALE model. Projections for the northern management area (NMA) are the most likely to be unrealistic, given the uncertainty of stock status due mainly to the relatively strong retrospective observed since 2002. The southern management area (SMA) projections are the more likely to be realistic, given the moderate retrospective pattern observed for that area. The combined area projections are intermediate with respect to the current management areas, as the relative scaling of the two populations is maintained when the areas are combined in one model. The projections indicate that the northern area is the most vulnerable to overfishing or becoming overfished during 2011-2016 if total catches approach the proposed ABC, while the southern area is the least vulnerable (Table A40 to Table A42).

SAW50 Editor's note: The SARC panel acknowledged the high degree of uncertainty in the projections due to uncertainty in the starting conditions (output from the SCALE model).

TOR 9. Review, evaluate and report on the status of the SARC and Working Group research recommendations listed in recent SARC reviewed assessments and review panel reports. Identify new research recommendations.

SAW 34 (2002) Research Recommendations

***** indicates suggested candidates for deletion from the active Research Recommendations list.

1) Research should be continued to define stock structure, including genetic studies, reproductive behavior analyses, morphometric studies, parasite studies, elemental analyses, and studies of egg and larvae transport.
- *A genetic study is underway by a student at UMES using mtDNA. Results to date found genetic groupings but these are not spatially coherent (do not indicate stock separation).*

- A conventional tagging study ongoing by investigators at GMRI. Results to date: monkfish tagged in fall/winter in western Gulf of Maine and southern New England were later recaptured in Mid-Atlantic Bight (see Appendix A2). Future plans include tagging in other seasons and further to the south.

- A data storage tagging study underway, joint project of NOAA and GMRI. ~150 tagged monkfish released during 2009, no recaptures yet.

- An otolith elemental composition study is ongoing using otoliths collected during 2004 cooperative monkfish survey. Otoliths have been processed but further work has been stalled due to change in responsibilities of primary PI.

- Web site established to gather information on location of egg veils – launched spring 2007. http://www.nefsc.noaa.gov/read/popdy/monkfish/MonkfishEggveilReporting/

Results: very little response to date.

*2) The SARC recommends changing the overfishing definitions for monkfish. Research on yield per recruit for monkfish should examine the effect and possible causes of differential natural mortality rates by sex, methods to estimate gear selectivity, and the incorporation of discards.

- OF definition was changed in 2003 via Framework 2 based on results of SAW 34 and again in 2008 based on the results of NEFSC (2007a).

- NEFSC (2007a) assessment explored length-based and age-based YPR with estimates of gear selectivity from SCALE model, incorporated discards, and examined higher M to reflect shorter longevity of males. NEFSC (2007a) accepted age-based model with M=0.3, which was used to revise reference points.

*3) Surplus production modeling should continue with special emphasis placed on uncertainty in under-reported catches and population size prior to 1980.

- Bayesian surplus production was explored unsuccessfully for SAW 40 (2005) and NEFSC (2007a). The DPSWG concluded that long-term production models were inappropriate for status determination of monkfish because of the general lack of correspondence between reported catch and survey trends.

*4) Size selectivity studies should be conducted in the trawl fishery to investigate the potential effectiveness of minimum mesh size and shape regulations to reduce discards of undersize monkfish. Additionally, comparative studies of the size selectivity and catchability of trawls and gill nets should be undertaken in order to understand the differences in the numbers of large fish captured in the two gear types.

- A study using 12" diamond and square mesh was completed in 2006 (Raymond and Glass 2006). The study showed reduced catch rates of groundfish in the experimental nets compared to controls (6-6.5" mesh) and reduced discard of monkfish in the experimental nets. Monkfish was 35% of the catch (kg) in control nets and 73% in experimental nets. Discard of monkfish was reduced from 15% to 6%.

*5) Another cooperative survey for monkfish should be conducted in 2004.

- Additional cooperative surveys were conducted during 2004 and 2009. The new NEFSC survey gear is much more effective for monkfish than the previous survey gear, thus reducing the need for further cooperative surveys.

*6) Improved sampling rates (as observed in 2000-2001) for commercial landings should be maintained, which should eventually lead to an age-based assessment approach for this species.

- age sampling rates have been variable.

Observer sampling was considered more useful for monkfish by NEFSC (2007a).

NEFSC (2007a) raised concerns over the validity of ageing methods for monkfish.
7) Tagging studies should be considered as a basis to evaluate adult movement and rates of growth.
- *conventional tagging study ongoing by investigators at GMRI. Results to date: monkfish tagged in fall/winter in western Gulf of Maine and southern New England were later recaptured in Mid-Atlantic Bight (see Appendix A2). Future plans include tagging in other seasons and further to the south.*
- *estimates of growth from conventional tagging study to date are too imprecise to estimate growth rate accurately.*
- *Data storage tagging study underway, joint project of NOAA and GMRI. ~150 tagged monkfish released during 2009, no recaptures yet. Fish are being marked with OTC when released for age validation studies (reward is for return of entire fish plus tags).*
8) Spatial distribution of mature and immature fish and the potential effects of size limits on fishing behavior should be evaluated as a basis for advising on strategies to minimize catch and discard of immature fish.
- *not done*
9) Indices of abundance should be developed from industry "study fleets," including coverage from outside the depth and spatial range of the NEFSC research surveys.
- *not addressed*

SAW 40 Research Recommendations
*(1) An examination of the influence of fixed stations on the estimate of biomass from the cooperative research survey should be undertaken.
- *As part of the 2006 cooperative monkfish survey review, catch rates, average monkfish size and density were compared between industry stations and random stations. Inclusion of the industry stations was judged to have had minimal impact on the population estimates.*
*(2) An exploration of a geostatistical approach to estimate biomass from the cooperative survey would also be of value.
- *not done*
(3) There are some concerns with the ageing results. An ageing validation study should be undertaken to confirm the accuracy of catch at age estimates.
- *Direct validation studies (e.g. tetracycline marking) have begun as part of a data storage tagging study, but no recaptures to date.*
- *SMAST UMass Dartmouth student working on age validation, developing tank studies (but difficult due to high mortality of captive monkfish).*
- *Indirect criteria have been satisfied (Armstrong et al. 1992)*
*(4) The changes in the distribution in the fishery over time may be influencing the results of the assessment. This should be examined more thoroughly.
- *this has not been addressed*.
*(5) The assessment lacks a reliable forecast. Since commercial catch-at-age data and survey catch-at-age data exist and assuming that ageing can be validated, alternative forward-projecting age structured models should be investigated.
- *a forward projecting length-tuned model (SCALE) was used to provide forecasts in the 2007 assessment and in the current assessment..*
*(6) An examination of transect survey data for changes in the distribution of the population by depth would be informative.

- not done

(7) Further, consideration should be given to a more complete treatment of the Canadian portion of this stock, with possibly some interaction with the team doing the assessment of monkfish in NAFO Divisions 4VWX5Zc, possibly through the TRAC process.

- not done. There is no longer a Canadian assessment scientist assigned to monkfish; however, we have estimated survey indices from Canadian surveys on the Scotian shelf, but not incorporated them into the model.

*(8) Ways of estimating of fishing mortality at age should be investigated. This could take the form of a general linear modeling approach with survey age and year effects in an analysis of Z. Alternatively a more fully specified population model based on survey-at-age data such as the RCRV1A model of Cook (1997) and recent developments described under SURBA may be applicable.

- SCALE model is being used to estimate mortality. Survey ages alone are too variable to reliably estimate Z due to low monkfish catch rates in surveys up through 2008. With the development of a time series on the FSV Bigelow, this approach may become viable in the future.

*(9) The cooperative survey should be continued as it is informative and can be used in the Bayesian surplus production model and may provide a means of calibrating the NEFSC survey data when the survey vessel is replaced.

- A cooperative survey was conducted in 2009. Results of the 2001 and 2004 surveys were used in the surplus production models, but the modeling approach still was not successful (see SAW 34, recommendation 3). The current assessment compares the 2009 cooperative survey with the NEFSC 2009 spring survey.

2007 Data-Poor Workshop, Research Recommendations

Working Group I

(1) Observer samples should be aged.

- *No further ageing has been done since NEFSC (2007a) due to questions raised about the validity of the current ageing method and because a length-based model for was adopted for the assessment.*

(2) Applications of the SCALE model for monkfish assessment should be developed further, including:

*a) Explore alternative growth functions (sigmoid etc.) since von Bertalanffy growth does not fit length-at-age data

- SCALE used mean length at age, not a growth function. At present, the only growth model that would be appropriate is a linear one.

*b) Explore changing weighting on catch in relation to reliability of catch data (more uncertainty in early part of time series)

-SCALE is not currently configured to be able to do this.

*c) Explore using the same M for males and females up to age 7, and then increasing M for males to account for the lack of males over age 7

-SCALE is not currently configured to be able to do this.

*d) Bin lengths into 2cm or 5 cm increments in order to eliminate zeros in survey length frequencies

-SCALE is not currently configured to be able to do this.

e) Develop independent estimates of selectivity for application to SCALE

-No new work has been done.

*(3) Length-based mortality:

-Examine effects of vonBertalanffy growth assumption on Gedamke-Hoenig mortality estimates.

- *not done, this method was not pursued because of the adoption of the SCALE model.*

Working Group II

*(1) Investigate foreign landings and reporting rates if possible.

- *not done, not clear what is being asked for here.*

(2) Examine aging further and develop tagging studies to validate M, growth rates and Longevity

- *studies are in progress, as described above*

(3) Estimate biomass by sex since age 6+ fish that are predominantly female appear to be decreasing in biomass at a greater rate

- *not done, but could be feasible as FSV Bigelow time series accumulates*

(4) SCALE model:

a) develop objective methods for weighting input series (e.g. inverse variance weighting)

- *not done*

b) do some runs with combined management areas

- *done for current assessment*

c) develop a two-sex model

- *explored in NEFSC (2007a), but problematic because males still remain in model after none are observed in reality*

d) incorporate cannibalism in SCALE model

- *not done*

(5) examine commercial sampling length modes in more detailed time steps (e.g. quarterly) to see if cohorts can be tracked (to indicate whether there are significant problems with aging).

- *not done.*

SAW 50 Southern Demersal Working Group Research Recommendations

1. Conduct a net efficiency experiment on the FSV Bigelow to help parameterize the population models for a range of species, including monkfish.

   SAW50 Editor's note: The SARC50 panel did not comment on the Research Recommendations.

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Tables

Table A1. Timeline of events influencing fishery management of monkfish.

Month/Year	Regulatory Action
Nov. 1999	FMP implemented - Included a multi-level limited access program; two management areas; target TACs; effort limitations (DAS); Year 3 default measures (0 DAS); trip limits for limited access vessels; bycatch allowances; minimum fish sizes; minimum mesh sizes; gear restrictions; spawning season restrictions; a framework adjustment process; annual review requirements; permitting and reporting requirements; and other measures for administration and enforcement.
Nov. 1999	Amendment 1 effective – EFH Omnibus Amendment
May. 2000	DAS implemented
Jul. 2000	SAW 31
Spring 2001	Cooperative Survey
Fall 2001	Hall v. Evans decision - trip limit on gillnet vessels set equal to trawls, based on permit category.
Jan. 2002	SAW 34
Spring 2002	Councils submit Framework 1 – Proposes to fix landings at existing levels and postpone default measures for 1 year while Councils develop Amendment 2.
May. 2002	Emergency Rule – Framework 1 disapproved for non-compliance with Fthreshold in the original plan (which was invalidated by SAW 31 and SAW 34). Implemented a revision to the OFD based on SAW 34 recommendations, and management measures in FW 1.
May. 2003	Framework 2 - Modified the OFD reference points recommended by SAW 34; established an index- and landings-based method for setting TACs to achieve annual rebuilding goals; contained a method for calculating DAS and trip limits; and eliminated the default measures.
Spring 2004	Cooperative Survey
May. 2005	Amendment 2 - Made minimum fish size in SFMA equivalent to that in NFMA (11-inch tail/17-inch whole); established a 6-inch roller gear restriction in the SFMA, implemented two canyon closure areas; removed the 20-day spawning block requirement; established a research set-aside program; established an Offshore Fishery Program in the SFMA; modified some incidental catch limits; and modified the monkfish limited entry program to include vessels that had historically fished off of VA and NC.
Spring 2007	Councils submit Framework 4 - Would establish target TACs, trip limits, and DAS requirements for final 3 years of rebuilding plan; would require use of DAS in NFMA; contains backstop measures if target TACs exceeded; would revise incidental catch limits for NFMA and scallop access areas; and would adjust boundary line applicable to Category H vessels.
May. 2007	Interim Rule - Tempoarily implemented target TAC, DAS, and trip limits recommended in Framework 4 for the NFMA (except does not include the at-sea declaration provision); continues FY 2006 target TAC, DAS, and trip limits for the SFMA; and prohibits the use of carryover DAS. Also temporarily implements other measures contained in Framework 4: Revision to border applicable to Category H vessels and revisions to incidental catch limits in NFMA and scallop access areas.
Autumn 2007	Framework 4 implemented.
Apr. 2008	Framework 5 - Adopted DPWG (2007) reference point definitions, tightened loopholes (e.g. reduced DAS carryover days allowed, tightened effort accounting methods)
Oct. 2008	Framework 6 - removed backstop provision of Framework 4.
2009-2010	Amendment 5 under development to implement ACLs and AMs, and set specifications of DAS, trip limits and other management measures to replace those adopted in Framework 4. Expected to be implemented May 2011.

Table A2. Management measures for monkfish 2000-2010 (note that regulations pertain to 'fishing years,' and do not correspond to the calendar year landings in Table A3). "NMA" and "SMA": Northern and Southern Management Areas.

Target TACs, trip limits, DAS restrictions, and landings (FY 2000 - FY 2010) for NMA

Fishing Year	Target TAC (mt)	Trip Limits* Cat. A & C	Trip Limits* Cat. B & D	DAS Restrictions**	Landings (mt)	Percent of TAC
2000	5,673	n/a	n/a	40	11,859	209%
2001	5,673	n/a	n/a	40	14,853	262%
2002	11,674	n/a	n/a	40	14,491	124%
2003	17,708	n/a	n/a	40	14,155	80%
2004	16,968	n/a	n/a	40	11,750	69%
2005	13,160	n/a	n/a	40	9,533	72%
2006	7,737	n/a	n/a	40	6,677	86%
2007	5,000	1,250	470	31	5,050	101%
2008	5,000	1,250	470	31	3,528	71%
2009	5,000	1,250	470	31		
2010	5,000	1,250	470	31		

* Trip limits in pounds tail weight per DAS

** Excluding up to 10 DAS carryover, became 4 DAS carryover in FY2008

Target TACs, trip limits, DAS restrictions, and landings (FY 2000 - FY 2010) for SMA

Fishing Year	Target TAC (mt)	Trip Limits* Cat. A & C	Trip Limits* Cat. B, D, & H	DAS Restrictions**	Landings (mt)	Percent of TAC
2000	6,024	1,500	1,000	40	7,960	132%
2001	6,024	1,500	1,000	40	11,069	184%
2002	7,921	550	450	40	7,478	94%
2003	10,211	1,250	1,000	40	12,198	119%
2004	6,772	550	450	28	6,223	92%
2005	9,673	700	600	39.3	9,656	100%
2006	3,667	550	450	12	5,909	161%
2007	5,100	550	450	23	7,180	141%
2008	5,100	550	450	23	6,751	132%
2009	5,100	550	450	23		
2010	5,100	550	450	23		

* Trip limits in pounds tail weight per DAS

** Excluding up to 10 DAS carryover, became 4 DAS carryover in FY2008

Table A3. Landings (calculated live weight, mt) of goosefish as reported in NEFSC weighout database (1964-1993) and vessel trip reports (1994-2009) (North = SA 511-523, 561; South = SA 524-639 excluding 551-561 plus landings from North Carolina for years 1977-1995); General Canvas database (1964-1989, North = ME, NH northern weighout proportion of MA; South = Southern weighout proportion of MA, RI-VA); Foreign landings from NAFO database areas 5 and 6. Shaded cells denote suggested source for landings which are used in the total column at the far right (see text for details).

	Weigh Out Plus NC			General Canvas				
Year	US North	US South	US Total	US North	US South	US Total	Foreign	Total
1964	45	19	64	45	61	106	0	106
1965	37	17	54	37	79	115	0	115
1966	299	13	312	299	69	368	2,397	2,765
1967	539	8	547	540	59	598	11	609
1968	451	2	453	449	36	485	2,231	2,716
1969	258	4	262	240	43	283	2,249	2,532
1970	199	12	211	199	53	251	477	728
1971	213	10	223	213	53	266	3,659	3,925
1972	437	24	461	437	65	502	4,102	4,604
1973	710	139	848	708	240	948	6,818	7,766
1974	1,197	101	1,297	1,200	183	1,383	727	2,110
1975	1,853	282	2,134	1,877	417	2,294	2,548	4,842
1976	2,236	428	2,663	2,256	608	2,865	341	3,206
1977	3,137	830	3,967	3,167	1,314	4,481	275	4,756
1978	3,889	1,384	5,273	3,976	2,073	6,049	38	6,087
1979	4,014	3,534	7,548	4,068	4,697	8,765	70	8,835
1980	3,695	4,232	7,927	3,623	6,035	9,658	132	9,790
1981	3,217	2,380	5,597	3,171	4,142	7,313	381	7,694
1982	3,860	3,722	7,582	3,757	4,492	8,249	310	7,892
1983	3,849	4,115	7,964	3,918	4,707	8,624	80	8,044
1984	4,202	3,699	7,901	4,220	4,171	8,391	395	8,296
1985	4,616	4,262	8,878	4,452	4,806	9,258	1,333	10,211
1986	4,327	4,037	8,364	4,322	4,264	8,586	341	8,705
1987	4,960	3,762	8,722	4,995	3,933	8,926	748	9,470
1988	5,066	4,595	9,661	5,033	4,775	9,809	909	10,570
1989	6,391	8,353	14,744	6,263	8,678	14,910	1,178	15,922
1990	5,802	7,204	13,006				1,557	14,563
1991	5,693	9,865	15,558				1,020	16,578
1992	6,923	13,942	20,865				473	21,338
1993	10,645	15,098	25,743				354	26,097
1994	10,950	12,126	23,076				543	23,619
1995	11,970	14,361	26,331				418	27,075
1996	10,791	15,715	26,507				184	26,978
1997	9,709	18,462	28,172				189	28,517
1998	7,281	19,337	26,618				190	26,866
1999	9,128	16,085	25,213				151	25,364
2000	10,729	10,147	20,876				176	21,052
2001	13,341	9,959	23,301				142	23,450
2002	14,011	8,884	22,896				294	23,189
2003	14,991	11,095	26,086				309	26,375
2004	13,209	7,978	21,186				166	21,352
2005	10,267	8,834	19,102				206	19,308
2006	6,672	7,906	14,578				279	14,857
2007	4,855	7,290	12,145				8	12,153
2008	4,013	6,940	10,953				2	10,955
2009	3,255	5,302	8,557					8,557

Table A4. U.S. landings of monkfish (calculated live weight, mt) by gear type.

	North					South					Regions Combined				
Year	Trawl	Gill Net	Scallop Dredge	Other	Total	Trawl	Gill Net	Scallop Dredge	Other	Total	Trawl	Gill Net	Scallop Dredge	Other	Total
1964	45	0			45	19				19	64	0			64
1965	36	0			37	17				17	53	0			53
1966	299	0		0	299	13			0	13	311	0		0	312
1967	532		8		539	8				8	540		8		547
1968	447		4		451	2				2	449		4		453
1969	253	1	4		258	4				4	257	1	4		262
1970	198	0		0	199	12				12	210	0		0	211
1971	213		0		213	10				10	223		0		223
1972	426	8	1	2	437	24				24	451	8	1	2	461
1973	661	29	12	8	710	132		5	1	137	794	29	17	9	848
1974	1,060	105	7	25	1,197	98			0	98	1,160	105	7	25	1,297
1975	1,712	123	10	9	1,853	265	0	2	2	269	1,990	123	12	10	2,135
1976	2,031	143	47	15	2,236	333		7	0	340	2,459	143	54	15	2,670
1977	2,737	230	142	28	3,137	508		57	26	591	3,487	230	202	53	3,973
1978	3,255	368	212	54	3,889	605	0	507	26	1,138	4,016	368	774	80	5,238
1979	2,967	393	584	71	4,014	944	6	1,015	16	1,981	3,989	399	2,070	87	6,545
1980	2,526	518	596	56	3,696	1,139	10	1,274	7	2,429	3,723	528	2,276	62	6,589
1981	2,266	461	443	47	3,217	1,100	16	782	105	2,003	3,483	477	1,399	152	5,512
1982	3,040	421	367	32	3,860	1,806	12	1,507	27	3,352	4,998	433	2,061	60	7,551
1983	3,233	314	266	37	3,849	1,819	11	2,119	17	3,966	5,166	325	2,431	56	7,977
1984	3,648	315	196	43	4,202	1,714	15	1,704	18	3,452	5,513	330	1,968	61	7,871
1985	3,982	315	264	55	4,616	1,739	17	2,347	3	4,106	5,757	332	2,611	58	8,758
1986	3,412	326	553	36	4,327	1,841	32	2,068	12	3,954	5,318	358	2,621	48	8,345
1987	3,853	374	695	38	4,960	1,680	26	1,997	3	3,707	5,561	400	2,692	41	8,694
1988	3,554	304	1,172	36	5,066	1,828	58	2,594	3	4,483	5,399	363	3,765	39	9,567
1989	3,429	349	2,584	30	6,391	3,240	17	5,036	3	8,297	6,679	366	7,620	33	14,698
1990	3,298	338	2,141	25	5,802	2,361	32	4,744	5	7,142	5,697	372	6,885	30	12,984
1991	3,299	338	2,033	24	5,694	5,515	363	3,907	16	9,800	8,847	700	5,941	39	15,528
1992	4,330	359	2,211	24	6,923	6,528	977	6,409	11	13,925	10,860	1,336	8,619	35	20,850
1993	5,890	695	4,034	26	10,645	5,987	1,722	7,158	192	15,059	11,879	2,417	11,192	218	25,707
1994	7,574	1,571	1,808	86	11,039	5,233	2,342	3,995	556	12,126	12,707	3,884	5,759	638	22,988
1995	9,119	1,531	1,266	54	11,970	5,785	3,800	4,030	746	14,361	14,905	5,331	5,296	800	26,331
1996	8,445	1,389	913	45	10,791	7,141	4,211	4,330	33	15,715	15,586	5,599	5,243	78	26,507
1997	7,363	988	1,318	40	9,709	8,161	5,203	4,890	208	18,462	15,524	6,192	6,208	249	28,172
1998	5,421	885	948	27	7,281	7,815	6,198	5,190	134	19,337	13,236	7,083	6,138	161	26,618
1999	7,037	1,470	598	24	9,128	6,364	6,187	3,481	54	16,085	13,401	7,656	4,079	78	25,213
2000	8,234	2,102	316	76	10,729	4,018	4,005	1,975	150	10,147	12,252	6,107	2,291	226	20,876
2001	9,990	2,959	381	11	13,341	3,091	5,119	1,719	30	9,959	13,081	8,078	2,100	41	23,301
2002	10,839	2,978	181	13	14,011	1,584	5,410	1,847	43	8,884	12,423	8,389	2,028	56	22,896
2003	12,028	2,488	222	254	14,991	2,034	7,262	1,717	83	11,095	14,062	9,750	1,939	336	26,086
2004	9,918	2,866	14	411	13,209	1,228	4,605	671	1,474	7,978	11,145	7,471	685	1,885	21,186
2005	6,826	2,425	26	990	10,267	1,697	4,532	449	2,156	8,834	8,524	6,957	475	3,146	19,102
2006	4,997	1,434	33	208	6,672	1,458	3,832	377	2,238	7,906	6,455	5,265	411	2,446	14,578
2007	3,474	1,071	108	202	4,855	1,066	3,734	484	2,007	7,290	4,540	4,805	591	2,209	12,145
2008	3,048	755	19	191	4,013	1,002	3,949	360	1,629	6,940	4,050	4,705	379	1,820	10,954
2009	2,513	646	12	83	3,255	702	2,967	305	1,327	5,302	3,216	3,613	318	1,410	8,557

Table A5. Landed weight (mt) of monkfish by market category for 1964-2009 for combined assessment areas (SA 511-636), NEFSC weighout database and vessel trip reports (1994-2009).

Year	Belly Flaps	Cheeks	Livers	Gutted	Round	Dressed	Tails Unc.	Tails Large	Tails Small	Tails Peewee	All Tails
1964	0.0	0.0	0.0	0.0	0.0	0.0	19.3	0.0	0.0	0.0	19.3
1965	0.0	0.0	0.0	0.0	0.0	0.0	16.1	0.0	0.0	0.0	16.1
1966	0.0	0.0	0.0	0.0	0.0	0.0	93.9	0.0	0.0	0.0	93.0
1967	0.0	0.0	0.0	0.0	0.0	0.0	164.8	0.0	0.0	0.0	164.8
1968	0.0	0.0	0.0	0.0	0.0	0.0	136.6	0.0	0.0	0.0	136.6
1969	0.0	0.0	0.0	0.0	0.0	0.0	79.1	0.0	0.0	0.0	79.1
1970	0.0	0.0	0.0	0.0	0.0	0.0	63.5	0.0	0.0	0.0	63.5
1971	0.0	0.0	0.0	0.0	0.0	0.0	67.1	0.0	0.0	0.0	67.1
1972	0.0	0.0	0.0	0.0	0.0	0.0	139.0	0.0	0.0	0.0	139.0
1973	0.0	0.0	0.0	0.0	0.0	0.0	255.5	0.0	0.0	0.0	255.5
1974	0.0	0.0	0.0	0.0	0.0	0.0	390.7	0.0	0.0	0.0	390.7
1975	0.0	0.0	0.0	0.0	0.0	0.0	642.8	0.0	0.0	0.0	642.8
1976	0.0	0.0	0.0	0.0	0.0	0.0	802.2	0.0	0.0	0.0	802.2
1977	0.0	0.0	0.0	0.0	0.0	0.0	1194.4	0.0	0.0	0.0	1194.4
1978	0.0	0.0	0.0	0.0	0.0	0.0	1574.5	0.0	0.0	0.0	1574.5
1979	0.0	0.0	0.0	0.0	0.0	0.0	2224.7	0.0	0.0	0.0	2224.7
1980	0.0	0.0	0.0	0.0	0.0	0.0	2302.4	0.0	0.0	0.0	2302.4
1981	0.0	0.0	0.0	0.0	0.0	0.0	1654.2	0.0	0.0	0.0	1654.2
1982	0.0	0.0	10.2	0.0	0.0	0.0	2059.8	153.1	53.3	0.0	2266.2
1983	0.0	0.0	11.6	0.0	0.0	0.0	2009.9	241.4	138.6	0.0	2390.0
1984	0.0	0.0	25.0	0.0	0.0	0.0	2121.6	186.8	44.5	0.0	2352.9
1985	0.0	0.0	28.0	0.0	0.0	0.0	2467.0	86.7	73.4	0.0	2627.1
1986	0.0	0.0	36.3	0.0	0.0	0.0	2365.4	76.4	52.2	0.0	2494.0
1987	0.0	0.0	54.2	0.0	0.0	0.0	2463.7	139.9	6.7	0.0	2610.3
1988	0.0	0.0	112.8	0.0	0.0	0.0	2646.3	195.1	34.8	0.0	2876.2
1989	0.0	0.0	146.3	0.0	15.6	0.0	3501.8	557.4	360.0	0.0	4419.2
1990	0.0	0.0	179.7	0.0	217.7	0.0	2601.8	854.1	377.4	0.0	3833.3
1991	0.0	8.6	270.3	0.0	415.4	0.0	2229.1	1661.9	614.1	36.6	4541.6
1992	0.2	3.7	321.5	0.0	386.0	0.0	2778.7	1908.1	1293.0	183.3	6163.1
1993	0.0	1.7	459.9	98.2	528.7	0.0	3503.2	1933.0	1851.1	262.4	7549.8
1994	0.0	5.3	458.1	1453.6	2044.8	0.0	1256.9	2230.7	2063.3	258.0	5808.9
1995	2.3	1.0	497.0	2752.4	2652.4	0.0	879.7	2521.4	2422.6	363.3	6187.1
1996	0.4	0.6	569.5	3467.8	1063.1	0.0	1086.0	2090.1	3027.2	269.6	6472.9
1997	0.1	0.1	628.0	3193.7	795.2	0.0	673.6	3050.1	3274.0	151.5	7149.3
1998	0.0	0.5	605.9	3586.9	581.8	0.0	858.3	3006.8	2649.8	95.5	6610.4
1999	0.1	0.2	597.4	5748.1	1131.4	0.0	537.2	2388.3	2200.8	153.4	5279.8
2000	0.0	3.7	624.0	6914.1	1091.0	0.0	293.6	1580.0	1707.3	4.3	3585.1
2001	0.5	0.0	559.4	7028.2	531.4	0.0	345.3	1958.9	2140.3	0.4	4444.9
2002	0.2	0.1	508.7	7801.7	575.4	0.0	246.6	1683.9	2113.3	0.2	4044.0
2003	0.0	1.0	486.3	7322.8	680.9	0.0	337.1	2362.6	2437.4	0.7	5137.8
2004	0.3	2.1	410.7	3404.6	2026.0	7.8	188.6	2553.4	1853.9	1.5	4597.4
2005	0.0	54.9	373.5	3361.0	2334.3	17.7	107.4	2209.9	1564.7	3.7	3885.6
2006	0.1	108.4	312.1	2972.8	2002.0	21.4	77.4	1548.2	1125.8	3.3	2754.7
2007	0.0	43.7	271.2	2340.1	1478.2	12.3	96.5	1596.5	707.3	1.8	2402.0
2008	0.0	4.8	256.8	2138.9	1280.5	15.4	60.1	1502.5	607.1	0.0	2169.8
2009	0.8	0.0	199.1	1692.9	1119.5	19.4	47.8	1065.0	534.0	0.3	1647.1

Table A6. Landed weight (mt) of monkfish by market category for 1964-2009 for northern assessment area (SA 511-523 and 561), NEFSC weighout database and vessel trip reports (1994-2009).

Year	Belly Flaps	Cheeks	Livers	Gutted	Round	Dressed	Heads	Tails Unc.	Tails Large	Tails Small	Tails Peewee	All Tails
1964	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.5	0.0	0.0	0.0	13.5
1965	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.0	0.0	0.0	0.0	11.0
1966	0.0	0.0	0.0	0.0	0.0	0.0	0.0	90.1	0.0	0.0	0.0	90.1
1967	0.0	0.0	0.0	0.0	0.0	0.0	0.0	162.5	0.0	0.0	0.0	162.5
1968	0.0	0.0	0.0	0.0	0.0	0.0	0.0	135.9	0.0	0.0	0.0	135.9
1969	0.0	0.0	0.0	0.0	0.0	0.0	0.0	77.8	0.0	0.0	0.0	77.8
1970	0.0	0.0	0.0	0.0	0.0	0.0	0.0	59.8	0.0	0.0	0.0	59.8
1971	0.0	0.0	0.0	0.0	0.0	0.0	0.0	64.1	0.0	0.0	0.0	64.1
1972	0.0	0.0	0.0	0.0	0.0	0.0	0.0	131.6	0.0	0.0	0.0	131.6
1973	0.0	0.0	0.0	0.0	0.0	0.0	0.0	213.8	0.0	0.0	0.0	213.8
1974	0.0	0.0	0.0	0.0	0.0	0.0	0.0	360.4	0.0	0.0	0.0	360.4
1975	0.0	0.0	0.0	0.0	0.0	0.0	0.0	558.0	0.0	0.0	0.0	558.0
1976	0.0	0.0	0.0	0.0	0.0	0.0	0.0	673.4	0.0	0.0	0.0	673.4
1977	0.0	0.0	0.0	0.0	0.0	0.0	0.0	944.7	0.0	0.0	0.0	944.7
1978	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1171.4	0.0	0.0	0.0	1171.4
1979	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1209.1	0.0	0.0	0.0	1209.1
1980	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1113.1	0.0	0.0	0.0	1113.1
1981	0.0	0.0	0.0	0.0	0.0	0.0	0.0	969.0	0.0	0.0	0.0	969.0
1982	0.0	0.0	10.0	0.0	0.0	0.0	0.0	1145.6	15.0	2.0	0.0	1162.6
1983	0.0	0.0	9.3	0.0	0.0	0.0	0.0	1152.3	4.8	2.4	0.0	1159.4
1984	0.0	0.0	14.7	0.0	0.0	0.0	0.0	1261.9	3.7	0.0	0.0	1265.6
1985	0.0	0.0	11.4	0.0	0.0	0.0	0.0	1385.9	1.6	2.6	0.0	1390.2
1986	0.0	0.0	13.7	0.0	0.0	0.0	0.0	1302.7	0.3	0.2	0.0	1303.2
1987	0.0	0.0	24.0	0.0	0.0	0.0	0.0	1491.5	1.7	0.7	0.0	1493.9
1988	0.0	0.0	47.4	0.0	0.0	0.0	0.0	1516.9	5.6	3.3	0.0	1525.8
1989	0.0	0.0	58.7	0.0	11.2	0.0	0.0	1464.5	327.0	130.2	0.0	1921.6
1990	0.0	0.0	77.9	0.0	30.3	0.0	0.0	1173.7	410.7	154.0	0.0	1738.4
1991	0.0	3.3	70.0	0.0	0.3	0.0	0.0	1013.9	538.6	153.2	9.1	1714.8
1992	0.0	0.7	83.0	0.0	0.1	0.0	0.0	910.5	589.9	505.4	79.4	2085.3
1993	0.0	0.6	208.3	98.2	350.6	0.0	0.0	1034.3	867.9	1061.8	102.9	3067.0
1994	0.0	1.4	207.6	532.7	981.3	0.0	0.0	403.0	1205.7	1074.8	136.2	2819.7
1995	0.0	0.7	45.7	1223.7	1113.3	0.0	0.0	361.7	1180.4	1003.3	304.4	2849.9
1996	0.3	0.2	65.1	1115.7	745.4	0.0	0.0	89.8	930.4	1398.6	223.9	2642.7
1997	0.0	0.1	50.9	634.3	244.3	0.0	0.0	26.4	1126.1	1361.5	119.1	2633.1
1998	0.0	0.0	24.0	550.9	143.9	0.0	0.0	16.3	1054.9	810.1	79.2	1960.5
1999	0.0	0.1	39.8	1700.8	510.6	0.0	0.0	28.3	995.5	848.4	139.4	2011.6
2000	0.0	0.0	93.9	3213.4	912.1	0.0	0.0	17.5	782.9	1050.4	2.7	1853.4
2001	0.0	0.0	93.5	3084.2	231.1	0.0	0.0	128.5	1114.6	1646.7	0.0	2889.8
2002	0.0	0.1	75.3	3788.7	24.1	0.0	0.0	79.6	1055.3	1777.2	0.0	2912.0
2003	0.0	0.0	60.6	2363.9	13.7	0.0	0.0	94.7	1572.5	2032.2	0.0	3699.5
2004	0.0	0.0	55.8	646.7	959.9	0.0	0.0	3.0	1882.5	1580.3	1.4	3467.3
2005	0.0	0.0	41.2	732.9	953.0	0.1	0.0	2.3	1498.5	1051.4	1.6	2553.8
2006	0.0	0.0	22.4	865.3	715.7	1.0	0.0	7.6	881.9	604.7	2.6	1496.9
2007	0.0	0.1	13.2	299.9	319.3	0.1	0.6	8.4	868.3	385.6	0.8	1263.1
2008	0.0	0.0	4.2	203.5	160.6	2.0	0.0	1.3	780.2	307.9	0.0	1089.3
2009	0.0	0.0	2.03	116.51	189.58	10.69	0.0	1.0	573.05	302.7	0.0	876.7

Table A7. Landed weight (mt) of monkfish by market category for 1964-2009 for southern assessment area (SA 524-636 excluding 561), NEFSC weighout database and vessel trip reports (1994-2009).

Year	Belly Flaps	Cheeks	Livers	Gutted	Round	Dressed	Heads	Tails Unc.	Tails Large	Tails Small	Tails Peewee	All Tails
1964	0.0	0.0	0.0	0.0	0.0	0.0		5.7	0.0	0.0	0.0	5.7
1965	0.0	0.0	0.0	0.0	0.0	0.0		5.0	0.0	0.0	0.0	5.0
1966	0.0	0.0	0.0	0.0	0.0	0.0		3.9	0.0	0.0	0.0	3.8
1967	0.0	0.0	0.0	0.0	0.0	0.0		2.3	0.0	0.0	0.0	2.3
1968	0.0	0.0	0.0	0.0	0.0	0.0		0.6	0.0	0.0	0.0	0.6
1969	0.0	0.0	0.0	0.0	0.0	0.0		1.2	0.0	0.0	0.0	1.2
1970	0.0	0.0	0.0	0.0	0.0	0.0		3.7	0.0	0.0	0.0	3.7
1971	0.0	0.0	0.0	0.0	0.0	0.0		3.0	0.0	0.0	0.0	3.0
1972	0.0	0.0	0.0	0.0	0.0	0.0		7.4	0.0	0.0	0.0	7.4
1973	0.0	0.0	0.0	0.0	0.0	0.0		41.7	0.0	0.0	0.0	41.7
1974	0.0	0.0	0.0	0.0	0.0	0.0		30.3	0.0	0.0	0.0	30.3
1975	0.0	0.0	0.0	0.0	0.0	0.0		84.8	0.0	0.0	0.0	84.8
1976	0.0	0.0	0.0	0.0	0.0	0.0		128.8	0.0	0.0	0.0	128.8
1977	0.0	0.0	0.0	0.0	0.0	0.0		249.6	0.0	0.0	0.0	249.6
1978	0.0	0.0	0.0	0.0	0.0	0.0		403.1	0.0	0.0	0.0	403.1
1979	0.0	0.0	0.0	0.0	0.0	0.0		1015.6	0.0	0.0	0.0	1015.6
1980	0.0	0.0	0.0	0.0	0.0	0.0		1189.3	0.0	0.0	0.0	1189.3
1981	0.0	0.0	0.0	0.0	0.0	0.0		685.0	0.0	0.0	0.0	685.0
1982	0.0	0.0	0.2	0.0	0.0	0.0		912.4	138.1	51.3	0.0	1101.8
1983	0.0	0.0	2.3	0.0	0.0	0.0		857.7	236.6	136.2	0.0	1230.5
1984	0.0	0.0	10.3	0.0	0.0	0.0		859.7	183.1	44.5	0.0	1087.3
1985	0.0	0.0	16.7	0.0	0.0	0.0		1081.1	85.1	70.8	0.0	1236.9
1986	0.0	0.0	22.6	0.0	0.0	0.0		1062.6	76.1	52.0	0.0	1190.8
1987	0.0	0.0	330.2	0.0	0.0	0.0		972.2	138.2	6.0	0.0	1116.4
1988	0.0	0.0	65.4	0.0	0.0	0.0		1129.3	189.5	31.5	0.0	1350.4
1989	0.0	0.0	87.6	0.0	4.5	0.0		2037.4	230.4	229.8	0.0	2497.5
1990	0.0	0.0	101.8	0.0	187.3	0.0		1428.1	443.4	223.4	0.0	2094.9
1991	0.0	5.2	200.2	0.0	415.1	0.0		1215.2	1123.3	460.9	27.5	2826.8
1992	0.2	3.0	238.5	0.0	385.9	0.0		1868.2	1318.3	787.6	103.9	4077.9
1993	0.0	1.1	251.5	0.0	178.1	0.0		2468.9	1065.1	789.3	159.4	4482.8
1994	0.0	3.8	250.5	921.0	1063.5	0.0		853.9	1025.0	988.5	121.8	2989.2
1995	2.3	0.3	451.3	1528.7	1539.1	0.0		518.0	1341.0	1419.3	58.9	3337.2
1996	0.4	0.5	504.4	2352.1	317.6	0.0		996.3	1159.7	1628.6	45.6	3830.2
1997	0.1	0.0	577.1	2559.4	550.9	0.0		647.2	1924.0	1912.6	32.4	4516.2
1998	0.0	0.5	581.9	3036.0	438.0	0.0		841.9	1952.0	1839.7	16.3	4649.9
1999	0.1	0.1	557.6	4047.4	620.9	0.0		508.9	1392.8	1352.4	14.1	3268.1
2000	0.0	3.7	530.1	3700.7	178.9	0.0		276.2	797.1	656.9	1.6	1731.8
2001	0.5	0.0	465.9	3944.0	300.3	0.0		216.8	844.3	493.6	0.4	1555.1
2002	0.2	0.0	433.3	4012.9	551.3	0.0		167.0	628.6	336.1	0.2	1132.0
2003	0.0	0.9	425.7	4958.8	667.2	0.0		242.4	790.1	405.1	0.7	1438.3
2004	0.3	2.1	354.9	2758.0	1066.1	7.8		185.6	670.8	273.6	0.1	1130.1
2005	0.0	54.9	332.3	2628.1	1381.3	17.7		105.0	711.3	513.3	2.1	1331.8
2006	0.1	108.4	289.6	2107.5	1286.3	20.4		69.8	666.3	521.1	0.7	1257.9
2007	0.0	43.6	258.0	2040.2	1158.9	12.2	0.1	88.2	728.2	321.7	0.9	1138.9
2008	0.0	4.8	252.6	1935.4	1119.9	13.4	1.1	58.8	722.4	299.3	0.0	1080.5
2009	0.8	0.0	197.0	1576.4	929.9	8.7	11.4	46.9	491.9	231.3	0.3	770.4

Table A8. Revised discard estimates. Dredge and shrimp trawl based on SBRM d/k all species, live weight; trawl and gillnet based on revised d/k monk in the northern and southern management areas.

North							
GEAR	YEAR	HALF	No. Trips	D/K Ratio	CV	mt	Monkfish Discard (mt)
Trawl	1989	1	17	0.041	0.63	1,550	63
		2	50	0.182	0.44	1,830	333
	1990	1	9	0.089	0.71	1,589	141
		2	30	0.040	0.46	1,694	68
	1991	1	21	0.043	0.47	1,239	53
		2	53	0.210	0.19	2,027	427
	1992	1	40	0.132	0.32	1,675	222
		2	18	0.266	0.38	2,625	698
	1993	1	8	0.076	0.36	2,821	216
		2	12	0.089	0.25	3,032	270
	1994	1	5	0.040	0.46	2,899	115
		2	4	0.037	0.44	4,353	161
	1995	1	22	0.154	0.32	4,224	652
		2	45	0.088	0.32	4,630	407
	1996	1	14	0.196	0.25	4,210	827
		2	41	0.134	0.57	4,188	559
	1997	1	10	0.099	0.49	3,364	332
		2	7	0.076	0.23	3,444	260
	1998	1	6	0.112	0.37	2,736	306
		2	3	0.088	0.09	2,376	210
	1999	1	2	0.098	0.04	3,742	368
		2	27	0.070	0.22	3,226	226
	2000	1	49	0.074	0.40	4,522	334
		2	53	0.081	0.21	4,200	341
	2001	1	40	0.099	0.22	5,564	553
		2	99	0.064	0.11	5,090	326
	2002	1	28	0.078	0.31	6,235	489
		2	198	0.102	0.12	5,037	514
	2003	1	123	0.099	0.16	7,256	717
		2	169	0.052	0.13	5,340	280
	2004	1	86	0.041	0.13	5,942	242
		2	225	0.045	0.14	4,120	184
	2005	1	55	0.091	0.36	3,825	348
		2	348	0.101	0.14	2,812	285
	2006	1	93	0.041	0.15	2,837	116
		2	58	0.083	0.13	2,259	189
	2007	1	53	0.039	0.14	2,133	82
		2	100	0.083	0.21	1,467	122
	2008	1	66	0.090	0.17	1,890	170
		2	95	0.121	0.23	1,285	155
	2009	1	74	0.204	0.17	1,731	353
		2	114	0.103	0.16	837	86

North							
GEAR	YEAR	HALF	No. Trips	D/K Ratio	CV	mt	Monkfish Discard (mt)
Gillnet	1989	1	1	0.000		84	0
		2	77	0.027	0.32	265	7
	1990	1	37	0.036	0.42	121	4
		2	51	0.029	0.37	219	6
	1991	1	131	0.030	0.48	120	4
		2	555	0.036	0.11	213	8
	1992	1	216	0.065	0.17	105	7
		2	430	0.040	0.25	248	10
	1993	1	106	0.084	0.22	119	10
		2	261	0.032	0.24	560	18
	1994	1	19	0.065	0.30	132	9
		2	38	0.054	0.20	959	52
	1995	1	26	0.141	0.31	334	47
		2	67	0.087	0.23	1,242	109
	1996	1	19	0.137	0.43	348	48
		2	31	0.131	0.19	1,063	140
	1997	1	15	0.036	0.32	244	9
		2	23	0.194	0.84	867	168
	1998	1	27	0.028	0.41	196	5
		2	63	0.043	0.28	746	32
	1999	1	27	0.067	0.66	344	23
		2	59	0.036	0.51	1,088	39
	2000	1	40	0.037	0.24	500	18
		2	59	0.077	0.24	1,879	145
	2001	1	25	0.061	0.70	919	56
		2	30	0.849	0.94	2,227	1,892
	2002	1	19	0.040	0.57	821	33
		2	38	0.048	0.30	2,127	103
	2003	1	83	0.037	0.24	567	21
		2	208	0.053	0.14	1,791	94
	2004	1	91	0.022	0.25	826	19
		2	504	0.054	0.12	2,067	112
	2005	1	37	0.106	0.29	545	58
		2	523	0.071	0.10	1,567	112
	2006	1	49	0.066	0.43	357	23
		2	48	0.082	0.18	1,172	96
	2007	1	22	0.059	0.32	291	17
		2	147	0.065	0.18	847	55
	2008	1	39	0.079	0.30	183	14
		2	94	0.047	0.25	634	30
	2009	1	27	0.202	0.47	190	38
		2	90	0.076	0.21	484	37

Table A8. continued (north)

North							
GEAR	YEAR	HALF	No. Trips	D/K Ratio	CV	mt	Monkfish Discard (mt)
Shrimp	1989	1	31	0.002	0.34	3,412	6
		2	9	0.001	0.62	931	1
	1990	1	27	0.020	0.34	4,548	92
		2	4	0.020	1.01	620	13
	1991	1	46	0.020	0.19	3,536	71
		2	7	0.020	0.40	340	7
	1992	1	76	0.003	0.23	3,285	10
		2	6	0.003	0.28	161	0
	1993	1	78	0.001	0.26	1,890	2
		2	4	0.001	0.70	316	0
	1994	1	69	0.002	0.39	2,431	6
		2	6	0.001	0.44	1,118	1
	1995	1	62	0.000	0.24	5,416	2
		2	9	0.001	0.43	1,509	1
	1996	1	31	0.000	0.34	7,687	1
		2	5	0.000	0.79	1,475	0
	1997	1	17	0.000	0.61	5,659	1
		2		0.001		655	0
	1998	1		0.000		3,423	1
		2		0.001		160	0
	1999	1		0.000		1,578	0
		2					
	2000	1		0.000		2,238	1
		2		0.001		98	0
	2001	1	3	0.000	0.14	1,094	0
		2					
	2002	1		0.000		417	0
		2					
	2003	1	13	0.000	1.00	1,017	0
		2					
	2004	1	12	0.000	0.25	1,518	0
		2		0.001		24	0
	2005	1	16	0.000	0.53	830	0
		2		0.001		56	0
	2006	1	10	0.000	0.72	618	0
		2	3	0.000	0.10	189	0
	2007	1	9	0.001	0.89	1,600	1
		2	0	0.000	0.00	217	0
	2008	1	15	0.000	1.04	1,763	1
		2	3	0.001	0.90	50	0
	2009	1	7	0.001	0.62	433	0
		2	0	0.000	0.00	25	0

North							
GEAR	YEAR	HALF	No. Trips	D/K Ratio	CV	mt	Monkfish Discard (mt)
Dredge	1989	1		0.002		18,213	37
		2		0.020		24,053	485
	1990	1		0.002		9,864	20
		2		0.020		19,293	389
	1991	1		0.002		16,608	34
		2		0.020		21,313	430
	1992	1		0.002		14,179	29
		2	1	0.003		20,033	56
	1993	1	2	0.002	0.05	13,702	27
		2	2	0.027	0.24	12,665	341
	1994	1	1	0.003		5,477	15
		2	2	0.006	0.64	4,500	27
	1995	1		0.002		2,915	6
		2	1	0.036		8,435	305
	1996	1	4	0.000	0.63	12,015	3
		2	1	0.034		12,182	420
	1997	1	3	0.004	0.79	19,009	69
		2	3	0.025	0.87	19,866	502
	1998	1	1	0.004		20,980	89
		2	2	0.017	0.07	16,979	281
	1999	1	1	0.002		27,495	65
		2		0.002		29,283	69
	2000	1		0.004		29,383	120
		2	84	0.004	0.15	13,809	56
	2001	1	13	0.003	0.52	16,174	44
		2		0.003		12,512	34
	2002	1		0.015		9,478	138
		2	5	0.015	0.95	11,713	170
	2003	1	3	0.000	1.50	17,082	2
		2	2	0.019	0.74	10,855	204
	2004	1	2	0.000		4,269	0
		2	7	0.276	0.61	1,080	298
	2005	1	15	0.001	0.60	2,427	3
		2	29	0.007	0.24	11,761	87
	2006	1	2	0.000	0.81	8,869	4
		2	10	0.010	0.36	5,445	54
	2007	1	19	0.002	0.22	3,096	6
		2	42	0.022	0.22	6,309	137
	2008	1	8	0.002	0.28	1,840	3
		2	10	0.007	0.57	1,016	7
	2009	1	2	0.013	0.09	593	7
		2	12	0.002	0.25	3,418	7

Table A8. continued (south)

South							
GEAR	YEAR	HALF	No. Trips	D/K Ratio	CV	mt	Monkfish Discard (mt)
Trawl	1989	1	37	0.791	0.37	2,195	1,736
		2	29	0.175	0.55	733	128
	1990	1	36	0.063	0.25	1,540	98
		2	19	0.114	0.33	755	86
	1991	1	51	0.255	0.30	1,251	319
		2	59	0.020	0.38	3,804	78
	1992	1	54	0.059	0.37	3,946	232
		2	25	0.028	0.84	2,134	60
	1993	1	36	0.089	0.59	2,598	232
		2	23	0.027	0.50	1,301	35
	1994	1	35	0.068	0.29	3,039	205
		2	18	0.228	0.63	2,089	477
	1995	1	43	0.150	0.41	3,252	488
		2	31	0.113	0.49	2,709	307
	1996	1	42	0.156	0.30	3,154	491
		2	29	0.094	0.19	3,818	359
	1997	1	43	0.025	0.47	4,355	107
		2	18	0.089	0.15	4,015	356
	1998	1	28	0.120	0.29	4,321	517
		2	15	0.027	0.52	3,648	100
	1999	1	29	0.050	0.36	4,180	209
		2	17	0.211	0.58	2,119	448
	2000	1	54	0.197	0.49	1,766	347
		2	37	0.102	0.52	1,645	167
	2001	1	42	1.551	0.46	1,460	2,265
		2	26	0.368	0.64	959	353
	2002	1	37	0.127	0.55	833	106
		2	30	0.128	0.25	314	40
	2003	1	94	0.156	0.24	712	111
		2	63	0.249	0.38	750	187
	2004	1	158	0.189	0.43	824	156
		2	176	0.981	0.36	755	740
	2005	1	149	0.592	0.34	730	432
		2	210	0.344	0.31	1,608	553
	2006	1	148	0.382	0.22	904	345
		2	102	0.130	0.35	925	121
	2007	1	142	0.228	0.45	660	150
		2	147	0.376	0.59	817	307
	2008	1	135	0.198	0.31	712	141
		2	94	0.062	0.44	609	38
	2009	1	115	0.085	0.33	593	51
		2	75	0.087	0.69	366	32

South							
GEAR	YEAR	HALF	No. Trips	D/K Ratio	CV	mt	Monkfish Discard (mt)
Gillnet	1989	1		0.031		12	0
		2		0.054		5	0
	1990	1		0.031		14	0
		2		0.054		18	1
	1991	1		0.031		209	7
		2	2	0.008	0.16	154	1
	1992	1	60	0.011	0.32	786	8
		2	41	0.020	0.20	176	4
	1993	1	50	0.034	0.71	1,306	44
		2	45	0.059	0.24	341	20
	1994	1	46	0.079	0.34	1,649	130
		2	61	0.058	0.19	830	48
	1995	1	156	0.038	0.19	2,810	108
		2	44	0.041	0.30	937	39
	1996	1	123	0.071	0.28	2,795	199
		2	14	0.052	0.30	1,363	70
	1997	1	150	0.070	0.35	3,688	257
		2	31	0.015	0.35	1,320	19
	1998	1	105	0.067	0.22	4,172	278
		2	13	0.063	0.46	1,948	122
	1999	1	22	0.052	0.35	4,338	227
		2	6	0.046	0.62	1,829	84
	2000	1	22	0.063	0.31	2,688	170
		2	10	0.056	0.93	1,034	58
	2001	1	16	0.030	0.44	2,175	65
		2	4	0.033	0.44	2,758	91
	2002	1	11	0.017	0.83	3,506	60
		2	7	0.063	0.47	1,933	122
	2003	1	31	0.016	0.35	4,671	73
		2	39	0.070	0.32	2,721	190
	2004	1	55	0.062	0.26	3,767	232
		2	43	0.096	0.26	1,221	118
	2005	1	66	0.127	0.23	3,586	456
		2	39	0.080	0.29	1,724	138
	2006	1	36	0.051	0.21	3,151	162
		2	7	0.087	0.37	1,034	89
	2007	1	26	0.228	0.41	2,922	666
		2	17	0.059	0.33	2,217	132
	2008	1	27	0.108	0.35	3,853	417
		2	18	0.121	0.30	1,290	156
	2009	1	29	0.054	0.25	3,035	164
		2	5	0.093	0.22	868	81

Table A8. continued (south)

South							
GEAR	YEAR	HALF	No. Trips	D/K Ratio	CV	mt	Monkfish Discard (mt)
Dredge	1989	1		0.012		59,697	706
		2		0.013		35,498	455
	1990	1		0.012		64,315	761
		2		0.013		53,041	679
	1991	1		0.012		67,830	802
		2	2	0.001	0.25	36,015	22
	1992	1	7	0.000	0.80	48,687	20
		2	7	0.006	0.62	39,127	253
	1993	1	11	0.008	0.29	23,971	184
		2	3	0.029	0.78	18,379	532
	1994	1	9	0.022	0.24	22,841	512
		2	8	0.015	0.29	27,175	420
	1995	1	14	0.029	0.17	34,832	1,016
		2	8	0.041	0.47	18,089	746
	1996	1	18	0.017	0.25	21,250	370
		2	14	0.024	0.28	18,878	448
	1997	1	16	0.026	0.21	10,175	261
		2	7	0.035	0.41	4,329	152
	1998	1	8	0.008	0.27	4,284	33
		2	15	0.011	0.55	4,700	53
	1999	1	2	0.016	0.18	11,695	192
		2	12	0.006	0.52	12,136	72
	2000	1	36	0.015	0.16	26,596	389
		2	132	0.008	0.17	42,541	360
	2001	1	44	0.014	0.12	62,987	907
		2	48	0.014	0.15	69,336	964
	2002	1	34	0.019	0.09	84,180	1,575
		2	55	0.018	0.10	81,242	1,479
	2003	1	46	0.014	0.16	82,123	1,138
		2	71	0.017	0.12	92,174	1,522
	2004	1	74	0.014	0.09	71,786	1,024
		2	164	0.014	0.10	30,188	430
	2005	1	98	0.012	0.14	41,192	500
		2	147	0.016	0.13	29,264	466
	2006	1	42	0.008	0.31	28,640	243
		2	135	0.024	0.14	35,961	846
	2007	1	130	0.010	0.14	27,584	278
		2	156	0.014	0.14	17,512	241
	2008	1	367	0.006	0.11	28,746	181
		2	241	0.010	0.14	20,230	197
	2009	1	318	0.006	0.09	36,251	213
		2	67	0.011	0.15	25,095	266

Table A9. Estimated discards of monkfish using SBRM methodology (mt monkfish discarded/mt all species landed) in trawls, gillnets, and scallop dredge

Stock	Year	Trawl	Gillnet	Scallop Dredge	Total
North	1989	119	15	465	599
	1990	183	12	321	515
	1991	357	19	417	792
	1992	444	20	56	520
	1993	186	21	368	575
	1994	237	117	56	410
	1995	1,295	148	354	1,797
	1996	1,398	156	383	1,938
	1997	730	152	302	1,184
	1998	610	30	167	807
	1999	774	34	53	861
	2000	766	214	100	1,079
	2001	1,193	1,671	80	2,944
	2002	1,069	116	321	1,507
	2003	1,090	151	215	1,455
	2004	543	101	1,079	1,723
	2005	437	194	55	686
	2006	283	74	37	394
	2007	204	73	143	420
	2008	325	44	10	380
	2009	439	75	14	528
North Total		12,683	3,436	4,996	21,115
South	1989	919	29	43	991
	1990	205	19	64	289
	1991	246	40	22	307
	1992	656	21	273	950
	1993	296	169	716	1,181
	1994	1,126	39	850	2,015
	1995	1,509	44	1,818	3,372
	1996	222	73	935	1,230
	1997	254	171	919	1,344
	1998	155	184	267	607
	1999	771	220	623	1,614
	2000	411	214	1,023	1,647
	2001	420	80	1,860	2,361
	2002	514	172	3,038	3,724
	2003	536	331	2,649	3,516
	2004	964	979	1,129	3,072
	2005	688	1,519	665	2,872
	2006	288	502	732	1,523
	2007	458	798	519	1,775
	2008	179	573	378	1,130
	2009	82	245	479	806
South Total		10,901	6,424	19,002	36,327
Grand Total		23,584	9,860	23,998	57,442

Table A10. Annual catch, discards using (mt monks discarded/mt kept of all species) for dredges and shrimp trawls and (mt monks discarded/mt monks kept) for trawls and gillnets. The new estimates also reflect minor changes to allocation to stock based on live weight rather than landed weight. Foreign is NAFO areas 5 and 6

	North			South			Areas Combined				
Year	Landings	Discard	Total (mt)	Landings	Discard	Total (mt)	Landings	Discard	Total (mt)	Foreign	Total (mt)
1980	3,623	767	4,390	6,035	395	6,430	9,658	1,163	10,821	132	10,953
1981	3,171	916	4,087	4,142	319	4,461	7,313	1,235	8,548	381	8,929
1982	3,860	841	4,701	3,722	417	4,139	7,582	1,258	8,840	310	9,150
1983	3,849	797	4,646	4,115	467	4,582	7,964	1,264	9,228	80	9,308
1984	4,202	733	4,935	3,699	483	4,182	7,901	1,216	9,117	395	9,512
1985	4,616	757	5,373	4,262	451	4,713	8,878	1,208	10,086	1,333	11,419
1986	4,327	652	4,979	4,037	439	4,476	8,364	1,091	9,455	341	9,796
1987	4,960	914	5,874	3,762	726	4,488	8,722	1,640	10,362	748	11,110
1988	5,066	942	6,008	4,595	721	5,316	9,661	1,664	11,325	909	12,234
1989	6,391	932	7,323	8,353	3,026	11,379	14,744	3,958	18,702	1,178	19,880
1990	5,802	733	6,535	7,204	1,626	8,830	13,006	2,359	15,365	1,557	16,922
1991	5,693	1,033	6,726	9,865	1,229	11,094	15,558	2,262	17,820	1,020	18,840
1992	6,923	1,031	7,954	13,942	577	14,519	20,865	1,608	22,473	473	22,946
1993	10,645	885	11,530	15,098	1,047	16,145	25,743	1,932	27,675	354	28,029
1994	10,950	385	11,335	12,126	1,793	13,919	23,076	2,178	25,254	543	25,797
1995	11,970	1,530	13,500	14,361	2,703	17,064	26,331	4,232	30,564	418	30,982
1996	10,791	1,998	12,789	15,715	1,937	17,652	26,507	3,934	30,441	184	30,625
1997	9,709	1,341	11,051	18,462	1,152	19,614	28,172	2,494	30,665	189	30,854
1998	7,281	924	8,205	19,337	1,102	20,438	26,618	2,026	28,643	190	28,833
1999	9,128	790	9,918	16,085	1,231	17,316	25,213	2,021	27,234	151	27,385
2000	10,729	1,015	11,743	10,147	1,491	11,638	20,876	2,506	23,382	176	23,558
2001	13,341	2,904	16,245	9,959	4,645	14,604	23,301	7,549	30,849	149	30,998
2002	14,011	1,446	15,457	8,884	3,382	12,266	22,896	4,828	27,724	294	28,018
2003	14,991	1,318	16,309	11,095	3,220	14,316	26,086	4,538	30,625	309	30,934
2004	13,209	854	14,062	7,978	2,699	10,677	21,186	3,553	24,739	166	24,905
2005	10,267	892	11,159	8,834	2,546	11,380	19,102	3,438	22,540	206	22,746
2006	6,706	481	7,187	7,755	1,806	9,561	14,461	2,288	16,748	279	17,027
2007	4,855	421	5,276	7,290	1,775	9,065	12,145	2,196	14,341	8	14,349
2008	4,013	380	4,393	6,940	1,130	8,070	10,953	1,510	12,463	2	12,465
2009	3,255	528	3,783	5,302	806	6,108	8,557	1,334	9,891		9,891

Table A11. Temporal stratification used in expanding landings and discard to length composition of the monkfish catch. Unless otherwise indicated, sampling was expanded within gear type and area.

		Trawl		Gillnet		Dredge	
		Kept	Discarded	Kept	Discarded	Kept	Discarded
2007	North	half year	half year	annual	annual N+S	annual	annual
	South	half year	half year	annual	annual	annual	annual
2008	North	half year	half year	annual	annual N+S	annual	annual
	South	half year	half year	annual	annual	annual	annual
2009	North	half year	half year	annual	annual N+S	annual	annual
	South	half year	half year	annual	annual	annual	annual

Table A12. Number of tows from 2009 cooperative monkfish survey with sensor data.

	MK Cookie	ER Cookie	ER Roller
Good Survey Tows	number of tows	number of tows	number of tows
Doorspread	1	2	0
Wingspread	1	17	69
Bottom contact	15	5	13
Temperature	78	14	63
Depth	41	21	73
Speed over ground	108	21	73
Total Survey Tows	*109*	*21*	*74*

Depletion Tows			
Doorspread	0	0	0
Wingspread	18	0	0
Bottom contact	21	1	2
Temperature	21	0	0
Depth	21	6	11
Speed over ground	21	6	11
Total Depletion Tows	*21*	*6*	*12*

Mensuration Tows	
Doorspread	7
Wingspread	9
Bottom contact	11
Temperature	12
Depth	12
Speed over ground	15
Total Mensuration Tows	*15*

Table A13. Summary statistics, 2009 Cooperative Monkfish Survey based on good survey tows and all depletion tows.

		Management Area		
Survey Tows		North	South	North + South
Number of survey tows[1]				
	Endurance cookie	3	18	21
	Endurance roller	64	10	74
	Mary K cookie	0	109	109
	Total	67	137	204
Depth (m)	min-max (median)	30-259 (157)	23-504 (80)	
Number caught		666	2,384	3,050
Kg caught		1,053	5,799	6,852
Number per tow	min-max (median)	0-49 (4)	0-143 (4)	0-143 (4)
Kg per tow	min-max (median)	0-121.5 (5.4)	0-402.2 (7.0)	0-402 (6.8)
Length (cm)	number measured	666	1500	2166
	min-max (median)	13-103 (40)	13-112 (52)	13-112 (49)
Number maturity and gender samples		666	1500	2166

Table A14. Efficiency estimates from 2009 depletion experiments. Gray-shaded estimates were not used in developing population estimates from cooperative survey data.

Cookie Sweep

Exp#	Vessel	Estimate	elower	eupper
1	MK	0.343	0.256	0.472
2	MK	0.950	0.727	1.480
3	MK	0.545	0.368	0.750
4	MK	0.682	0.526	0.846
Average (1, 3, 4)		0.523		

Exp#	Vessel	Estimate	elower	eupper
5	ER	0.382	0.265	0.550
7	ER	0.116	0.079	0.167
Average		0.249		

Roller Sweep

Exp#	Vessel	Estimate	elower	eupper
6	ER	0.050	0.039	0.064
8	ER	0.050	0.038	0.063

Table A15. Comparison of minimum population estimates from 2001, 2004, and 2009 cooperative surveys.

A. Minimum Estimates (assuming 100% net efficiency)

		Nominal Minimum		Sensor Minimum			
		Biomass (mt)	Numbers ('000)	Biomass (mt)	Numbers ('000)	Survey Dates	Percent Zero Tows
2001	North	32,589	25,047	31,454	24,183	Feb. 26- Apr 6	7.9
	South	39,255	22,617	32,622	19,070	Feb. 26- Apr 6	7.6
	N+S	71,844	47,664	64,076	43,253		
2004	North	28,227	14,283	25,583	12,941	~March 1-June 16	10.5
	South	67,879	37,485	61,340	33,971	~March 1-June 16	8.7
	N+S	96,105	51,768	86,923	46,911		
2009	North	12,581	7,951	13,549	8,555	Feb 10 - Apr 17	23.9
	South	28,739	12,693	27,092	11,995	Feb 11 - Apr 26	24.1
	N+S	41,320	20,644	40,642	20,550		

B. Point estimates of population number and biomass assuming intermediate net efficiency.

		Nominal Tow Duration		Sensor Tow Duration	
		Biomass (mt)	Numbers ('000)	Biomass (mt)	Numbers ('000)
2001	North	68,680	52,834	68,680	52,834
	South	66,230	38,037	55,400	32,228
	N+S	134,910	90,870	124,081	85,062
2004	North	86,627	44,053	78,474	39,896
	South	142,410	80,130	128,712	72,614
	N+S	229,037	124,183	207,186	112,510
2009	North	54,916	34,709	59,142	37,345
	South	58,960	25,733	56,398	24,584
	N+S	113,876	60,442	115,540	61,929

Table A16. Absolute biomass estimates from cooperative surveys based on bootstrapping analysis.

Year	Area	Biomass (mt)	Standard Deviation	25th Percentile	Median	75th Percentile
2001	North	80,316	32,512	57,229	74,099	96,238
2001	South	97,475	39,458	69,458	89,921	116,803
2001	N+S	177,791	71,970	126,687	164,020	213,041
2004	North	63,050	23,204	46,591	58,777	74,588
2004	South	182,554	67,187	134,908	170,169	215,922
2004	N+S	245,605	90,391	181,499	228,946	290,510
2009	North	31,451	9,643	24,559	29,921	36,590
2009	South	67,447	20,679	52,663	64,170	78,473
2009	N+S	98,899	30,323	77,222	94,091	115,063

Table A17. Parameters of length-weight equations for monkfish from 2009 cooperative survey and earlier studies. Regression model used was *logW = log a+b log L* where W = weight in kg, L = length in cm.

		Males	Females	Total
2009 Cooperative Survey				
North				
Number of samples		304	356	666
Length range (cm)		13 - 74	13 - 103	13 - 103
Parameter estimates	log(*a*)	-4.613	-4.840	-4.7638
	std err	0.0418	0.0328	0.0259
	b	**2.864**	**3.013**	**2.9627**
	std err	0.0265	0.0202	0.0161
South				
Number of samples		915	567	1498
Length range (cm)		17 - 71	17 - 112	17 - 112
Parameter estimates	log(*a*)	-4.532	-4.799	-4.6846
	std err	0.0234	0.0285	0.0190
	b	**2.834**	**3.011**	**2.9315**
	std err	0.0138	0.0168	0.0112
North + South				
Number of samples		1219	923	2164
Length range (cm)		13 - 74	13 - 112	13 - 112
Parameter estimates	log(*a*)	-4.630	-4.855	-4.7566
	std err	0.0196	0.0219	0.0150
	b	**2.888**	**3.036**	**2.9694**
	std err	0.0118	0.0131	0.0090
DPWG (2007) SCALE model				
North + South (Spring)	log(*a*)			-10.8461
	b			2.9468
Richards et al. 2008				
North + South (Spring)				
Number of samples		2913	3229	
Length range (cm)		40 - 85	40 - 110	
Parameter estimates*****	log(*a*)	-1.4165	-2.0180	
	std err	0.0464	0.0339	
	b	**2.7604**	**3.1228**	
	std err	0.0271	0.0190	

***** weight in grams

Table A18. Maturity parameters estimated from 2009 cooperative monkfish survey and from earlier studies.

			Males	Females
2009 Cooperative Survey				
North	Number of samples		304	356
	Length range (cm)			
		a	-22.982	-19.981
		std err	3.2167	2.5656
		b	0.644	0.511
		std err	0.0895	0.0665
		$\mathbf{L_{50}}$	**35.7**	**39.1**
South	Number of samples		915	567
	Length range (cm)			
		a	-13.518	-17.8882
		std err	1.2552	2.1432
		b	0.366	0.426
		std err	0.0328	0.0506
		$\mathbf{L_{50}}$	**36.9**	**42.0**
North + South	Number of samples		1219	923
	Length range (cm)			
		a	-15.243	-17.221
		std err	1.2285	1.4768
		b	0.421	0.428
		std err	0.0336	0.0371
		$\mathbf{L_{50}}$	**36.2**	**40.3**
DPWG (2007) assessment (2001 cooperative survey data)				
North + South		*a*		-8.7508
		b		0.2045
		$\mathbf{L_{50}}$		**42.8**
Richards et al. (2008) (2001, 2004 coop monkfish surveys)				
North + South				
	Number of samples		2156	2463
	Length range (cm)			
	Parameter	*a*	-11.486	-9.056
		b	0.312	0.221
		$\mathbf{L_{50}}$	**36.8**	**41.0**

Table A19. Nominal minimum area swept biomass and population size estimates from spring 2009, cooperative monkfish survey and NEFSC survey on FSV Henry Bigelow.

	Coop Survey		NEFSC	
	mt	# ('000)	mt	# ('000)
North	12,581	7,951	13,790	7,980
South	28,739	12,693	13,429	6,138
N+S	41,320	20,644	27,218	14,118

Table A20. Stratified mean weight (kg), number, individual fish weight, and length (cm) per tow for goosefish from NEFSC offshore research vessel autumn bottom trawl surveys in the northern management region (strata 20-30, 34-40); confidence limits for both the raw index and the indices smoothed using an integrated moving average (theta = 0.45); minimum and maximum lengths; number of fish caught, number of positive tows, and total number of tows completed each year

	Biomass						Abundance													Number	Number of	
	Raw Index			Smoothed Index			Raw Index			Smoothed Index				Length						of	Nonzero	Number
	Mean	L95%	U95%	Mean	L95%	U95%	Mean	L95%	U95%	Mean	L95%	U95%	Ind wt	Min	5%	50%	Mean	95%	Max	Fish	Tows	of Tows
1963	3.821	2.339	5.304	2.948			0.801	0.512	1.090	0.570			4.661	11	14	59	58.3	103	111	86	39	90
1964	1.892	1.030	2.753	2.476			0.392	0.219	0.564	0.453			4.813	21	21	58	59.4	92	102	32	23	87
1965	2.537	1.407	3.667	2.491			0.347	0.230	0.463	0.397			7.279	28	36	70	71.6	96	110	40	30	88
1966	3.382	2.164	4.600	2.476	1.644	3.730	0.511	0.343	0.678	0.380	0.264	0.549	6.527	37	48	73	73.1	90	96	55	33	86
1967	1.226	0.404	2.049	1.996	1.325	3.007	0.189	0.090	0.288	0.299	0.207	0.431	6.504	48	48	69	70.3	91	92	18	14	86
1968	2.050	0.533	3.568	2.232	1.482	3.363	0.286	0.115	0.457	0.320	0.222	0.461	7.170	11	26	72	71.4	105	106	32	16	86
1969	3.757	1.823	5.690	2.644	1.755	3.983	0.418	0.278	0.559	0.369	0.256	0.532	8.839	13	41	78	78.8	101	110	39	30	88
1970	2.281	0.982	3.580	2.472	1.641	3.724	0.395	0.222	0.569	0.391	0.271	0.564	5.849	22	36	67	67.2	90	98	41	21	92
1971	2.928	1.450	4.405	2.440	1.619	3.676	0.491	0.312	0.671	0.411	0.285	0.593	5.864	15	22	69	67.0	97	101	44	27	94
1972	1.420	0.667	2.174	2.130	1.414	3.209	0.319	0.195	0.442	0.384	0.266	0.554	4.354	21	21	61	56.9	97	99	29	22	94
1973	3.183	1.773	4.594	2.442	1.621	3.679	0.514	0.320	0.709	0.406	0.282	0.586	5.992	16	16	58	65.2	109	112	63	29	92
1974	2.063	1.114	3.011	2.343	1.555	3.529	0.313	0.189	0.436	0.367	0.255	0.530	6.362	13	13	69	64.9	109	111	37	23	97
1975	1.726	1.020	2.432	2.448	1.625	3.688	0.298	0.178	0.418	0.369	0.256	0.533	5.721	11	11	60	62.9	97	102	40	27	106
1976	3.387	1.555	5.219	3.235	2.147	4.874	0.423	0.244	0.601	0.429	0.298	0.619	7.620	29	30	71	72.1	106	121	32	24	87
1977	5.568	3.489	7.646	4.146	2.752	6.246	0.626	0.458	0.794	0.504	0.350	0.727	7.167	21	35	73	71.1	107	119	112	56	126
1978	5.109	3.496	6.722	4.357	2.892	6.564	0.579	0.429	0.729	0.511	0.355	0.738	6.728	10	24	70	67.6	104	116	146	78	201
1979	5.116	3.566	6.665	4.114	2.731	6.198	0.474	0.364	0.584	0.477	0.331	0.689	8.887	15	19	77	73.5	103	115	125	78	211
1980	4.458	2.234	6.682	3.355	2.227	5.055	0.535	0.366	0.703	0.448	0.311	0.646	6.266	6	16	66	63.9	101	111	65	39	97
1981	2.004	0.345	1.529	2.260	1.500	3.405	0.406	0.068	0.216	0.373	0.259	0.538	4.399	9	13	55	57.5	93	101	46	30	93
1982	0.936	0.380	1.492	1.651	1.096	2.487	0.142	0.070	0.213	0.293	0.203	0.423	6.606	29	29	71	68.9	97	100	17	14	95
1983	1.617	0.927	2.308	1.766	1.172	2.661	0.470	0.284	0.656	0.375	0.260	0.541	3.415	13	17	54	53.0	88	96	38	27	82
1984	3.010	1.413	4.607	2.004	1.330	3.020	0.483	0.353	0.613	0.412	0.286	0.595	5.803	11	26	63	62.7	102	106	36	29	88
1985	1.441	0.419	2.463	1.731	1.149	2.608	0.369	0.191	0.548	0.408	0.283	0.588	3.965	12	15	55	53.1	101	102	32	23	88
1986	2.354	1.099	3.608	1.691	1.122	2.547	0.604	0.379	0.829	0.431	0.299	0.621	3.670	19	23	52	53.8	82	100	46	26	90
1987	0.873	0.256	1.491	1.322	0.877	1.991	0.264	0.116	0.411	0.363	0.252	0.524	3.324	15	15	53	52.2	92	96	22	15	87
1988	1.525	0.484	2.565	1.366	0.907	2.058	0.313	0.130	0.496	0.379	0.263	0.546	4.859	11	11	53	57.1	92	93	26	17	89
1989	1.403	0.496	2.310	1.311	0.870	1.974	0.428	0.266	0.590	0.449	0.312	0.648	2.569	9	9	39	40.8	93	96	39	25	87
1990	1.058	0.496	1.620	1.201	0.797	1.810	0.593	0.383	0.804	0.551	0.382	0.795	1.415	9	10	25	32.3	72	89	55	35	89
1991	1.253	0.599	1.908	1.199	0.796	1.806	0.576	0.383	0.769	0.643	0.446	0.927	1.715	9	10	31	38.3	83	95	62	33	88
1992	1.116	0.571	1.661	1.161	0.771	1.750	0.938	0.602	1.274	0.808	0.560	1.165	1.183	9	9	26	33.0	79	86	78	37	86
1993	1.133	0.513	1.754	1.155	0.767	1.741	0.989	0.691	1.287	0.917	0.636	1.323	0.894	6	9	20	27.1	71	94	103	45	86
1994	1.046	0.446	1.645	1.165	0.773	1.755	1.351	0.969	1.732	0.991	0.687	1.429	0.668	9	9	19	24.9	55	98	110	51	87
1995	1.711	0.663	2.759	1.262	0.838	1.902	0.922	0.688	1.155	0.869	0.602	1.253	1.724	10	12	34	39.6	84	91	87	40	93
1996	1.091	0.516	1.665	1.115	0.740	1.680	0.630	0.407	0.853	0.732	0.507	1.055	1.688	8	11	38	40.3	63	95	51	30	88
1997	0.751	0.400	1.102	1.000	0.664	1.507	0.498	0.304	0.693	0.681	0.473	0.983	1.335	8	9	35	35.4	70	86	39	27	90
1998	1.020	0.570	1.470	1.087	0.721	1.637	0.609	0.397	0.820	0.784	0.543	1.130	1.531	10	10	30	35.5	68	77	56	38	104
1999	0.895	0.370	1.420	1.233	0.818	1.857	1.084	0.737	1.431	1.068	0.740	1.540	0.716	8	8	22	25.7	58	81	111	44	106
2000	2.529	1.322	3.736	1.734	1.151	2.613	2.398	1.564	3.232	1.439	0.998	2.076	1.032	9	11	25	30.3	70	88	165	43	87
2001	2.071	1.136	3.005	1.893	1.256	2.852	1.620	1.212	2.027	1.377	0.955	1.986	1.144	8	12	31	34.7	65	93	145	50	90
2002	2.320	1.088	3.553	1.944	1.290	2.930	1.283	0.922	1.645	1.181	0.819	1.704	1.423	9	9	34	35.1	65	93	114	45	86
2003	2.723	1.054	4.393	1.774	1.177	2.674	1.067	0.778	1.357	0.959	0.664	1.384	1.695	8	8	40	37.8	73	88	90	39	88
2004	0.626	0.262	0.989	1.213	0.802	1.835	0.516	0.313	0.720	0.724	0.500	1.048	1.227	8	8	21	29.8	68	89	36	24	85
2005	1.623	0.152	3.094	1.294	0.844	1.986	0.595	0.359	0.830	0.687	0.468	1.006	1.686	8	8	24	34.3	79	88	46	29	87
2006	1.042	0.527	1.557	1.186	0.724	1.943	0.764	0.519	1.010	0.717	0.461	1.114	1.346	6	7	33	33.2	69	86	56	37	94
2007	1.198	0.431	1.965				0.638	0.431	0.844				1.680	9	17	31	37.5	77	81	63	32	90
2008	0.992	0.374	1.609				0.782	0.434	1.129				1.240	9	9	27	31.6	68	85	60	27	90
Bigelow, no calibration coefficient applied:																						
2009	4.275	3.238	5.566				3.091	2.536	3.734				1.369	9	9	32	34.5	69	101	257	61	90
Bigelow, calibration coefficient applied:																						
2009	0.530						0.434															

Table A21. Stratified mean weight (kg), number, individual fish weight, and length (cm) per tow for goosefish from NEFSC offshore research vessel spring bottom trawl surveys in the northern management region (strata 20-30, 34-40); confidence limits for both the raw index and the indices smoothed using an integrated moving average (theta = 0.45); minimum and maximum lengths; number of fish caught, number of positive tows, and total number of tows completed each year.

	Biomass						Abundance													Number	Number of	
	Raw Index			Smoothed Index			Raw Index			Smoothed Index				Length						of	Nonzero	Number
	Mean	L95%	U95%	Mean	L95%	U95%	Mean	L95%	U95%	Mean	L95%	U95%	Ind wt	Min	5%	50%	Mean	95%	Max	Fish	Tows	of Tows
1968	1.008	0.298	1.718	1.223			0.168	0.065	0.272	0.193			5.980	50	51	68	70.4	89	90	13	11	86
1969	1.341	0.160	2.523	1.393			0.180	0.045	0.315	0.213			7.453	33	33	71	71.5	99	100	15	10	87
1970	2.021	0.798	3.245	1.626			0.344	0.216	0.472	0.262			5.867	30	30	62	65.4	98	99	32	22	90
1971	1.039	0.439	1.639	1.641	1.088	2.475	0.158	0.072	0.245	0.268	0.176	0.407	6.488	45	53	69	72.6	99	100	20	15	96
1972	4.678	3.048	6.307	2.252	1.493	3.397	0.643	0.453	0.832	0.390	0.257	0.593	7.105	13	39	74	72.7	100	105	59	38	96
1973	1.908	0.956	2.860	1.891	1.254	2.852	0.435	0.184	0.686	0.407	0.268	0.618	4.313	17	26	68	65.7	99	106	91	36	87
1974	1.477	0.863	2.090	1.578	1.047	2.380	0.438	0.315	0.561	0.405	0.267	0.616	3.391	20	23	58	58.3	97	111	86	41	83
1975	0.936	0.596	1.277	1.377	0.913	2.077	0.339	0.228	0.450	0.384	0.253	0.583	2.760	16	19	53	54.0	87	109	73	36	87
1976	2.826	1.691	3.962	1.558	1.033	2.350	0.673	0.469	0.877	0.394	0.260	0.599	3.759	14	20	60	61.5	95	106	158	52	99
1977	1.028	0.578	1.478	1.182	0.783	1.782	0.259	0.159	0.360	0.283	0.186	0.430	3.594	10	31	66	63.4	93	106	61	37	107
1978	0.626	0.340	0.913	0.984	0.652	1.484	0.141	0.095	0.186	0.216	0.142	0.328	4.014	15	19	73	65.5	89	92	37	30	113
1979	0.904	0.284	1.523	1.110	0.736	1.674	0.144	0.102	0.185	0.219	0.144	0.332	4.652	12	14	67	62.5	100	118	48	40	139
1980	1.622	0.787	2.458	1.438	0.953	2.169	0.379	0.270	0.488	0.294	0.194	0.447	3.748	17	22	43	53.3	98	107	84	38	85
1981	1.744	0.913	2.576	1.718	1.139	2.590	0.376	0.282	0.470	0.333	0.219	0.506	4.444	11	21	52	57.7	95	120	95	42	87
1982	3.015	1.273	4.758	2.031	1.346	3.062	0.346	0.155	0.536	0.348	0.229	0.528	8.594	25	36	61	68.8	105	108	33	22	92
1983	1.587	0.530	2.643	1.840	1.220	2.776	0.418	0.191	0.645	0.365	0.240	0.554	3.663	12	13	49	49.9	96	112	34	22	90
1984	1.696	0.596	2.796	1.843	1.222	2.779	0.328	0.181	0.475	0.349	0.230	0.530	4.732	17	19	62	60.8	93	100	26	19	86
1985	2.113	1.094	3.133	1.951	1.294	2.942	0.346	0.199	0.492	0.347	0.229	0.528	6.122	13	13	68	66.9	104	108	25	21	81
1986	2.165	0.960	3.370	1.957	1.298	2.952	0.340	0.200	0.481	0.347	0.229	0.527	6.244	11	14	63	65.4	109	121	30	22	90
1987	1.728	0.726	2.730	1.835	1.217	2.768	0.245	0.138	0.352	0.352	0.232	0.534	7.052	16	16	66	64.2	99	100	21	16	83
1988	2.111	0.906	3.315	1.792	1.188	2.703	0.610	0.398	0.822	0.454	0.299	0.690	3.343	10	20	49	49.8	89	110	43	26	90
1989	1.636	0.639	2.634	1.567	1.039	2.364	0.625	0.321	0.929	0.481	0.317	0.731	2.590	10	11	40	43.2	80	94	48	24	85
1990	1.005	0.366	1.643	1.332	0.883	2.009	0.282	0.157	0.407	0.428	0.281	0.649	3.587	15	18	47	49.1	106	107	25	17	90
1991	1.827	0.478	3.175	1.368	0.907	2.063	0.593	0.374	0.811	0.502	0.331	0.763	2.723	12	15	35	42.3	78	100	48	28	86
1992	0.910	-0.188	2.008	1.157	0.767	1.744	0.492	0.159	0.825	0.528	0.348	0.802	1.793	16	17	35	40.6	82	101	36	20	83
1993	1.202	0.736	1.668	1.149	0.762	1.733	0.684	0.475	0.893	0.582	0.383	0.885	1.695	10	11	44	41.0	71	90	59	27	87
1994	0.948	0.400	1.496	1.107	0.734	1.669	0.452	0.275	0.629	0.576	0.379	0.875	2.159	10	13	40	41.0	83	89	45	24	88
1995	1.752	0.806	2.698	1.183	0.785	1.785	0.984	0.662	1.305	0.671	0.442	1.020	1.817	15	16	33	39.9	73	97	83	39	88
1996	1.006	0.449	1.563	0.972	0.645	1.466	0.668	0.344	0.992	0.605	0.398	0.919	1.466	15	17	41	43.0	60	70	49	20	82
1997	0.560	0.174	0.946	0.780	0.517	1.176	0.339	0.158	0.520	0.510	0.336	0.775	1.595	9	9	36	39.4	75	89	34	19	89
1998	0.485	0.225	0.745	0.782	0.519	1.180	0.414	0.288	0.540	0.566	0.372	0.859	1.065	11	11	19	31.3	67	78	46	33	115
1999	1.225	0.646	1.804	1.081	0.717	1.631	0.824	0.547	1.102	0.774	0.509	1.175	1.389	9	14	31	35.5	71	97	62	33	87
2000	1.438	0.846	2.030	1.375	0.912	2.074	1.128	0.843	1.413	1.014	0.667	1.540	1.236	15	17	29	34.5	75	87	99	42	89
2001	1.970	0.690	3.251	1.696	1.125	2.558	1.686	1.221	2.151	1.237	0.814	1.879	1.109	9	11	24	31.4	75	86	151	50	89
2002	1.996	1.337	2.655	1.892	1.254	2.854	1.756	1.334	2.178	1.225	0.807	1.862	1.105	12	15	34	36.6	60	73	155	50	91
2003	2.383	0.817	3.949	2.036	1.349	3.073	0.811	0.479	1.144	0.953	0.627	1.449	2.304	10	13	42	44.2	69	95	79	30	86
2004	2.285	0.911	3.659	1.971	1.302	2.984	0.910	0.577	1.243	0.826	0.542	1.260	2.494	9	11	48	46.7	81	85	69	36	88
2005	2.057	0.505	3.609	1.728	1.125	2.654	0.708	0.487	0.929	0.672	0.434	1.039	2.050	11	13	48	45.1	68	75	52	31	87
2006	0.930	0.184	1.675	1.347	0.821	2.209	0.367	0.161	0.573	0.527	0.318	0.871	2.533	15	13	43	44.8	72	105	33	23	95
2007	1.647	-0.614	3.908				0.555	0.247	0.864				1.909	11	10	32	36.8	78	85	43	19	86
2008	1.783	0.1834	3.383				0.681	0.392	0.971				1.910	8	16	35	40.8	73	85	61	24	86
Bigelow, no calibration coefficient applied:																						
2009	4.251	2.7992	5.703				2.33	1.796	2.863													
Bigelow, calibration coefficient applied:																						
2009	0.527						0.327															

Table A22. Stratified mean weight (kg), number, individual fish weight, and length (cm) per tow for goosefish from NEFSC shrimp summer surveys in the northern management region (strata 1, 3, 5-8); confidence limits for indices; minimum and maximum lengths; number of fish caught, number of positive tows, and total number of tows completed. (SURVAN version 8.13)

	Biomass Raw Index			Abundance Raw Index				Length						Number of	Number of Nonzero	Number
	Mean	L95%	U95%	Mean	L95%	U95%	Ind wt	Min	5%	50%	Mean	95%	Max	Fish	Tows	of Tows
1991	1.957	1.165	2.749	2.903	2.268	3.538	0.654	11	15	24	27.5	59	96	125	39	43
1992	2.915	1.399	4.431	2.907	2.27	3.544	0.928	11	13	28	31.5	56	78	135	40	45
1993	3.342	1.388	5.297	3.757	2.699	4.814	0.829	7	9	23	27.6	59	102	170	42	46
1994	1.644	0.837	2.452	3.475	2.430	4.520	0.484	5	10	19	24.1	48	95	166	37	43
1995	1.637	0.729	2.544	2.087	1.216	2.958	0.747	11	19	26	31.2	67	76	83	24	35
1996	3.431	1.331	5.530	2.967	2.105	3.830	1.123	13	14	34	34.4	63	90	107	30	32
1997	2.081	1.040	3.122	1.583	1.073	2.093	1.321	11	16	32	37.7	62	73	72	31	40
1998	2.301	0.714	3.888	2.118	1.500	2.735	1.070	12	16	23	31.3	61	77	84	31	35
1999	6.347	4.766	7.928	7.016	5.305	8.727	0.927	8	9	28	30.9	65	82	301	39	42
2000	4.121	2.090	6.152	5.756	4.101	7.412	0.671	11	15	28	30.2	51	82	215	30	35
2001	8.553	4.443	12.662	11.124	8.463	13.786	0.668	11	13	26	29.5	51	85	442	36	36
2002	12.857	9.180	16.535	11.789	9.379	14.198	1.067	11	17	32	35.3	59	94	493	38	38
2003	8.243	4.470	12.015	5.855	4.174	7.535	1.268	3	13	38	37.4	63	87	236	36	37
2004	4.604	3.464	5.744	3.388	2.662	4.113	1.315	11	11	34	35.7	66	75	142	33	35
2005	7.599	5.133	10.064	5.254	4.185	6.323	1.382	9	14	34	37.4	66	89	271	44	46
2006	7.360	3.812	10.908	4.344	3.089	5.598	1.519	7	11	30	37.2	70	89	143	29	29
2007	5.134	1.844	8.423	4.386	3.264	5.507	0.919	9	11	19	28.2	64	79	218	36	43
2008	3.895	2.120	5.671	2.849	2.078	3.620	1.346	10	14	32	36.1	67	82	116	31	37
2009	4.229	1.519	6.939	3.099	2.361	3.837	1.030	11	13	30	32.7	60	80	159	45	49

Table A23. Monkfish indices from Maine-New Hampshire surveys, strata 1-4.

Year	Fall Stratified Mean Number	SE	Fall Stratified Mean Weight	SE
2000	4.8	0.6	1.65	0.28
2001	11.1	1.6	4.83	0.50
2002	4.1	1.1	3.45	1.14
2003	3.7	0.6	3.60	0.80
2004	3.0	0.5	3.63	0.84
2005	1.8	0.2	2.04	0.47
2006	2.9	0.3	1.79	0.20
2007	3.1	0.4	2.13	0.35
2008	4.1	0.7	2.96	0.41
2009	2.0	0.4	1.93	0.52

Year	Spring Stratified Mean Number	SE	Spring Stratified Mean Weight	SE
2001	6.0	0.91	0.99	0.15
2002	2.4	0.33	1.12	0.17
2003	1.0	0.14	0.64	0.18
2004	1.4	0.17	0.41	0.12
2005	1.1	0.16	0.79	0.15
2006	0.3	0.06	0.15	0.03
2007	1.1	0.18	0.38	0.10
2008	1.37	0.19	0.49	0.08
2009	0.79	0.11	0.20	0.04

Table A24. Stratified mean weight (kg), number, individual fish weight, and length (cm) per tow for goosefish from NEFSC offshore research vessel autumn bottom trawl surveys in the southern management region (strata 1-19, 61-76); confidence limits for both the raw index and the indices smoothed using an integrated moving average (theta = 0.45); minimum and maximum lengths; number of fish caught, number of positive tows, and total number of tows completed each year.

	Biomass						Abundance							Length						Number	Number of	
	Raw Index			Smoothed Index			Raw Index			Smoothed Index										of	Nonzero	Number
	Mean	L95%	U95%	Mean	L95%	U95%	Mean	L95%	U95%	Mean	L95%	U95%	Ind wt	Min	5%	50%	Mean	95%	Max	Fish	Tows	of Tows
1963	3.642	1.818	5.466	4.237			1.197	0.737	1.656	1.270			2.969	7	17	53	50.4	91	97	102	36	73
1964	6.139	2.667	9.612	4.691			1.637	0.907	2.366	1.322			3.482	14	21	53	52.0	86	101	132	34	83
1965	5.093	2.907	7.279	4.335			1.148	0.778	1.519	1.192			4.247	10	15	59	56.3	91	104	83	39	85
1966	7.060	5.062	9.057	3.594	2.156	5.991	1.926	1.364	2.488	1.102	0.650	1.870	3.607	7	7	51	49.6	87	98	101	56	87
1967	1.151	0.623	1.679	1.893	1.136	3.155	0.519	0.324	0.715	0.700	0.413	1.188	2.195	14	19	31	40.6	83	100	98	42	163
1968	0.904	0.461	1.346	1.393	0.836	2.322	0.399	0.206	0.591	0.544	0.321	0.923	2.211	12	17	45	46.3	75	86	77	39	164
1969	1.360	0.506	2.214	1.370	0.822	2.284	0.537	0.308	0.766	0.520	0.307	0.883	2.466	10	14	41	45.4	88	96	101	43	163
1970	1.340	0.643	2.037	1.355	0.813	2.258	0.350	0.235	0.466	0.487	0.287	0.827	3.632	4	13	55	53.3	84	104	58	35	161
1971	0.711	0.282	1.139	1.350	0.810	2.250	0.282	0.150	0.414	0.570	0.336	0.967	2.788	5	8	39	42.3	95	98	55	28	168
1972	5.045	3.374	6.716	2.068	1.241	3.447	4.113	1.281	6.944	1.070	0.631	1.816	1.298	12	16	23	31.8	74	99	604	85	161
1973	2.030	1.036	3.025	1.740	1.044	2.901	1.176	0.857	1.495	0.813	0.479	1.379	1.568	13	14	32	37.7	77	93	280	70	154
1974	0.710	0.322	1.098	1.320	0.792	2.201	0.218	0.116	0.320	0.482	0.284	0.817	3.277	14	16	54	52.9	81	101	56	26	153
1975	2.050	1.333	2.767	1.519	0.912	2.533	0.653	0.434	0.871	0.487	0.287	0.825	2.653	8	17	45	46.3	87	105	127	51	158
1976	1.093	0.547	1.639	1.430	0.858	2.384	0.314	0.189	0.438	0.403	0.238	0.684	3.166	11	11	51	50.7	77	95	60	34	165
1977	1.883	1.203	2.563	1.612	0.967	2.688	0.372	0.265	0.479	0.395	0.233	0.670	4.170	5	16	55	53.1	95	106	94	50	172
1978	1.395	0.883	1.906	1.638	0.982	2.730	0.259	0.178	0.340	0.403	0.238	0.683	4.469	13	17	61	56.5	87	101	68	39	219
1979	2.275	1.278	3.272	1.853	1.112	3.089	0.694	0.483	0.905	0.553	0.326	0.938	2.307	7	16	34	40.5	84	109	182	70	205
1980	1.883	1.181	2.585	1.826	1.096	3.044	0.726	0.427	1.024	0.652	0.384	1.105	2.211	3	16	34	41.6	85	104	113	42	159
1981	2.864	0.889	4.840	1.763	1.058	2.939	0.965	0.579	1.351	0.714	0.421	1.211	1.961	6	17	38	40.7	71	99	176	59	146
1982	0.657	0.361	0.953	1.229	0.737	2.048	0.610	0.373	0.847	0.638	0.376	1.083	1.060	13	15	26	32.5	66	73	98	42	143
1983	2.156	0.700	3.611	1.304	0.782	2.174	0.776	0.470	1.082	0.589	0.347	0.999	2.304	7	16	45	44.4	72	100	109	49	146
1984	0.750	0.158	1.343	0.987	0.592	1.645	0.311	0.114	0.508	0.451	0.266	0.765	2.445	5	13	47	45.7	68	93	42	25	146
1985	1.327	0.761	1.893	0.899	0.539	1.498	0.524	0.356	0.692	0.443	0.261	0.752	2.055	17	17	40	42.0	72	96	100	46	145
1986	0.561	0.245	0.877	0.630	0.378	1.049	0.325	0.169	0.481	0.389	0.229	0.660	1.523	7	14	34	37.6	68	78	60	33	146
1987	0.276	0.118	0.433	0.477	0.286	0.794	0.482	0.308	0.657	0.385	0.227	0.654	0.575	12	13	20	25.0	56	61	67	27	132
1988	0.554	0.210	0.898	0.521	0.312	0.868	0.230	0.097	0.364	0.328	0.194	0.557	2.376	19	27	36	45.1	87	91	27	19	129
1989	0.642	0.300	0.985	0.546	0.328	0.910	0.382	0.182	0.582	0.356	0.210	0.603	1.366	7	7	42	38.0	57	77	57	23	129
1990	0.445	0.047	0.844	0.514	0.308	0.856	0.294	0.115	0.472	0.367	0.216	0.623	1.050	9	13	24	33.1	61	81	47	22	136
1991	0.797	0.244	1.349	0.532	0.319	0.886	0.690	0.248	1.133	0.440	0.259	0.746	0.901	14	15	23	30.8	57	81	106	27	131
1992	0.318	0.193	0.444	0.419	0.252	0.699	0.342	0.223	0.461	0.390	0.230	0.661	0.919	8	11	30	32.2	54	74	46	21	129
1993	0.295	0.058	0.532	0.399	0.239	0.664	0.290	0.136	0.444	0.377	0.222	0.639	0.784	10	13	32	30.4	52	68	46	24	130
1994	0.620	0.190	1.050	0.464	0.278	0.773	0.598	0.353	0.843	0.434	0.256	0.737	0.906	8	12	25	29.2	59	83	85	31	135
1995	0.413	0.186	0.640	0.443	0.266	0.739	0.493	0.259	0.727	0.404	0.238	0.685	0.777	11	13	25	29.4	54	66	72	29	129
1996	0.387	0.217	0.557	0.445	0.267	0.741	0.235	0.132	0.338	0.329	0.194	0.557	1.638	18	19	42	42.3	62	68	31	21	131
1997	0.592	0.354	0.829	0.490	0.294	0.816	0.308	0.198	0.418	0.335	0.197	0.568	1.914	9	9	49	44.6	70	71	43	24	131
1998	0.500	0.244	0.756	0.475	0.285	0.792	0.332	0.150	0.514	0.361	0.213	0.612	1.525	11	11	36	37.0	68	87	45	20	131
1999	0.304	0.196	0.412	0.445	0.267	0.741	0.450	0.319	0.582	0.410	0.242	0.696	0.672	12	14	27	29.2	52	55	109	44	106
2000	0.485	0.269	0.700	0.538	0.323	0.896	0.422	0.270	0.575	0.439	0.259	0.745	1.102	5	15	33	34.3	63	70	64	30	132
2001	0.712	0.373	1.050	0.696	0.418	1.161	0.378	0.239	0.518	0.483	0.285	0.819	1.724	4	11	39	41.69	70	80	51	30	130
2002	1.315	0.785	1.846	0.889	0.533	1.482	0.829	0.565	1.092	0.626	0.369	1.062	1.514	6	14	41	39.12	61	81	110	47	130
2003	0.827	0.542	1.112	0.872	0.523	1.455	0.951	0.627	1.276	0.671	0.395	1.139	0.858	6	7	18	28.25	59	70	128	41	130
2004	0.969	0.332	1.606	0.886	0.529	1.485	0.474	0.247	0.702	0.569	0.334	0.970	1.598	7	15	45	40.36	64	78	67	32	133
2005	0.804	0.409	1.198	0.849	0.498	1.447	0.575	0.339	0.811	0.546	0.314	0.949	1.309	7	13	42	38.47	57	67	76	34	123
2006	0.834	0.379	1.288	0.843	0.456	1.559	0.452	0.280	0.624	0.506	0.268	0.956	1.660	6	12	44	40.6	65	77	83	36	151
2007	0.505	0.247	0.764				0.195	0.106	0.284				2.571	25	25	51	50.1	68	69	27	19	142
2008	0.412	0.112	0.712				0.198	0.098	0.305				2.076	4	4	45	38.6	69	88	39	20	142
Bigelow, no calibration coefficient applied:																						
2009	1.524	1.303	1.767				1.417	1.197	1.658				1.2	6	7	63	33.4	27	77	351	85	176
Bigelow, calibration coefficient applied:																						
2009	0.189						0.199															

Table A25. Stratified mean weight (kg), number, individual fish weight, and length (cm) per tow for goosefish from NEFSC offshore research vessel spring bottom trawl surveys in the southern management region (strata 1-19, 61-76); confidence limits for both the raw index and the indices smoothed using an integrated moving average (theta = 0.45); minimum and maximum lengths; number of fish caught, number of positive tows, and total number of tows completed each year. Data prior to 1971 has been revised following an audit of historical data and the data reflect an increase in precision in the calculations of delta distributions. (SAGA version 3.55)

	Biomass						Abundance														Number	Number of	
	Raw Index			Smoothed Index			Raw Index			Smoothed Index				Length							of	Nonzero	Number
	Mean	L95%	U95%	Mean	L95%	U95%	Mean	L95%	U95%	Mean	L95%	U95%	Ind wt	Min	5%	50%	Mean	95%	Max	Fish	Tows	of Tows
1968	1.159	0.568	1.750	1.083			0.212	0.126	0.297	0.217			5.414	21	23	63	62.5	94	95	65	31	150
1969	0.955	0.444	1.466	1.034			0.221	0.138	0.305	0.220			4.097	7	25	47	54.3	91	111	41	31	155
1970	1.009	0.465	1.553	1.042			0.176	0.104	0.248	0.223			5.648	22	22	65	63.9	102	108	40	31	166
1971	0.769	0.322	1.216	1.072	0.653	1.761	0.204	0.105	0.304	0.264	0.173	0.403	3.675	13	16	50	53.3	101	115	42	24	160
1972	1.892	1.172	2.612	1.379	0.840	2.265	0.364	0.266	0.461	0.373	0.244	0.569	5.169	14	22	59	59.1	103	123	79	48	165
1973	1.897	1.539	2.255	1.435	0.874	2.357	1.051	0.854	1.249	0.534	0.350	0.816	2.172	11	19	32	41.1	80	110	589	128	187
1974	1.164	0.769	1.560	1.238	0.754	2.032	0.486	0.369	0.604	0.486	0.318	0.742	3.236	14	21	44	49.1	93	117	201	70	132
1975	0.947	0.574	1.320	1.112	0.677	1.827	0.447	0.326	0.568	0.441	0.289	0.674	2.795	10	22	44	47.6	87	107	169	61	134
1976	1.209	0.833	1.585	1.114	0.678	1.829	0.404	0.307	0.500	0.397	0.260	0.607	3.340	13	22	48	51.5	91	110	259	78	162
1977	1.205	0.771	1.640	1.055	0.642	1.733	0.299	0.231	0.367	0.354	0.232	0.540	4.607	16	21	51	56.8	95	116	173	75	160
1978	0.745	0.522	0.968	0.914	0.557	1.501	0.335	0.265	0.405	0.353	0.231	0.538	2.986	11	17	39	45.9	90	104	196	66	161
1979	0.757	0.464	1.051	0.908	0.553	1.492	0.281	0.164	0.397	0.364	0.238	0.555	2.944	10	14	37	44.4	98	124	125	50	194
1980	0.799	0.494	1.104	1.021	0.621	1.676	0.451	0.355	0.548	0.446	0.292	0.681	1.926	18	21	34	40.8	83	106	346	99	204
1981	1.816	1.157	2.475	1.351	0.823	2.219	0.784	0.542	1.027	0.543	0.356	0.830	2.563	12	22	40	44.6	89	113	345	74	141
1982	2.810	1.591	4.028	1.467	0.893	2.410	0.942	0.657	1.226	0.517	0.339	0.790	2.324	11	14	38	42.4	89	104	251	68	150
1983	0.955	0.421	1.489	1.029	0.627	1.690	0.270	0.176	0.365	0.329	0.216	0.503	3.514	24	24	47	51.8	97	112	55	36	147
1984	0.748	0.223	1.272	0.759	0.462	1.247	0.182	0.090	0.275	0.239	0.157	0.365	4.067	21	21	47	50.9	96	97	35	22	149
1985	0.327	0.089	0.565	0.565	0.344	0.928	0.159	0.072	0.247	0.209	0.137	0.319	2.052	22	22	39	42.3	85	90	31	21	147
1986	0.832	0.352	1.312	0.608	0.371	0.999	0.283	0.125	0.442	0.219	0.144	0.335	2.917	15	24	43	48.7	90	102	65	36	149
1987	0.496	-0.014	1.007	0.531	0.323	0.871	0.108	0.054	0.162	0.194	0.127	0.296	4.612	15	15	59	52.7	102	103	30	21	150
1988	0.427	0.302	0.552	0.484	0.295	0.795	0.440	0.286	0.595	0.253	0.166	0.387	0.971	17	18	30	34.0	61	82	67	33	132
1989	0.365	0.237	0.493	0.480	0.292	0.789	0.202	0.102	0.302	0.229	0.150	0.349	1.500	15	24	41	41.4	69	79	36	18	129
1990	1.005	0.565	1.445	0.573	0.349	0.941	0.205	0.152	0.258	0.224	0.147	0.343	4.034	16	21	53	56.5	86	93	39	23	128
1991	0.590	0.316	0.865	0.469	0.285	0.770	0.319	0.144	0.494	0.234	0.153	0.357	1.509	15	23	33	37.6	69	101	61	31	132
1992	0.210	0.070	0.350	0.329	0.200	0.540	0.177	0.089	0.266	0.198	0.130	0.302	1.235	14	19	28	35.0	69	85	28	17	128
1993	0.264	0.098	0.430	0.311	0.189	0.511	0.195	0.099	0.292	0.180	0.118	0.275	1.319	17	19	38	38.6	56	72	29	18	128
1994	0.321	0.138	0.504	0.329	0.200	0.540	0.114	0.058	0.170	0.156	0.102	0.238	2.379	13	13	41	44	91	93	24	18	131
1995	0.526	0.032	1.020	0.353	0.215	0.579	0.196	0.109	0.283	0.166	0.109	0.254	2.637	18	19	38	46	80	81	32	20	129
1996	0.286	0.146	0.426	0.289	0.176	0.475	0.135	0.075	0.196	0.158	0.104	0.242	2.083	9	9	44	44	80	81	27	20	143
1997	0.132	0.071	0.193	0.239	0.146	0.393	0.124	0.070	0.177	0.168	0.110	0.256	1.064	18	18	37	36	58	75	38	14	130
1998	0.282	0.190	0.374	0.295	0.180	0.485	0.254	0.175	0.333	0.218	0.143	0.333	1.110	12	16	35	36	64	77	40	30	131
1999	0.629	0.375	0.883	0.376	0.229	0.618	0.335	0.229	0.441	0.256	0.168	0.391	1.899	16	19	41	43	74	94	63	32	131
2000	0.294	0.179	0.408	0.339	0.206	0.556	0.242	0.155	0.329	0.250	0.164	0.382	1.222	14	14	38	38	61	78	32	25	131
2001	0.243	0.094	0.393	0.336	0.204	0.551	0.234	0.136	0.332	0.251	0.164	0.383	1.092	11	15	34	36	57	68	44	50	89
2002	0.375	0.134	0.616	0.413	0.252	0.679	0.318	0.096	0.540	0.263	0.172	0.401	1.181	22	23	37	39	53	62	50	50	91
2003	1.423	0.894	1.953	0.543	0.330	0.892	0.308	0.200	0.415	0.242	0.158	0.369	3.721	15	29	57	57	80	87	65	30	86
2004	0.193	0.061	0.324	0.373	0.226	0.616	0.116	0.055	0.178	0.189	0.123	0.290	1.565	22	21	37	40	61	62	24	36	88
2005	0.369	0.234	0.504	0.399	0.238	0.671	0.259	0.111	0.407	0.206	0.132	0.320	1.424	20	20	36	39	61	68	41	26	131
2006	0.540	0.216	0.863	0.451	0.248	0.819	0.172	0.097	0.247	0.191	0.115	0.319	3.136	24	15	37	53	80	80	28	20	132
2007	0.559	0.295	0.823				0.259	0.172	0.345				2.136	20	23	48	46	69	75	77	30	158
2008	0.3866	0.137	0.636				0.1887	0.0731	0.3044				2.064	17	17	41	46	64	84	32	19	140
Bigelow, no calibration coefficient applied:																						
2009	3.0167	1.467	4.566				1.1726	0.8171	1.5281													
Bigelow, calibration coefficient applied:																						
2009	0.374						0.164															

Table A26. Stratified mean weight (kg), number, individual fish weight, and length (cm) per tow for goosefish from NEFSC winter flatfish surveys in the southern management region (strata 1-3, 5-7, 9-11, 13-14, 61-63, 65-67, 69-71, 73-75); confidence limits for indices; minimum and maximum lengths; number of fish caught, number of positive tows, and total number of tows completed. The last survey in this time series was completed in 2007.

	Biomass Raw Index			Abundance Raw Index				Length						Number of Fish	Number of Nonzero Tows	Number of Tows
	Mean	L95%	U95%	Mean	L95%	U95%	Ind wt	Min	5%	50%	Mean	95%	Max			
1992	6.314	4.160	8.468	5.234	3.854	6.614	1.139	11	22	33	36.0	51	95	582	66	100
1993	6.357	4.563	8.150	4.952	3.898	6.005	1.193	9	21	36	37.7	53	98	555	77	108
1994	3.321	2.372	4.270	2.484	1.870	3.097	1.298	8	16	31	35.1	61	78	278	56	77
1995	3.774	2.472	5.076	3.137	2.104	4.170	1.209	19	21	35	37.4	57	101	365	76	106
1996	4.496	3.435	5.557	3.438	2.662	4.213	1.294	10	22	37	39.1	57	100	456	87	119
1997	4.460	3.190	5.731	2.976	2.323	3.629	1.456	10	18	39	39.8	59	82	359	89	107
1998	2.849	1.997	3.701	1.494	1.150	1.838	1.876	10	20	41	44.1	69	103	203	77	114
1999	4.090	3.066	5.114	3.068	2.370	3.767	1.319	10	17	34	37.8	61	87	362	83	115
2000	5.690	4.023	7.356	4.428	3.166	5.689	1.265	11	24	103	39.2	103	96	616	93	118
2001	7.182	4.501	9.863	4.380	2.997	5.762	1.383	8	24	103	39.3	103	84	729	115	142
2002	6.235	4.794	7.675	3.474	2.737	4.212	1.744	15	30	103	44.5	103	86	550	113	143
2003	5.482	3.491	7.473	2.258	1.580	2.937	2.418	12	25	103	45.5	103	85	316	72	86
2004	7.171	4.308	10.034	4.397	2.836	5.957	1.568	13	23	103	41.2	103	88	682	103	123
2005	4.531	2.657	6.405	2.972	2.043	3.902	1.497	13	23	103	40.0	103	90	313	59	91
2006	5.481	4.022	6.939	3.082	2.327	3.837	1.743	22	31	103	44.7	103	92	430	78	114
2007	3.395	2.586	4.205	1.472	1.212	1.732	2.251	14	23	42	48.3	103	91	217	83	118

Table A27. Stratified mean number and length (cm) per tow for goosefish from NEFSC summer scallop surveys in the southern management region (shellfish strata 6, 7, 10, 11, 14, 15, 18, 19, 22-31, 33-35, 46, 47, 55, 58-61, 621, 631); confidence limits for the raw index using an integrated moving average (theta = 0.45); minimum and maximum lengths; number of fish caught, number of positive tows, and the total number of tows completed each year. (SURVAN version 8.13)

	Abundance														
	Raw Index			Smoothed Index			Length						Number of Fish	Number of Nonzero Tows	Number of Tows
	Mean	L95%	U95%	Mean	L95%	U95%	Min	5%	50%	Mean	95%	Max			
1984	1.285	1.109	1.461				6	11	28	29.5	54	82	410	165	254
1985	1.521	1.256	1.786				7	9	25	28.7	53	84	493	183	282
1986	1.246	1.045	1.446				8	10	15	22.9	54	95	431	183	296
1987	3.152	2.767	3.537				8	9	13	18.6	51	90	1253	255	315
1988	1.666	1.385	1.947				7	12	28	29.8	49	97	572	187	316
1989	0.995	0.833	1.156				6	10	31	31.9	53	101	303	147	304
1990	1.534	1.339	1.729				6	10	18	24.4	54	94	563	205	303
1991	2.284	1.994	2.574				7	9	14	21.0	45	94	808	241	315
1992	1.939	1.661	2.217				5	9	25	27.3	52	97	644	235	316
1993	2.845	2.568	3.123				8	10	15	21.8	48	73	995	258	301
1994	3.401	3.006	3.796				8	10	15	22.2	51	87	1145	265	314
1995	2.263	1.968	2.558				7	9	27	29.6	57	92	764	243	314
1996	2.005	1.746	2.265				7	9	23	29.9	59	81	638	226	298
1997	1.110	0.954	1.265				7	13	33	36.7	65	76	388	196	313
1998	1.014	0.876	1.152				6	11	20	30.2	61	79	371	183	319
1999	2.592	2.161	3.022				6	10	16	23.5	55	84	856	248	306
2000	2.242	1.973	2.510				8	9	18	27.3	54	87	832	240	315
2001	1.710	1.484	1.936				7	8	35	36.0	64	77	549	233	334
2002	1.711	1.488	1.933				7	11	35	34.2	60	86	598	203	310
2003	2.784	2.394	3.174				6	9	15	24.4	58	87	819	211	294
2004	2.875	2.506	3.244				9	11	26	29.8	61	83	860	290	348
2005	2.013	1.753	2.274				8	10	28	31.3	56	83	859	265	344
2006	1.445	1.272	1.618				7	7	29	31.1	61	83	571	230	327
2007	0.8272	0.6938	0.9606				7	12	39	40.2	69	84	366	183	336
2008	1.0024	0.8283	1.1765				7	7	26	31.297	68	75	350	162	285
2009	0.7858	0.6341	0.9375				6	10	25	30.9	65	80	248	133	269

Table A28. Stratified mean weight (kg), number, individual fish weight, and length (cm) per tow for goosefish from NEFSC offshore research vessel autumn bottom trawl surveys in the northern and southern management regions; confidence limits for both the raw index and the indices smoothed using an integrated moving average (theta = 0.45); minimum and maximum lengths; number of fish caught, number of positive tows, and total number of tows completed each year.

	Biomass			Abundance												
	Raw Index			Raw Index				Length						Number of Fish	Number of Nonzero Tows	Number of Tows
	Mean	L95%	U95%	Mean	L95%	U95%	Ind wt	Min	5%	50%	Mean	95%	Max			
1963	7.4	3.046	11.75	0.993	0.725	1.261	7.951	7	16	55	53.9	96	111	188	75	164
1964	3.822	2.846	4.798	0.985	0.626	1.343	3.994	14	20	54	53.5	89	102	164	57	170
1965	4.627	2.924	6.331	0.728	0.542	0.915	6.433	10	19	62	60.1	93	110	123	69	173
1966	5.3	4.137	6.464	1.185	0.903	1.466	4.42	7	8	57	55.0	89	98	214	88	169
1967	2.027	1.148	2.907	0.381	0.26	0.501	5.578	14	19	41	46.8	91	100	116	56	250
1968	2.697	1.224	4.169	0.351	0.219	0.484	7.913	11	20	53	54.8	89	106	109	55	250
1969	3.291	1.884	4.697	0.487	0.342	0.632	7.024	10	16	56	56.9	95	110	134	70	240
1970	3.341	1.731	4.952	0.369	0.27	0.468	8.895	4	17	58	59.5	90	104	99	56	251
1971	3.529	1.309	5.749	0.37	0.262	0.477	8.715	5	9	58	56.1	95	101	99	55	262
1972	8.911	5.512	12.31	2.52	0.876	4.164	4.464	12	16	23	33.1	75	99	633	107	252
1973	4.34	2.018	6.662	0.898	0.696	1.1	4.769	13	15	36	44.3	92	112	343	99	246
1974	2.014	0.945	3.084	0.258	0.179	0.337	7.69	13	14	63	59.0	97	111	93	49	250
1975	2.763	1.736	3.791	0.504	0.368	0.64	5.385	8	17	50	50.4	89	105	167	78	264
1976	2.103	1.265	2.941	0.359	0.255	0.464	5.504	11	27	62	61.3	94	121	92	58	252
1977	3.445	2.487	4.403	0.479	0.385	0.573	7.05	5	19	64	63.0	99	119	206	106	298
1978	2.987	2.247	3.727	0.393	0.315	0.472	7.159	10	18	65	63.4	99	116	214	117	420
1979	3.562	2.659	4.465	0.604	0.471	0.736	5.338	7	16	47	51.1	97	115	307	148	416
1980	3.115	2.056	4.174	0.645	0.458	0.832	4.667	3	16	40	49.4	98	111	178	81	256
1981	2.705	1.469	3.94	0.73	0.501	0.96	3.244	6	17	42	44.6	80	101	222	89	239
1982	0.885	0.516	1.254	0.414	0.273	0.554	2.142	13	15	32	37.7	75	100	115	56	238
1983	2.214	1.18	3.248	0.651	0.455	0.847	3.123	7	16	48	47.0	79	100	147	76	228
1984	1.9	1.112	2.689	0.383	0.257	0.51	4.825	5	13	56	54.7	93	106	78	54	234
1985	1.548	0.915	2.18	0.459	0.336	0.582	3.456	12	17	44	45.7	88	102	132	69	233
1986	1.827	0.708	2.947	0.442	0.311	0.573	4.018	7	17	43	46.9	81	100	106	59	236
1987	0.541	0.267	0.816	0.392	0.273	0.511	1.383	12	14	22	32.6	65	96	89	42	219
1988	0.957	0.48	1.433	0.265	0.156	0.374	3.607	11	23	46	51.0	89	93	53	36	218
1989	1.419	0.707	2.132	0.401	0.266	0.536	3.49	7	8	41	39.2	84	96	96	48	216
1990	1.295	0.71	1.879	0.418	0.282	0.554	3.034	9	10	25	32.6	70	89	102	57	225
1991	1.536	0.837	2.235	0.643	0.372	0.914	2.294	9	13	27	33.6	69	95	168	60	219
1992	1.08	0.562	1.597	0.59	0.434	0.746	1.886	8	8	27	32.7	72	86	124	58	215
1993	1.777	0.813	2.74	0.58	0.427	0.733	2.752	6	9	22	28.1	56	94	149	69	216
1994	1.512	0.636	2.389	0.91	0.697	1.124	1.523	8	10	21	26.5	56	98	195	82	222
1995	1.429	0.655	2.203	0.671	0.503	0.838	2.039	10	13	33	35.2	69	91	159	69	222
1996	0.781	0.445	1.117	0.399	0.288	0.509	1.946	8	14	40	41.0	63	95	82	51	219
1997	1.135	0.662	1.607	0.387	0.284	0.49	2.913	8	9	40	39.7	70	86	82	51	221
1998	1	0.634	1.367	0.447	0.309	0.585	2.199	10	10	30	36.2	68	87	101	58	235
1999	1.051	0.498	1.603	0.713	0.55	0.876	1.265	8	9	23	27.1	54	81	220	80	236
2000	1.656	1.027	2.285	1.242	0.885	1.599	1.315	5	11	25	31.1	65	88	229	77	219
2001	1.276	0.84	1.711	0.894	0.706	1.081	1.289	4	11	32	36.4	65	93	196	80	220
2002	1.732	1.134	2.33	1.017	0.802	1.232	1.466	6	10	37	37.0	63	93	224	92	216
2003	1.614	0.902	2.327	0.999	0.775	1.224	1.227	6	8	25	32.5	62	88	218	80	218
2004	0.827	0.424	1.229	0.492	0.334	0.649	1.434	7	8	29	35.7	66	89	103	56	218
2005	1.144	0.491	1.798	0.583	0.414	0.752	1.468	7	8	32	36.7	66	88	122	63	217
2006	0.92	0.579	1.261	0.582	0.438	0.725	1.49	6	7	38	36.6	65	86	139	74	245
2007	0.793	0.441	1.145	0.379	0.279	0.479	1.949	9	17	36	41.3	77	90	89	51	232
2008	0.652	0.342	0.963	0.44	0.284	0.596	1.458	4	5	29	33.5	68	88	100	47	232
2009	2.949	2.129	3.769	2.166	1.79	2.541	1.288	6	9	30	34.1	68	101	608	146	266

Table A29. Stratified mean weight (kg), number, individual fish weight, and length (cm) per tow for goosefish from NEFSC offshore research vessel spring bottom trawl surveys in the northern and southern management regions; confidence limits for both the raw index and the indices smoothed using an integrated moving average (theta = 0.45); minimum and maximum lengths; number of fish caught, number of positive tows, and total number of tows completed each year.

	Biomass			Abundance										Number	Number of	
	Raw Index			Raw Index				Length						of	Nonzero	Number
	Mean	L95%	U95%	Mean	L95%	U95%	Ind wt	Min	5%	50%	Mean	95%	Max	Fish	Tows	of Tows
1968	1.501	0.586	2.417	0.193	0.127	0.259	7.704	21	23	63	65.2	89	95	78	42	238
1969	1.139	0.56	1.718	0.204	0.129	0.278	5.458	7	21	63	61.2	95	111	56	41	242
1970	1.774	0.871	2.676	0.247	0.178	0.315	7.167	22	25	62	64.7	98	108	72	53	255
1971	0.948	0.573	1.322	0.185	0.117	0.253	5.061	13	20	58	60.2	99	115	62	39	257
1972	3.857	2.679	5.035	0.481	0.383	0.578	7.898	13	25	67	66.8	100	123	138	84	259
1973	2.629	1.862	3.397	0.792	0.637	0.948	3.667	11	20	41	46.8	88	110	680	164	274
1974	2.198	1.281	3.114	0.466	0.381	0.551	5.162	14	22	46	52.7	93	117	287	111	215
1975	1.301	0.85	1.751	0.402	0.318	0.487	3.449	10	21	47	49.8	87	109	242	97	221
1976	1.888	1.364	2.412	0.517	0.414	0.619	3.31	13	21	56	57.0	93	110	417	130	261
1977	1.152	0.835	1.469	0.284	0.226	0.342	3.796	10	23	58	59.5	93	116	234	113	268
1978	0.71	0.529	0.891	0.253	0.209	0.298	2.674	11	17	45	50.4	89	104	233	96	273
1979	0.951	0.587	1.315	0.221	0.152	0.291	3.66	10	14	42	49.3	99	123	173	90	333
1980	1.144	0.752	1.537	0.421	0.348	0.494	2.439	17	21	37	45.6	89	107	430	137	289
1981	1.786	1.268	2.303	0.612	0.466	0.759	2.832	11	22	42	48.0	93	120	440	116	228
1982	3.002	1.962	4.042	0.691	0.508	0.875	4.189	11	17	44	47.9	99	108	284	90	242
1983	1.22	0.679	1.761	0.332	0.222	0.442	3.593	12	19	49	50.8	96	112	89	58	237
1984	1.146	0.593	1.699	0.243	0.162	0.325	4.445	17	20	58	56.5	93	100	61	41	235
1985	1.754	0.956	2.552	0.238	0.158	0.317	7.387	13	21	55	57.3	104	108	56	42	228
1986	1.592	0.96	2.224	0.307	0.198	0.417	5.202	11	20	54	56.5	99	121	95	58	239
1987	1.115	0.561	1.669	0.165	0.11	0.219	6.774	15	15	65	59.8	99	103	51	37	233
1988	1.126	0.621	1.632	0.511	0.384	0.637	2.146	10	19	34	41.8	80	110	110	59	222
1989	1.181	0.531	1.831	0.377	0.238	0.516	2.945	10	11	40	42.6	74	94	84	42	214
1990	1.224	0.657	1.792	0.237	0.177	0.297	5.156	15	18	49	52.8	92	107	64	40	217
1991	1.48	0.665	2.295	0.432	0.295	0.569	3.087	12	15	33	40.2	78	101	109	59	218
1992	0.754	0.149	1.36	0.307	0.16	0.453	2.461	14	17	33	38.7	82	101	64	37	211
1993	1.082	0.584	1.58	0.399	0.295	0.502	2.838	10	12	42	40.3	71	90	88	45	215
1994	0.844	0.401	1.288	0.255	0.174	0.335	3.315	10	13	40	41.8	83	93	69	42	219
1995	1.371	0.679	2.064	0.523	0.38	0.665	2.744	15	16	34	41.2	75	97	115	59	217
1996	0.647	0.388	0.906	0.356	0.217	0.495	1.783	9	15	43	43.2	67	81	76	40	225
1997	0.408	0.225	0.591	0.214	0.132	0.295	1.925	9	11	36	38.2	75	89	72	33	219
1998	0.677	0.194	1.159	0.32	0.251	0.39	2.089	11	12	30	33.4	66	78	86	63	246
1999	1.085	0.585	1.584	0.535	0.406	0.665	2.068	9	15	32	38.2	71	97	125	65	218
2000	0.85	0.558	1.143	0.609	0.481	0.738	1.373	14	16	31	35.3	70	87	131	67	220
2001	0.96	0.422	1.497	0.836	0.635	1.037	1.106	9	12	27	32.0	71	86	195	76	220
2002	1.047	0.74	1.355	0.914	0.696	1.132	1.121	12	16	35	37.1	58	73	205	73	222
2003	1.821	1.102	2.541	0.517	0.365	0.668	3.064	10	14	47	48.5	74	95	144	57	211
2004	1.06	0.485	1.635	0.445	0.303	0.588	2.351	9	6	99	45.6	117	85	93	48	219
2005	1.069	0.421	1.717	0.445	0.319	0.571	1.839	11	8	100	43.1	115	75	93	57	218
2006	0.702	0.339	1.064	0.253	0.157	0.349	2.773	16	5	101	48.3	115	105	61	43	227
2007	1.01	0.06	1.96	0.382	0.244	0.519	2	11	7	99	40.6	117	85	120	49	244
2008	0.966	0.287	1.645	0.393	0.255	0.531	1.954	8	4	101	42.4	116	85	93	43	226
2009	3.529	2.441	4.618	1.653	1.349	1.957	1.885	11	5	101	42.0	115	93	0	127	297

Table A30. Age length key used for estimating mean lengths at age and variation from ages in the spring, winter, 2001 & 2004 cooperative, and fall surveys.

	age										
length	1	2	3	4	5	6	7	8	9	10	total
8	1										1
9	4										4
10	19										19
11	25	3									28
12	26	9									35
13	23	21									44
14	24	18									42
15	27	28									55
16	15	48									63
17	22	43									65
18	26	56	2								84
19	8	54	16								78
20	4	50	34								88
21		25	72								97
22		29	82								111
23		32	81	1							114
24		22	120								142
25		23	127								150
26		27	149								176
27		22	174	5							201
28		20	140	53							213
29		6	89	130							225
30		4	46	163							213
31		3	26	178							207
32			26	183							209
33			22	154							176
34		1	19	192							212
35			23	203							226
36			25	184							209
37			20	197	6						223
38			20	173	31						224
39			11	104	84						199
40			8	63	140						211
41			3	29	171						203
42				26	200						226
43			1	22	209						232
44				26	197						223
45				19	200						219
46				24	179						203
47				28	184	4					216
48				17	197	32					246
49				12	123	81					216
50				13	98	141					252
51				2	33	157					192
52				1	28	186					215
53					24	186					210
54					20	184					204
55					19	198					217
56					15	191	1				207
57					12	179	1				192
58					20	143	3				166
59					19	117	25				161
60					8	68	87				163
61					2	37	99				138
62						19	113				132
63					1	13	81				95
64						9	101				110
65						12	86				98
66						7	60				67
67						5	63				68
68						3	66				69
69						8	53	2			63
70						3	38	23			64
71						3	27	32			62
72							16	52			68
73							2	52			54
74							4	51			55
75							1	38			39
76							4	42			46
77							4	31			35
78							2	41			43
79							1	26			27
80							3	40	9		52
81							2	18	9		29
82							1	18	20		39
83								5	20		25
84								2	25		27
85								2	18		20
86								3	10	1	14
87								1	15		16
88								4	12		16
89								2	7		9
90									2	1	3
91									7		7
92									3	2	5
93									4		4
94									2		2
95								1	2	2	5
96									1	2	3
97									2		2
98									1	1	2
102										2	2
103										1	1
105										2	2
107										1	1
110										1	1
total	224	544	1336	2202	2220	1986	944	486	169	16	10127

Table A31. Area swept expansions used for scaling the stratified numbers per tow indices. Nm^2 represents the square nautical miles covered by the survey.

Survey	nm^2	footprint	expansions
Shrimp North	6,147	0.00350	1,756,286
Winter South	30,014	0.01270	2,363,307
Scallop South	13,204	0.00110	12,003,636
Fall & Spring North	26,265	0.01120	2,345,089
Fall & Spring South	37,081	0.01120	3,310,804
Fall and spring combine albatross	63,346	0.01120	5,655,893
Fall and spring combine Bigelow	63,346	0.00700	9,049,429
ME/NH Fall North	4,517	0.00462	977,324
MDMF Fall North	1,055	0.00385	274,311

Table A32. Northern area goosefish SCALE runs residual sum of squares, input weights & effective sample sizes, estimated Qs, Fstart, age-1 recruitment in year 1 (1980), and estimated logistic selectivity parameters (L_{50}, slope). First column under each run=weights, second column=residual sum of square.

Run number	2007		1		2		3		4		5		6		7		8	
Discription	Data Poor Final run		add 07-09		add ME/NH and MDMF		drop MDMF		est Fstart		high eff samp catch lf		low vrec		high vrec		Final WG run fix Fstart	
total objective function		241.34		263.77		428.14		289.85		288.54		509.84		267.04		338.43		291.22
total catch	10	0.68	10	1.67	10	4.12	10	3.27	10	3.53	10	11.49	10	4.69	10	1.10	10	3.57
catch len freq 1+	400	9.57	400	11.67	400	13.50	400	12.24	400	12.39	10k	207.35	400	14.43	400	11.31	400	12.35
Vrec	5	24.93	5	24.72	5	29.14	5	28.09	5	28.01	5	24.37	2	18.86	25	29.00	5	28.02
Fall age 1	2	32.41	2	35.19	2	35.45	2	35.15	2	34.83	2	43.23	2	29.25	2	50.20	2	34.69
Spring age 2	2	29.45	2	31.78	2	29.71	2	30.28	2	30.19	2	34.39	2	24.32	2	45.29	2	29.35
Spring age 3	2	30.78	2	31.79	2	31.68	2	31.55	2	31.79	2	34.76	2	29.69	2	40.59	2	32.16
Shrimp age 1	2	21.54	2	25.74	2	28.04	2	25.81	2	25.72	2	30.63	2	25.70	2	25.63	2	26.49
Shrimp age 2	2	6.52	2	7.13	2	6.15	2	6.46	2	6.46	2	11.14	2	6.03	2	9.23	2	6.35
Fall ME/NH age 1					2	15.92	2	16.40	2	16.38	2	20.67	2	15.33	2	20.14	2	15.76
Fall MDMF age 1					2	16.11												
Fall adult 40+	3	15.96	3	15.68	3	13.74	3	14.80	3	14.52	3	12.98	3	14.54	3	14.41	3	15.17
Spring adult 40+	3	12.84	3	14.00	3	12.84	3	13.09	3	11.33	3	9.59	3	11.41	3	12.65	3	14.32
Shrimp adult 40+	3	15.11	3	17.83	3	20.59	3	18.25	3	18.48	3	15.09	3	17.69	3	22.02	3	18.60
Fall ME/NH 40+					3	3.00	3	3.51	3	3.33	3	3.90	3	2.73	3	5.51	3	3.35
Fall MDMF 40+					3	24.30												
Fall len freq 30+	25	13.82	25	14.78	25	15.16	25	14.94	25	15.26	25	15.00	25	15.44	25	14.75	25	14.96
Spring len freq 30+	25	13.18	25	14.21	25	14.60	25	14.37	25	14.67	25	14.59	25	14.90	25	14.12	25	14.40
Shrimp len freq 30+	75	14.28	75	15.85	75	16.29	75	15.91	75	15.95	75	15.11	75	16.25	75	16.24	75	15.95
Coop len freq 30+	100	0.26	100	0.49	100	0.68	100	0.57	100	0.60	100	0.45	100	0.70	100	0.56	100	0.58
Fall Bigelow len freq 30+				0.72	100	0.90	100	0.78	100	0.80	100	0.90	100	0.86	100	0.68	100	0.79
Spring Bigelow len freq 30+				0.51	100	0.62	100	0.54	100	0.55	100	0.62	100	0.59	100	0.50	100	0.55
Fall ME/NH len freq 30+					50	3.60	50	3.85	50	3.74	50	3.61	50	3.61	50	4.51	50	3.81
Fall MDMF len freq 30+					50	91.99												
Q Fall age 1		0.024		0.009		0.011		0.010		0.010		0.011		0.010		0.007		0.010
Q Spring age 2		0.036		0.008		0.010		0.009		0.009		0.010		0.010		0.007		0.009
Q Spring age 3		0.049		0.014		0.017		0.016		0.016		0.017		0.017		0.012		0.016
Q Shrimp age 1		0.025		0.034		0.041		0.038		0.039		0.040		0.038		0.031		0.040
Q Shrimp age 2		0.038		0.098		0.116		0.109		0.110		0.115		0.108		0.088		0.112
Q ME/NH age 1						0.015		0.013		0.013		0.015		0.013		0.011		0.014
Q MDMF age 1						0.001												
Q Fall adult 40+		0.041		0.040		0.054		0.047		0.052		0.055		0.058		0.029		0.048
Q Spring adult 40+		0.044		0.043		0.059		0.051		0.056		0.060		0.062		0.032		0.052
Q Shrimp adult 40+		0.130		0.107		0.156		0.129		0.138		0.147		0.151		0.079		0.134
Q ME/NH adult 40+						0.066		0.051		0.055		0.057		0.059		0.033		0.054
Q MDMF adult 40+						0.003												
Fstart		0.01		0.01		0.01		0.01		0.36		0.39		0.36		0.12		0.01
recruitment year 1		20.5		18.8		15.7		16.5		16.6		15.9		14.3		25.7		16.1
Selectivity																		
block 1 (1980-2009)																		
alpha		42.7		43.1		56.5		47.7		49.3		49.2		56.4		39.2		48.9
beta		0.16		0.16		0.12		0.14		0.13		0.14		0.12		0.19		0.13

Table A33. Southern area goosefish SCALE runs residual sum of squares, input weights & effective sample sizes, estimated Qs, Fstart, age1 recruitment in year 1, and the estimated logistic selectivity parameters (L_{50}, slope). First column under each run are weights, residual sum of squares in the second .

Run number	2007		1		2		3		4		5		6		7		8	
Discription	Data Poor Final run		add 07-09		est Fstart		1 block		2 block		3 block		high eff samp catch lf		higher eff samp catch lf		Final run 2 block, fix Fstart	
total objective function		287.71		357.68		348.72		353.23		348.78		348.32		390.70		450.93		358.77
total catch	10	0.93	10	0.96	10	0.50	10	0.59	10	0.50	10	0.48	10	1.22	10	4.69	10	0.91
catch len freq 1+	400	9.22	400	12.12	400	12.33	400	13.22	400	12.53	400	11.67	2k	45.68	5k	91.47	400	12.09
Vrec	5	13.59	5	20.97	5	20.35	5	20.63	5	20.35	5	20.40	5	18.49	5	17.39	5	22.00
Fall age 1	2	29.50	2	49.64	2	49.10	2	49.34	2	49.14	2	48.99	2	51.08	2	53.65	2	49.34
Spring age 2	2	16.95	2	33.49	2	33.45	2	33.36	2	33.45	2	33.46	2	33.69	2	34.02	2	33.79
Spring age 3	2	36.32	2	40.27	2	40.15	2	40.41	2	40.16	2	40.14	2	41.03	2	42.46	2	40.00
Winter age 2	2	6.85	2	6.65	2	6.62	2	6.70	2	6.61	2	6.63	2	7.06	2	7.83	2	6.67
Winter age 3	2	12.27	2	13.21	2	12.98	2	13.24	2	12.97	2	12.98	2	12.69	2	12.92	2	13.03
Scallop age 1	3	29.31	3	33.14	3	32.87	3	33.08	3	32.89	3	32.82	3	35.12	3	37.69	3	32.55
Scallop age 2	3	13.56	3	16.39	3	16.06	3	16.27	3	16.07	3	16.03	3	17.11	3	18.70	3	15.95
Fall adult 40+	3	20.74	3	22.84	3	20.14	3	20.93	3	20.03	3	20.28	3	20.73	3	21.45	3	24.44
Spring adult 40+	3	27.87	3	28.86	3	24.54	3	26.43	3	24.46	3	24.75	3	24.65	3	25.36	3	28.82
winter adult 40+	3	4.08	3	5.18	3	5.01	3	5.18	3	5.00	3	5.08	3	5.21	3	5.37	3	5.25
Scallop adult 40+	3	16.66	3	17.42	3	17.73	3	16.78	3	17.76	3	17.65	3	19.28	3	20.93	3	17.36
fall len freq 30+	25	12.60	25	13.92	25	14.04	25	13.99	25	14.04	25	14.04	25	13.90	25	13.86	25	13.91
spring len freq 30+	25	16.84	25	17.98	25	18.02	25	18.00	25	18.02	25	18.01	25	18.02	25	18.10	25	17.97
winter len freq 30+	75	5.64	75	6.43	75	6.53	75	6.56	75	6.52	75	6.55	75	6.25	75	6.17	75	6.43
Coop len freq 30+	100	0.33	100	0.71	100	0.73	100	0.75	100	0.72	100	0.73	200	1.36	200	1.33	100	0.72
Scallop len freq 30+	75	14.46	75	16.37	75	16.42	75	16.61	75	16.41	75	16.47	75	16.01	75	15.67	75	16.40
Fall Bigelow len freq 30+			100	0.70	100	0.71	100	0.72	100	0.71	100	0.71	200	1.34	200	1.19	100	0.70
Spring Bigelow len freq 30+			100	0.42	100	0.44	100	0.44	100	0.43	100	0.44	200	0.80	200	0.68	100	0.43
Q Fall age 1		0.024		0.006		0.005		0.005		0.005		0.005		0.006		0.008		0.006
Q Spring age 2		0.045		0.002		0.002		0.002		0.002		0.002		0.002		0.003		0.002
Q Spring age 3		0.045		0.010		0.008		0.008		0.008		0.008		0.010		0.012		0.009
Q Winter age 2		0.038		0.010		0.008		0.008		0.008		0.008		0.010		0.012		0.010
Q Winter age 3		0.046		0.086		0.072		0.072		0.073		0.069		0.084		0.100		0.083
Q Scallop age 1		0.026		0.286		0.237		0.240		0.241		0.229		0.280		0.334		0.281
Q Scallop age 2		0.040		0.172		0.142		0.144		0.145		0.138		0.168		0.201		0.168
Q Fall adult 40+		0.027		0.025		0.020		0.019		0.021		0.019		0.025		0.033		0.023
Q Spring adult 40+		0.018		0.017		0.014		0.013		0.014		0.013		0.017		0.023		0.016
Q winter adult 40+		0.249		0.162		0.137		0.127		0.140		0.130		0.174		0.229		0.155
Q Scallop adult 40+		0.510		0.196		0.164		0.155		0.168		0.157		0.205		0.267		0.187
Fstart		0.2		0.2		0		0		0		0		0		0		0.2
recruitment year 1		31.05		27.4		32.2		32.3		31.7		33.4		26.9		31.5		28.1
Selectivity																		
block 1		80-95		80-95		80-95		80-09		80-95		80-95		80-95		80-95		80-01
alpha		40.238		47.802		25.83		43.99		25.87		25.81		32.33		37.13		45.59
beta		0.1304		0.1017		0.28		0.15		0.28		0.28		0.19		0.15		0.15
block 2		96-03		96-03		96-03				96-09		96-01		96-01		96-01		02-09
alpha		48.323		48.495		46.21				47.68		42.63		42.45		44.12		50.69
beta		0.1469		0.1456		0.16				0.15		0.19		0.18		0.17		0.13
block 3		04-07		04-07		04-07						02-07		02-07		02-07		
alpha		50.981		50.13		48.77						49.70		52.78		60		
beta		0.134		0.14		0.14						0.14		0.13		0.1196		

Table A34. Combined management area goosefish runs of residual sum of squares, input weights & effective sample sizes, estimated Qs, Fstart, age1 recruitment in year 1, and the estimated logistic selectivity parameters (L_{50}, slope). First column under each run are the weights. Residual sum of squares are in the second column.

Run number	1		2		3		4	
Discription	1 block combined		2 block		high eff samp catch lf		Final run add ME/NH	
total objective function		324.83		324.70		386.14		356.83
total catch	10	0.89	10	0.86	10	4.63	10	1.73
catch len freq 1+	400	8.60	400	8.36	4k	57.50	400	8.42
Vrec	5	16.05	5	15.90	5	15.06	5	17.59
Fall age 1	2	23.93	2	23.96	2	26.42	2	24.48
Spring age 2	2	26.71	2	26.82	2	27.86	2	25.05
Spring age 3	2	23.15	2	23.19	2	25.74	2	23.70
Winter age 2	2	8.97	2	8.96	2	9.39	2	9.41
Winter age 3	2	15.00	2	14.97	2	15.10	2	14.98
Scallop age 1	2	28.03	2	27.97	2	29.53	2	28.58
Scallop age 2	2	16.52	2	16.46	2	17.81	2	16.76
Shrimp age 1	2	31.58	2	31.51	2	31.84	2	32.18
Shrimp age 2	2	9.34	2	9.35	2	10.01	2	8.66
Fall ME/NH age 1							2	18.42
Fall adult 40+	3	10.55	3	10.66	3	9.56	3	11.81
Spring adult 40+	3	11.01	3	11.08	3	10.25	3	11.70
winter adult 40+	3	5.48	3	5.53	3	4.68	3	5.32
Scallop adult 40+	3	12.47	3	12.49	3	14.17	3	12.56
Shrimp adult 40+	3	21.06	3	21.11	3	22.03	3	21.12
Fall ME/NH 40+							3	4.77
fall len freq 30+	25	7.27	25	7.27	25	7.20	25	7.29
spring len freq 30+	25	8.28	25	8.28	25	8.38	25	8.33
winter len freq 30+	75	6.50	75	6.52	75	6.13	75	6.46
Coop len freq 30+	100	0.44	100	0.45	100	0.80	100	0.44
Scallop len freq 30+	75	15.63	75	15.64	75	15.08	75	15.44
Fall Bigelow len freq 30+	100	0.38	100	0.38	100	0.70	100	0.39
Spring Bigelow len freq 30	100	0.28	100	0.28	100	0.51	100	0.29
Shrimp len freq 30+	75	16.69	75	16.70	75	15.76	75	16.43
Fall ME/NH len freq 30+							50	4.51
Q Fall age 1		0.007		0.007		0.010		0.008
Q Spring age 2		0.004		0.004		0.005		0.005
Q Spring age 3		0.011		0.011		0.015		0.013
Q Winter age 2		0.004		0.004		0.005		0.005
Q Winter age 3		0.036		0.035		0.049		0.043
Q Scallop age 1		0.120		0.116		0.161		0.145
Q Scallop age 2		0.073		0.071		0.098		0.088
Q Shrimp age 1		0.014		0.014		0.019		0.017
Q Shrimp age 2		0.038		0.037		0.051		0.046
Q ME/NH age 1								0.006
Q Fall adult 40+		0.024		0.023		0.037		0.030
Q Spring adult 40+		0.022		0.021		0.034		0.027
Q winter adult 40+		0.068		0.066		0.111		0.086
Q Scallop adult 40+		0.088		0.085		0.139		0.111
Q Shrimp adult 40+		0.032		0.031		0.052		0.041
Q ME/NH adult 40+								0.017
Fstart		0		0		0		0.1
recruitment year 1		56.2		58.2		40.2		47.0
Selectivity								
block 1		80-09		80-01		80-01		80-01
alpha		41.02		39.16		42.53		43.73
beta		0.17		0.20		0.16		0.16
block 2				02-09		02-09		02-09
alpha				42.27		49.78		42.34
beta				0.16		0.14		0.16

Table A35. Estimates of age-1 recruitment, biomass and fishing mortality rates from SCALE model final runs. Estimates by area do not sum to combined area because combined data were fit independently to the SCALE model.

North					South					North+South				
Year	Age-1 Recruitment (millions)	Exploitable Biomass (kt)	Total Biomass (kt)	F	Year	Age-1 Recruitment (millions)	Exploitable Biomass (kt)	Total Biomass (kt)	F	Year	Age-1 Recruitment (millions)	Exploitable Biomass (kt)	Total Biomass (kt)	F
1980	16.10	82.46	100.41	0.06	1980	28.15	81.96	107.06	0.09	1980	47.01	185.69	224.35	0.07
1981	11.46	78.75	96.30	0.06	1981	29.97	89.37	115.01	0.06	1981	40.21	190.56	229.05	0.06
1982	11.91	75.72	92.72	0.07	1982	24.06	98.43	124.27	0.05	1982	33.52	197.14	234.75	0.06
1983	11.63	72.64	88.83	0.08	1983	21.67	107.29	132.90	0.05	1983	29.94	202.77	238.44	0.06
1984	10.63	70.08	85.11	0.09	1984	21.24	114.83	139.68	0.05	1984	31.26	206.82	239.60	0.06
1985	8.18	67.05	80.64	0.11	1985	20.38	121.29	144.76	0.05	1985	30.39	207.98	237.52	0.07
1986	11.94	62.73	75.29	0.10	1986	23.54	124.26	146.10	0.04	1986	36.68	202.91	230.28	0.06
1987	11.17	58.72	70.65	0.13	1987	35.80	125.30	146.74	0.04	1987	53.11	195.62	223.31	0.07
1988	13.62	53.13	64.71	0.16	1988	9.86	123.74	144.90	0.05	1988	26.26	184.10	212.73	0.08
1989	18.60	47.13	59.08	0.23	1989	25.47	119.42	141.06	0.12	1989	47.96	170.54	201.39	0.15
1990	21.67	39.86	53.05	0.26	1990	33.10	108.17	130.58	0.10	1990	60.76	150.32	184.00	0.14
1991	17.09	34.17	48.97	0.28	1991	38.97	101.92	124.95	0.14	1991	60.04	138.62	174.57	0.17
1992	18.94	30.59	47.29	0.35	1992	31.91	93.72	117.58	0.21	1992	55.46	128.64	167.51	0.23
1993	29.38	29.19	47.97	0.59	1993	43.44	82.27	109.37	0.28	1993	82.42	120.00	164.34	0.34
1994	26.59	26.01	45.86	0.60	1994	35.18	73.93	104.02	0.25	1994	69.22	111.59	159.72	0.30
1995	12.33	24.98	45.20	0.75	1995	29.46	73.01	104.47	0.31	1995	44.06	113.24	163.06	0.35
1996	15.79	22.70	43.10	0.89	1996	22.94	72.48	103.37	0.32	1996	36.24	114.10	163.68	0.37
1997	28.49	20.93	41.24	0.71	1997	24.03	73.69	102.86	0.33	1997	54.61	117.86	164.65	0.32
1998	34.25	22.80	42.80	0.42	1998	42.71	74.33	101.37	0.32	1998	87.62	125.04	168.26	0.25
1999	44.00	27.41	49.04	0.42	1999	37.69	73.38	99.18	0.26	1999	90.31	132.81	176.67	0.21
2000	44.14	30.09	56.03	0.46	2000	33.29	75.61	102.21	0.17	2000	89.04	140.18	190.91	0.18
2001	29.07	32.00	63.18	0.68	2001	16.24	80.07	108.54	0.21	2001	51.68	149.19	208.16	0.24
2002	18.41	31.86	65.53	0.82	2002	32.18	75.42	111.90	0.20	2002	50.72	159.36	217.60	0.22
2003	18.77	32.88	65.46	1.13	2003	41.83	79.97	117.06	0.22	2003	59.05	172.86	227.53	0.25
2004	19.80	30.01	57.08	0.96	2004	24.29	84.23	119.19	0.16	2004	48.59	181.57	228.84	0.19
2005	14.75	28.98	50.61	0.71	2005	16.46	89.88	123.05	0.16	2005	31.23	189.35	230.49	0.17
2006	25.03	29.00	47.89	0.38	2006	14.45	92.91	125.72	0.13	2006	49.41	195.11	233.33	0.12
2007	18.37	32.74	51.41	0.22	2007	13.11	97.80	129.20	0.12	2007	33.19	207.81	243.26	0.09
2008	17.46	38.96	58.23	0.14	2008	17.88	103.98	131.09	0.10	2008	38.97	219.86	252.43	0.07
2009	16.15	46.15	66.06	0.10	2009	18.99	108.74	131.22	0.07	2009	35.74	224.32	255.33	0.05

Table A36. Calculated age-specific retrospective adjustments based on 7 peels.

	AGE											
area	1	2	3	4	5	6	7	8	9	10	11	12
North	78%	74%	73%	71%	71%	64%	51%	39%	29%	23%	19%	17%
South	71%	89%	92%	92%	92%	90%	88%	86%	85%	83%	81%	78%
Combined	76%	79%	80%	79%	80%	78%	75%	73%	71%	69%	66%	63%

Table A37. Summary of possible explanations for lack of fit and/or retrospective error in SCALE model results.

Error type	**Observation**	**Hypothesis for Observation**	**Perceived Likelihood**	**Evidence For or Against**
Observation Error	Recruitment pulse in North late 1990s	Caused by change in survey q	Low	NO: -Multiple surveys show pulse -shows up in CPUE at plausible lags -No reason to expect Q change YES: -Discarding did not show major increase
	Declining / not-increasing survey indices	Caused by change in survey q	Low	NO: - multiple surveys show trend - no changes in survey gear or method until 2009
	Declining / not-increasing survey indices	Caused by change in availability of monks to survey	Low	NO: -survey timing has not changed in recent years (except scallop 2009) -habitat compression due to climate change not seen in GoM or Northern MAB
	Catch has declined	Due to more than change in regulations	Low	NO: -reporting methods haven’t changed recent years -recent discard sampling rates decent
	Catch and survey LF’s do not expand when catches decline	Fish move out of survey / fishery area	???	NO: -Scotian Shelf summer indices have same trend as US North MAYBE: -monkfish do occur in deeper water (at least ~900 m) but not necessarily just large ones

	Catch and survey LF's do not expand when catches decline	Larger fish do not grow rapidly (aging method wrong)	Possibly high	See below (Growth model wrong)
Process Error	Growth is linear	Growth model wrong	Possibly high	-Age method has not been validated -Other Lophius: some show curvature in growth curve -European studies: early growth faster than previously thought
		M wrong	High	Probably live longer than we give them credit for (max obs size = 138 cm, max size aged = 113 cm = 13 yr) If age method missing annuli, then they live longer
		Emigration	Med-High	YES: Patterns in sex ratio at length suggest portion of the stock (maturing females) absent from the US shelf at least some parts of the year NO: Scotian Shelf survey indices show same trends as US North

Table A38. Results of age-based yield-per-recruit analysis using M=0.3 and area-specific selectivity patterns estimated by SCALE model. A-B: 2006 analysis, C-E: 2009 analysis.

DPWG

A. North

Reference Point	F	YPR	SSBR	Total B / R
Fzero	0.00	0.00	7.97	9.94
F-01	0.18	0.56	3.22	4.81
F-Max	0.31	0.60	2.06	3.51
F at 40% MSP	0.18	0.56	3.19	4.77

B. South

Reference Point	F	YPR	SSBR	Total B / R
Fzero	0.00	0.00	5.32	6.41
F-01	0.25	0.50	2.43	3.39
F-Max	0.40	0.53	1.72	2.61
F at 40% MSP	0.31	0.52	2.13	3.06

SAW50

C. North

Reference Point	F	YPR	SSBR	Total B / R
Fzero	0.00	0.00	5.39	6.41
F-01	0.27	0.51	2.55	3.46
F-Max	0.43	0.54	1.85	2.69
F at 40% MSP	0.35	0.54	2.15	3.03

D. South

Reference Point	F	YPR	SSBR	Total B / R
Fzero	0.00	0.00	5.39	6.41
F-01	0.28	0.52	2.59	3.51
F-Max	0.46	0.55	1.88	2.73
F at 40% MSP	0.38	0.55	2.15	3.04

E. North+South

Reference Point	F	YPR	SSBR	Total B / R
Fzero	0.00	0.00	5.39	6.41
F-01	0.24	0.48	2.44	3.32
F-Max	0.37	0.51	1.74	2.55
F at 40% MSP	0.28	0.50	2.15	3.00

Table A39. Estimated biological reference points, biomass and F for monkfish in northern and southern management regions and areas combined.

Management Areas	Biomass BRPs in metric tons				Estimates			
North	**BRP**	**Basis**	**DPSWG 2007**	**SDWG 2010**		**DPSWG 2007**	**SDWG 2010**	**SDWG 2010 Adjust**
	Fmax	YPR	0.31	0.43	Current F	0.09	0.10	0.17
					Current B	119,000	66,062	31,761
	Bthreshold	Bloss 1980-2006	65,200					
	Bthreshold	Bloss 1980-2009		41,238				
	Bthreshold	0.5*Bmax Projected		26,465				
	Bthreshold	0.5*Bmax Proj Adjust		20,643				
	Btarget	Bavg 1980-2006	92,200	62,371				
	Btarget	Bavg 1980-2009		61,991				
	Btarget	Bmax Projected		52,930				
	Btarget	Bmax Proj Adjust		41,286				
	MSY	Fmax Projected		10,745				
South	**BRP**	**Basis**	**DPSWG 2007**	**SDWG 2010**		**DPSWG 2007**	**SDWG 2010**	**SDWG 2010 Adjust**
	Fmax	YPR	0.40	0.46	Current F	0.12	0.07	0.08
					Current B	135,000	131,218	113,119
	Bthreshold	Bloss 1980-2006	96,400					
	Bthreshold	Bloss 1980-2009		99,181				
	Bthreshold	0.5*Bmax Projected		37,245				
	Bthreshold	0.5*Bmax Proj Adjust		28,461				
	Btarget	Bavg 1980-2006	122,500	120,292				
	Btarget	Bavg 1980-2009		121,313				
	Btarget	Bmax Projected		74,490				
	Btarget	Bmax Proj Adjust		56,922				
	MSY	Fmax Projected		15,279				
Combined	**BRP**	**Basis**	**DPSWG 2007**	**SDWG 2010**		**DPSWG 2007**	**SDWG 2010**	**SDWG 2010 Adjust**
	Fmax	YPR		0.37	Current F		0.05	0.06
					Current B		255,326	186,369
	Bthreshold	Bloss 1980-2009		159,715				
	Bthreshold	0.5*Bmax Projected		64,501				
	Bthreshold	0.5*Bmax Proj Adjust		49,021				
	Btarget	Bavg 1980-2009		208,190				
	Btarget	Bmax Projected		129,002				
	Btarget	Bmax Proj Adjust		98,041				
	MSY	Fmax Projected		25,943				

Table A40. Projected catch and biomass (mt) for northern management region.

NMA Projection Table: Catch and Biomass in Metric tons
Annual P relative to BRP **n/a = not applicable**

ACT

Year	F	Total Catch	Total Biomass	P < 0.5*Bmax	P < Bloss2006	P < Bloss2009	P > Fmax
2010	0.10	4,447	74,102	0%	5%	0%	0%
2011	0.22	10,750	81,907	0%	0%	0%	0%
2012	0.22	10,750	81,204	0%	1%	0%	0%
2013	0.22	10,750	80,225	0%	2%	0%	0%
2014	0.23	10,750	78,944	0%	4%	0%	0%
2015	0.24	10,750	77,548	0%	8%	0%	0%
2016	0.24	10,750	76,383	0%	14%	0%	0%

ABC

Year	F	Total Catch	Total Biomass	P < 0.5*Bmax	P < Bloss2006	P < Bloss2009	P > Fmax
2010	0.10	4,447	74,102	0%	3%	0%	0%
2011	0.38	17,485	81,907	0%	0%	0%	4%
2012	0.44	17,485	73,769	0%	4%	0%	52%
2013	0.54	17,485	64,796	0%	52%	0%	94%
2014	0.71	17,485	55,815	0%	86%	1%	99%
2015	1.01	17,485	46,871	0%	96%	26%	100%
2016	1.69	17,485	37,631	12%	99%	72%	100%

Fthreshold

Year	F	Total Catch	Total Biomass	P < 0.5*Bmax	P < Bloss2006	P < Bloss2009	P > Fmax
2010	0.10	4,447	74,102	0%	5%	0%	0%
2011	0.43	19,557	81,907	0%	0%	0%	n/a
2012	0.43	16,553	70,831	0%	12%	1%	n/a
2013	0.43	14,120	62,846	0%	68%	44%	n/a
2014	0.43	12,402	57,627	0%	89%	73%	n/a
2015	0.43	11,384	54,619	0%	93%	80%	n/a
2016	0.43	10,883	53,298	0%	93%	84%	n/a

Table A41. Projected catch and biomass (mt) for southern management region.

SMA Projection Table: Catch and Biomass in Metric tons							
Annual P relative to BRP			**n/a = not applicable**				
ACT							
Year	**F**	**Total Catch**	**Total Biomass**	**P < 0.5*Bmax**	**P < Bloss2006**	**P < Bloss2009**	**P > Fmax**
2010	0.07	6,235	131,344	0%	0%	0%	0%
2011	0.13	11,469	132,243	0%	0%	0%	0%
2012	0.14	11,469	126,295	0%	0%	0%	0%
2013	0.15	11,469	121,055	0%	1%	1%	0%
2014	0.16	11,469	116,674	0%	2%	4%	0%
2015	0.17	11,469	113,979	0%	5%	8%	0%
2016	0.17	11,469	113,777	0%	7%	11%	0%
ABC							
Year	**F**	**Total Catch**	**Total Biomass**	**P < 0.5*Bmax**	**P < Bloss2006**	**P < Bloss2009**	**P > Fmax**
2010	0.07	6,235	131,344	0%	0%	0%	0%
2011	0.15	13,326	132,243	0%	0%	0%	0%
2012	0.16	13,326	124,255	0%	0%	0%	0%
2013	0.18	13,326	114,149	0%	1%	2%	0%
2014	0.20	13,326	111,160	0%	7%	12%	0%
2015	0.22	13,326	107,047	0%	16%	23%	0%
2016	0.23	13,326	105,443	0%	22%	30%	0%
Fthreshold							
Year	**F**	**Total Catch**	**Total Biomass**	**P < 0.5*Bmax**	**P < Bloss2006**	**P < Bloss2009**	**P > Fmax**
2010	0.07	6,235	131,344	0%	0%	0%	0%
2011	0.46	36,245	132,243	0%	0%	0%	n/a
2012	0.46	25,171	99,182	0%	33%	50%	n/a
2013	0.46	18,484	80,735	0%	99%	100%	n/a
2014	0.46	15,033	72,167	0%	100%	100%	n/a
2015	0.46	13,857	69,597	0%	100%	100%	n/a
2016	0.46	13,878	69,949	0%	100%	100%	n/a

Table A42. Projected catch and biomass (mt) for northern and southern management regions combined.

Combined Management Areas Projection Table: Catch and Biomass in Metric tons							
Annual P relative to BRP			**n/a = not applicable**				
ACT							
Year	**F**	**Total Catch**	**Total Biomass**	**P < 0.5*Bmax**	**P < Bloss2006**	**P < Bloss2009**	**P > Fmax**
2010	0.05	9,903	254,702	0%	n/a	0%	0%
2011	0.12	22,219	259,839	0%	n/a	0%	0%
2012	0.13	22,219	248,386	0%	n/a	0%	0%
2013	0.14	22,219	238,189	0%	n/a	0%	0%
2014	0.15	22,219	229,182	0%	n/a	0%	0%
2015	0.16	22,219	222,237	0%	n/a	0%	0%
2016	0.16	22,219	218,434	0%	n/a	0%	0%
ABC							
Year	**F**	**Total Catch**	**Total Biomass**	**P < 0.5*Bmax**	**P < Bloss2006**	**P < Bloss2009**	**P > Fmax**
2010	0.05	9,903	254,702	0%	n/a	0%	0%
2011	0.17	30,811	259,839	0%	n/a	0%	0%
2012	0.19	30,811	238,818	0%	n/a	0%	0%
2013	0.21	30,811	219,525	0%	n/a	0%	0%
2014	0.24	30,811	202,164	0%	n/a	0%	0%
2015	0.26	30,811	187,460	0%	n/a	7%	0%
2016	0.29	30,811	176,021	0%	n/a	23%	7%
Fthreshold							
Year	**F**	**Total Catch**	**Total Biomass**	**P < 0.5*Bmax**	**P < Bloss2006**	**P < Bloss2009**	**P > Fmax**
2010	0.05	9,903	254,702	0%	n/a	0%	0%
2011	0.37	62,664	259,839	0%	n/a	0%	n/a
2012	0.37	47,163	203,542	0%	n/a	0%	n/a
2013	0.37	36,947	167,133	0%	n/a	25%	n/a
2014	0.37	30,678	145,682	0%	n/a	87%	n/a
2015	0.37	27,411	134,286	0%	n/a	97%	n/a
2016	0.37	26,005	129,290	0%	n/a	98%	n/a

Figures

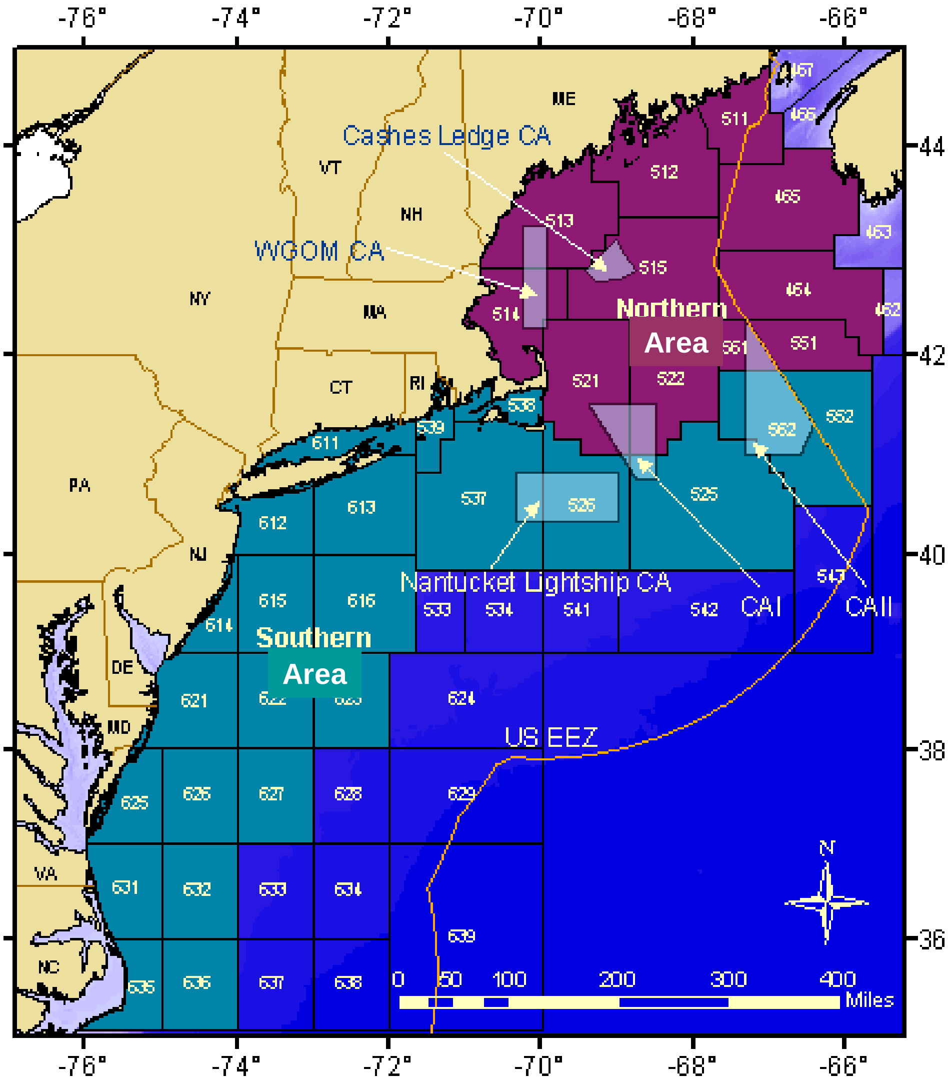


Figure A1. Statistical areas used to define the northern and southern monkfish management areas (from Richards 2006).

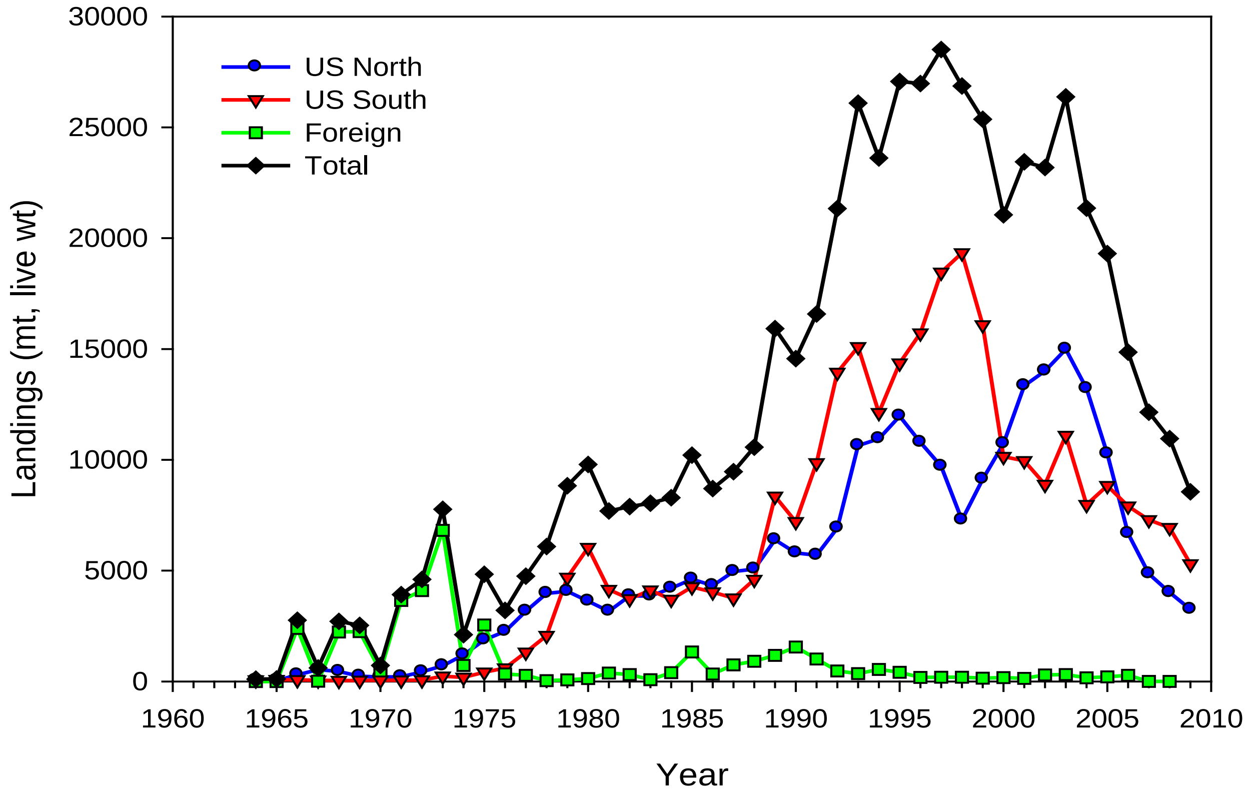


Figure A2. Monkfish landings, by management area and total, 1964-2009.

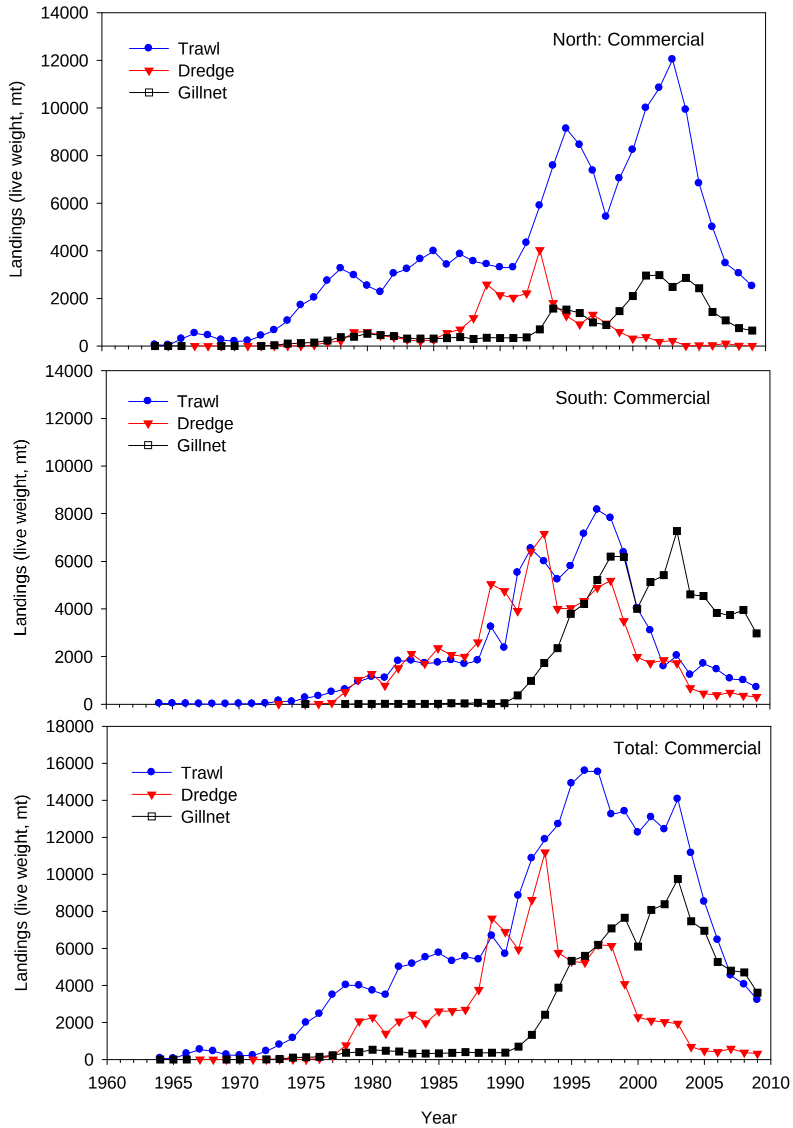
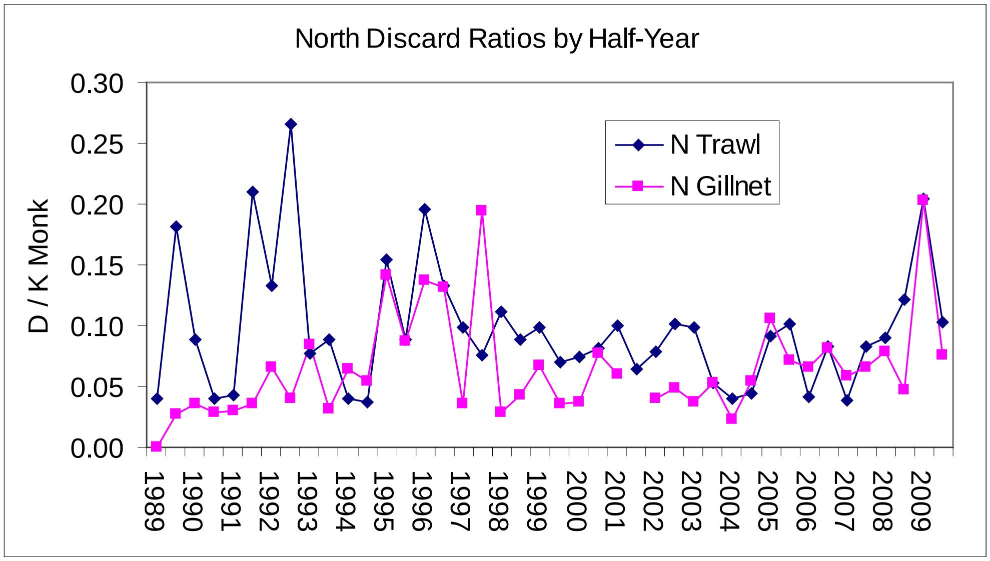


Figure A3. Commercial landings for monkfish by gear type and area.



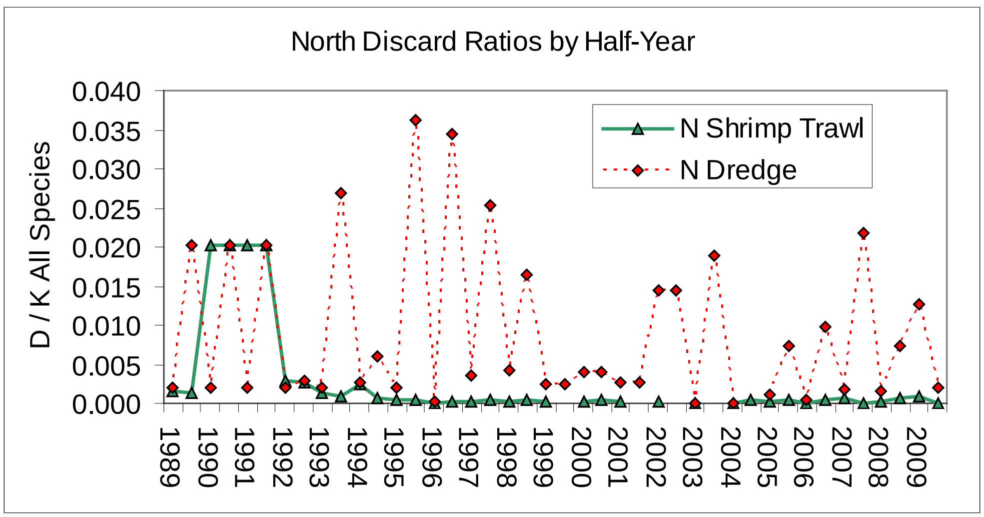


Figure A4. Discard ratios (mt monkfish discarded/mt all species landed) of goosefish by gear and half year using the SBRM methodology in the northern area. Gillnet 2001 half=2 and dredge 2004 half=2 are not shown to preserve scale.

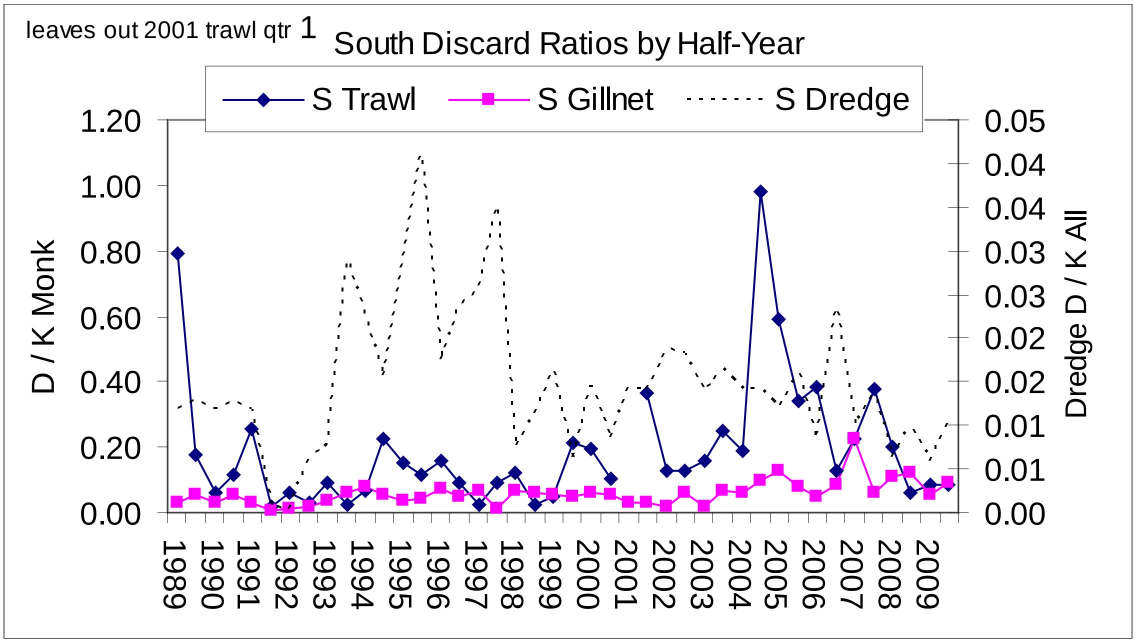


Figure A5. Discard ratios (mt monkfish discarded/mt all species landed) of goosefish by gear and half year using the SBRM methodology in the southern area. Trawl 2001 half=1 not shown to preserve scale.

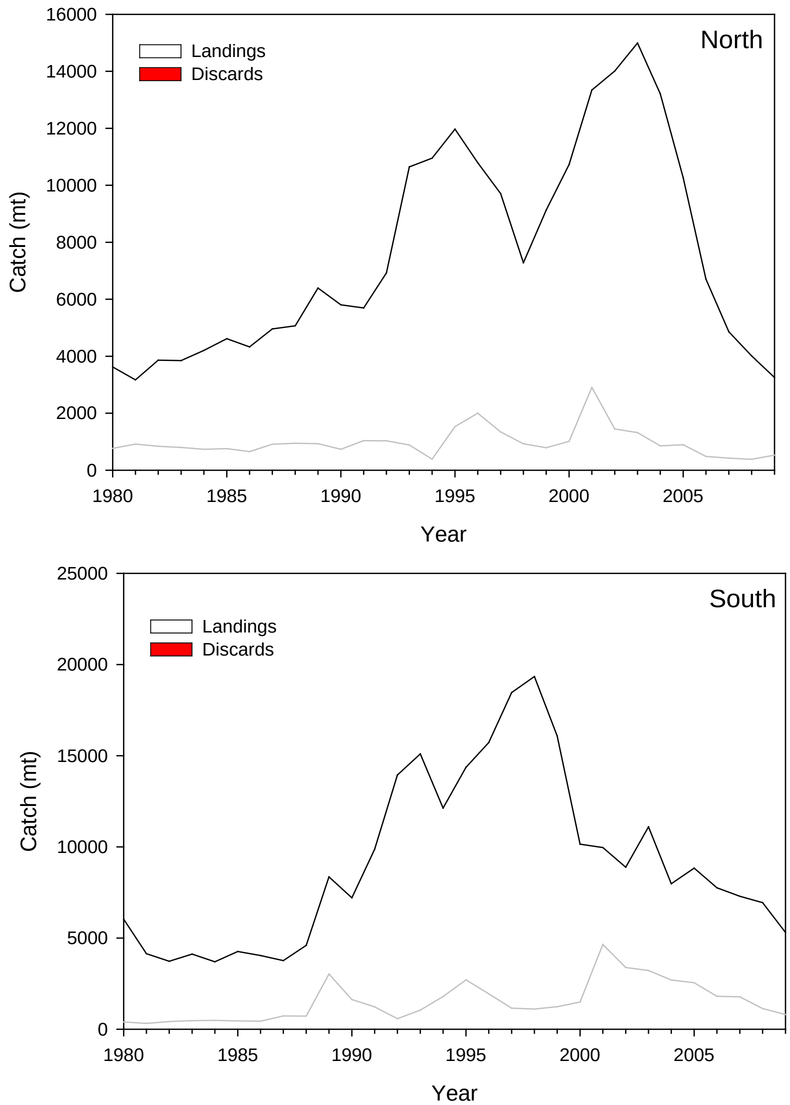


Figure A6. Annual catch of monkfish by management area.

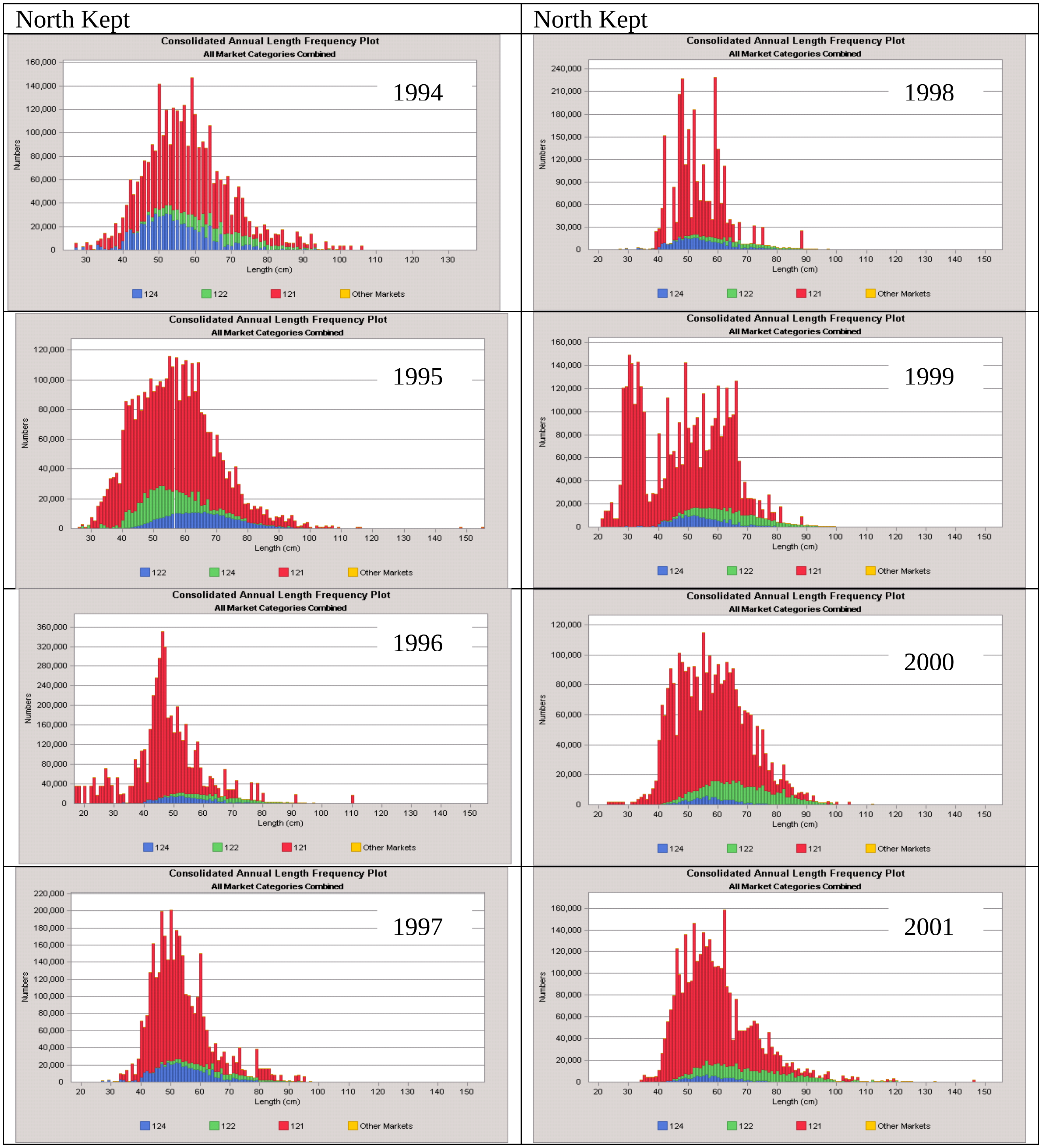


Figure A7. Northern management area, landings at length by gear type, estimated using data from fishery observers. Red=trawls, green=gillnets, blue=dredges, gold=other.

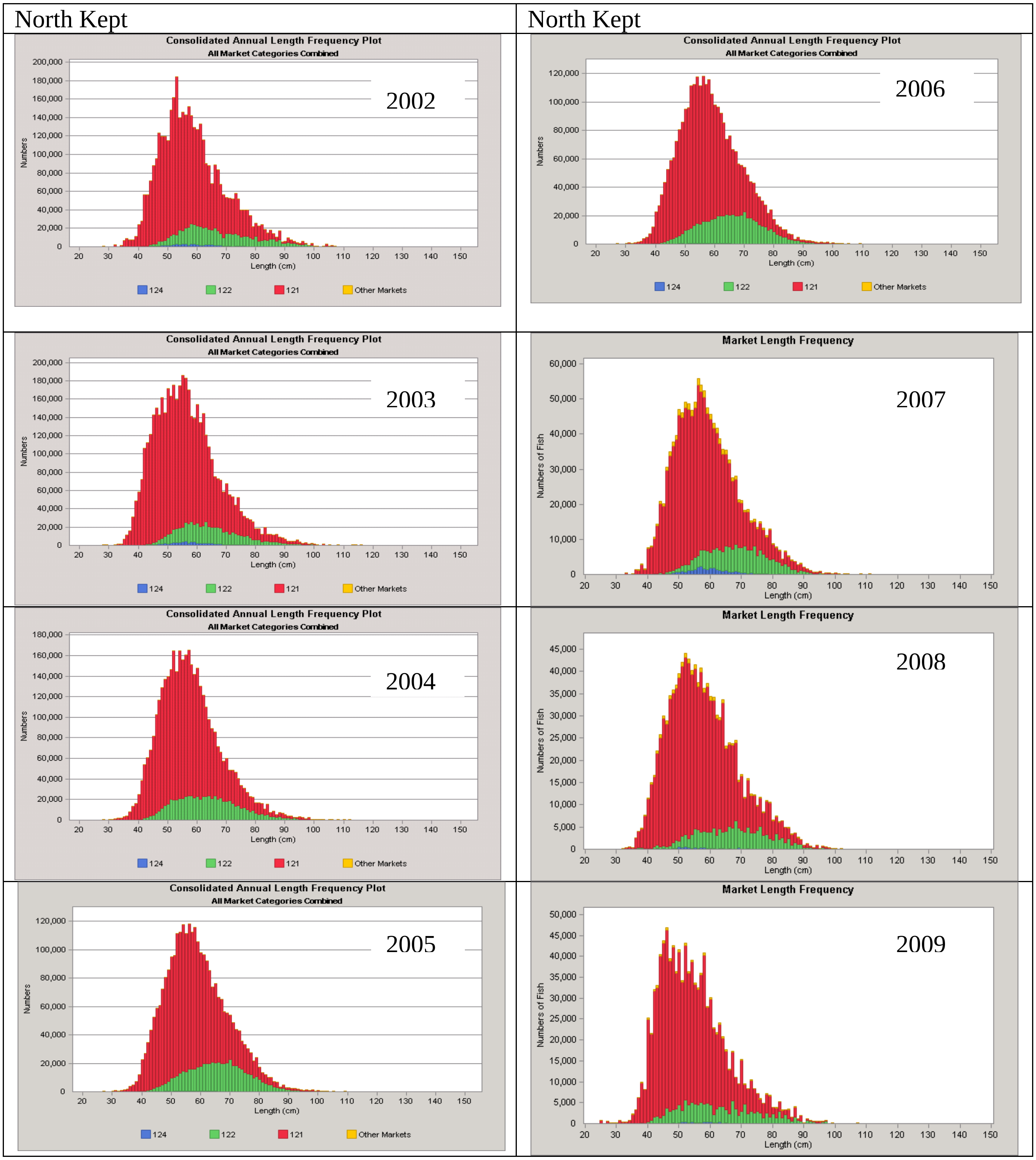


Figure A7, continued. Northern management area, landings at length by gear type, estimated using data from fishery observers. Red=trawls, green=gillnets, blue=dredges, gold=other.

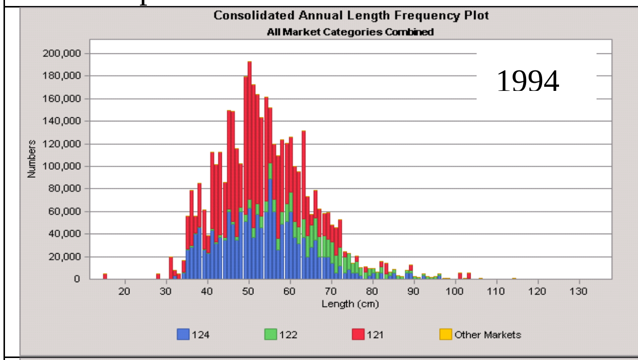
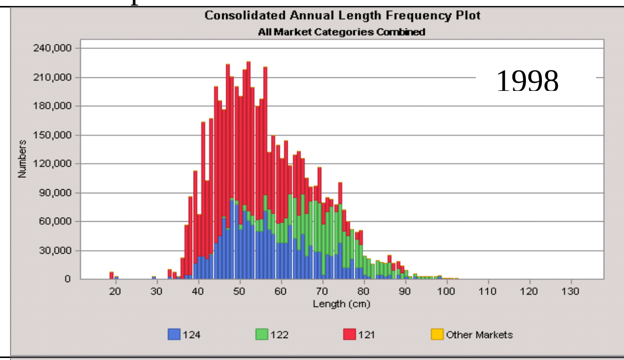
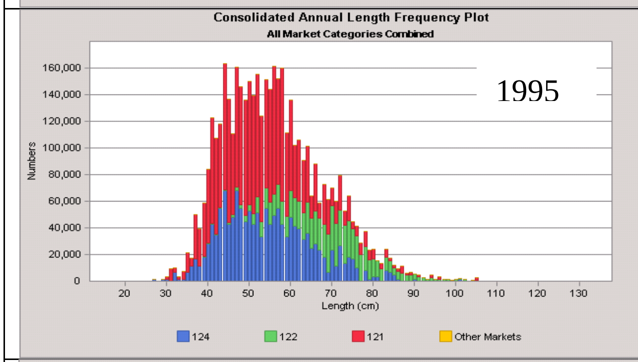
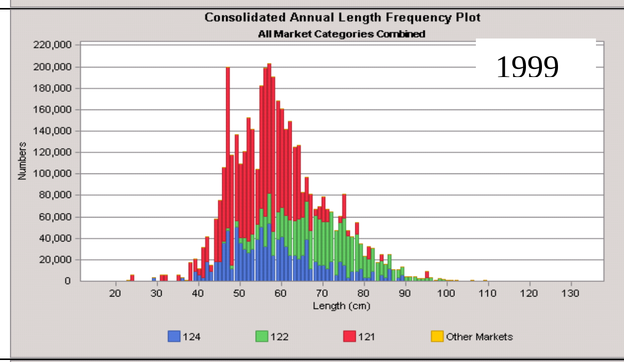
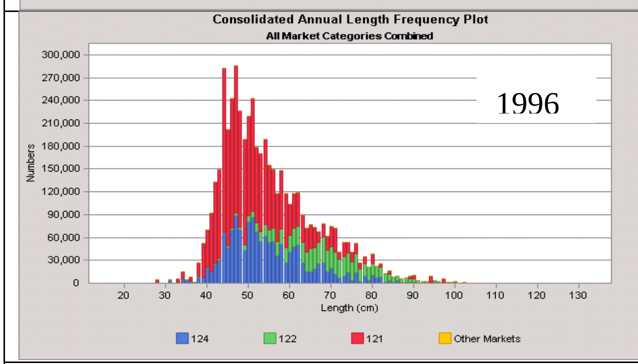
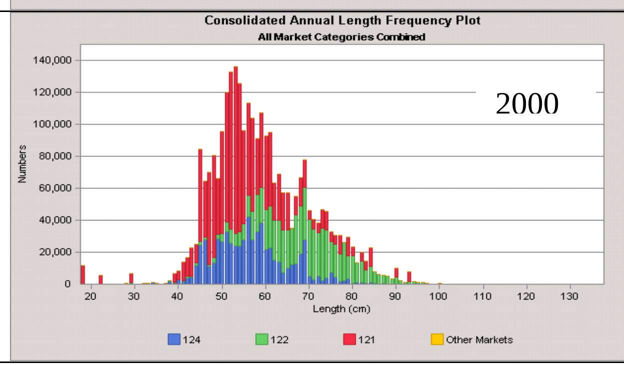
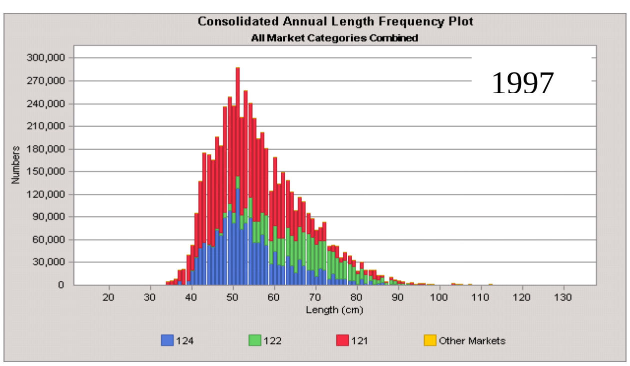
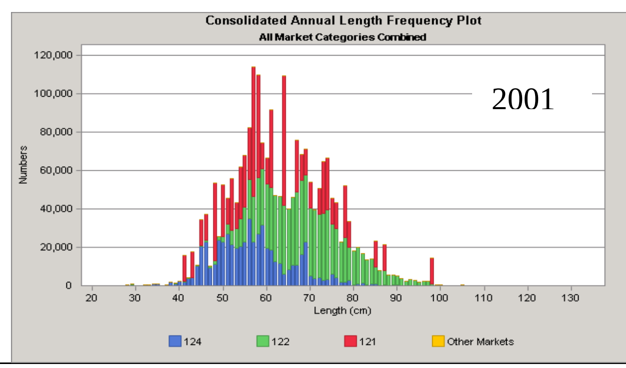
South Kept	South Kept
	
	
	
	

Figure A8. Southern management area, landings at length by gear type, estimated using data from fishery observers. Red=trawls, green=gillnets, blue=dredges, gold=other.

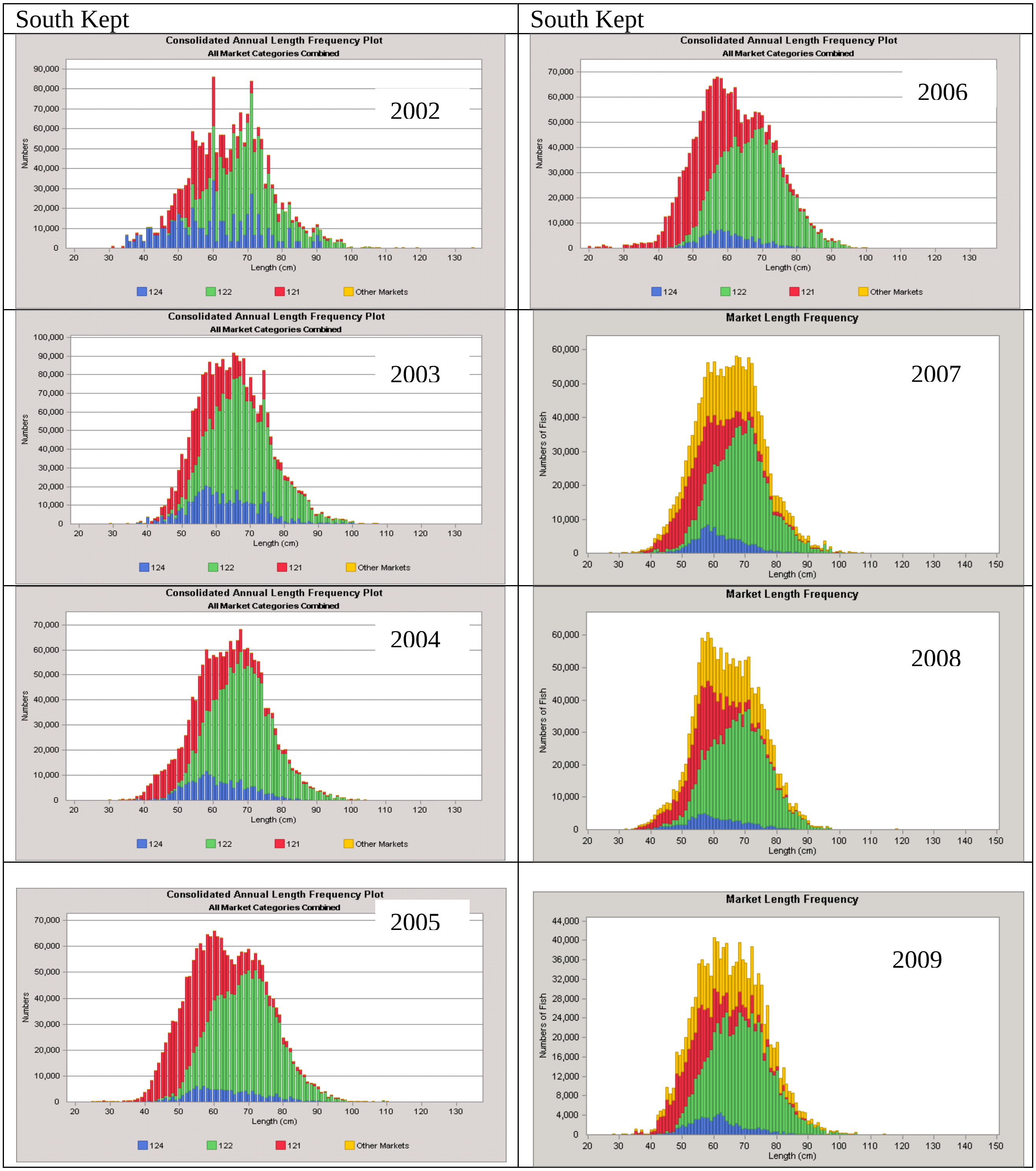


Figure A8, continued. Southern management area, landings at length by gear type, estimated using data from fishery observers. Red=trawls, green=gillnets, blue=dredges, gold=other.

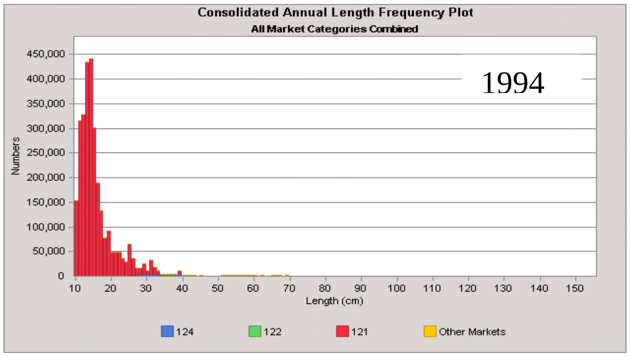
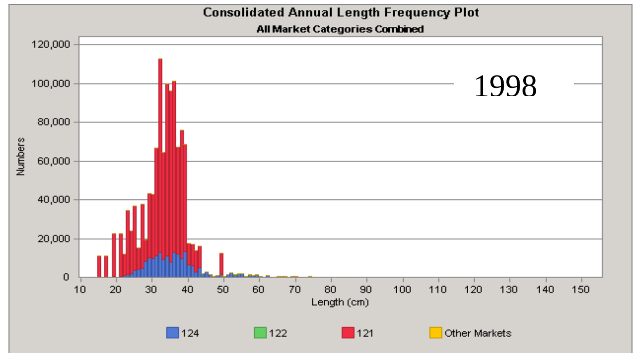
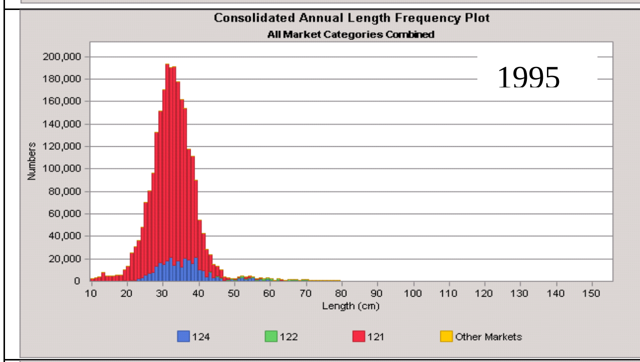
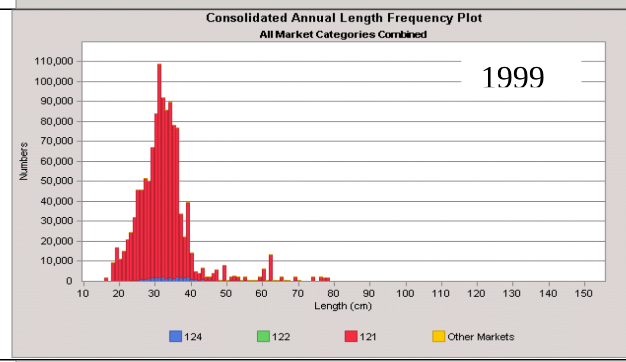
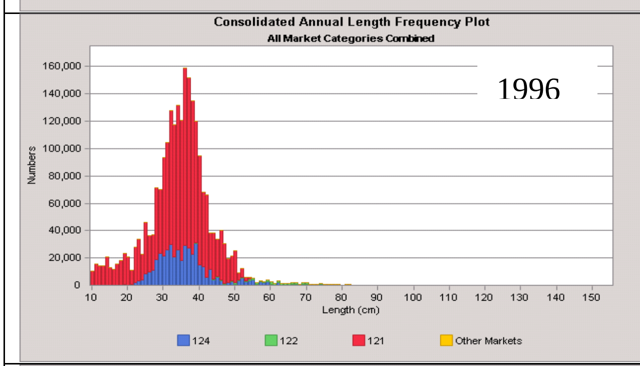
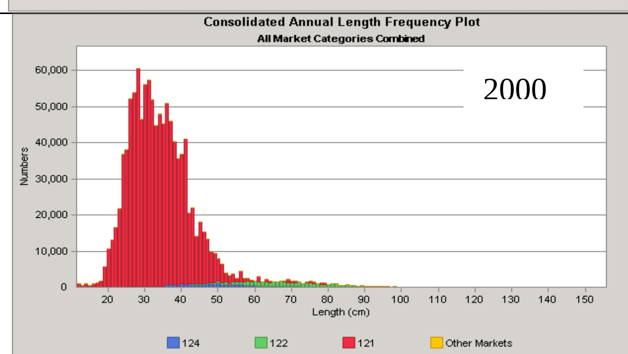
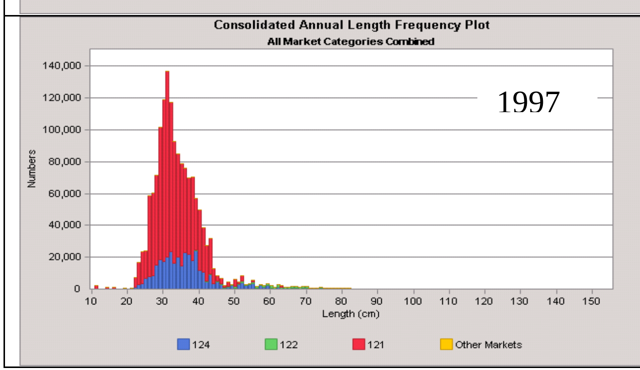
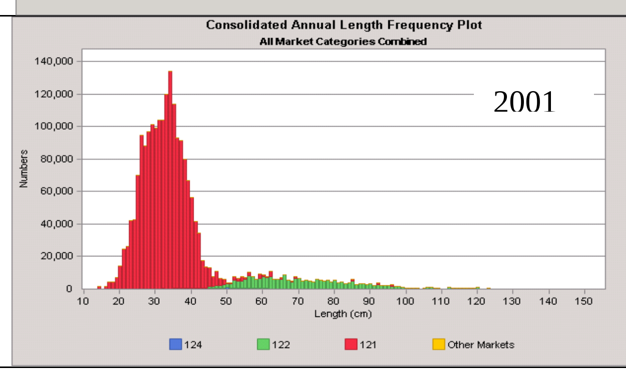
North Discarded	North Discarded
	
	
	
	

Figure A9. Northern management area, discards at length by gear type, estimated using data from fishery observers. Red=trawls, green=gillnets, blue=dredges, gold=other.

North Discarded | North Discarded

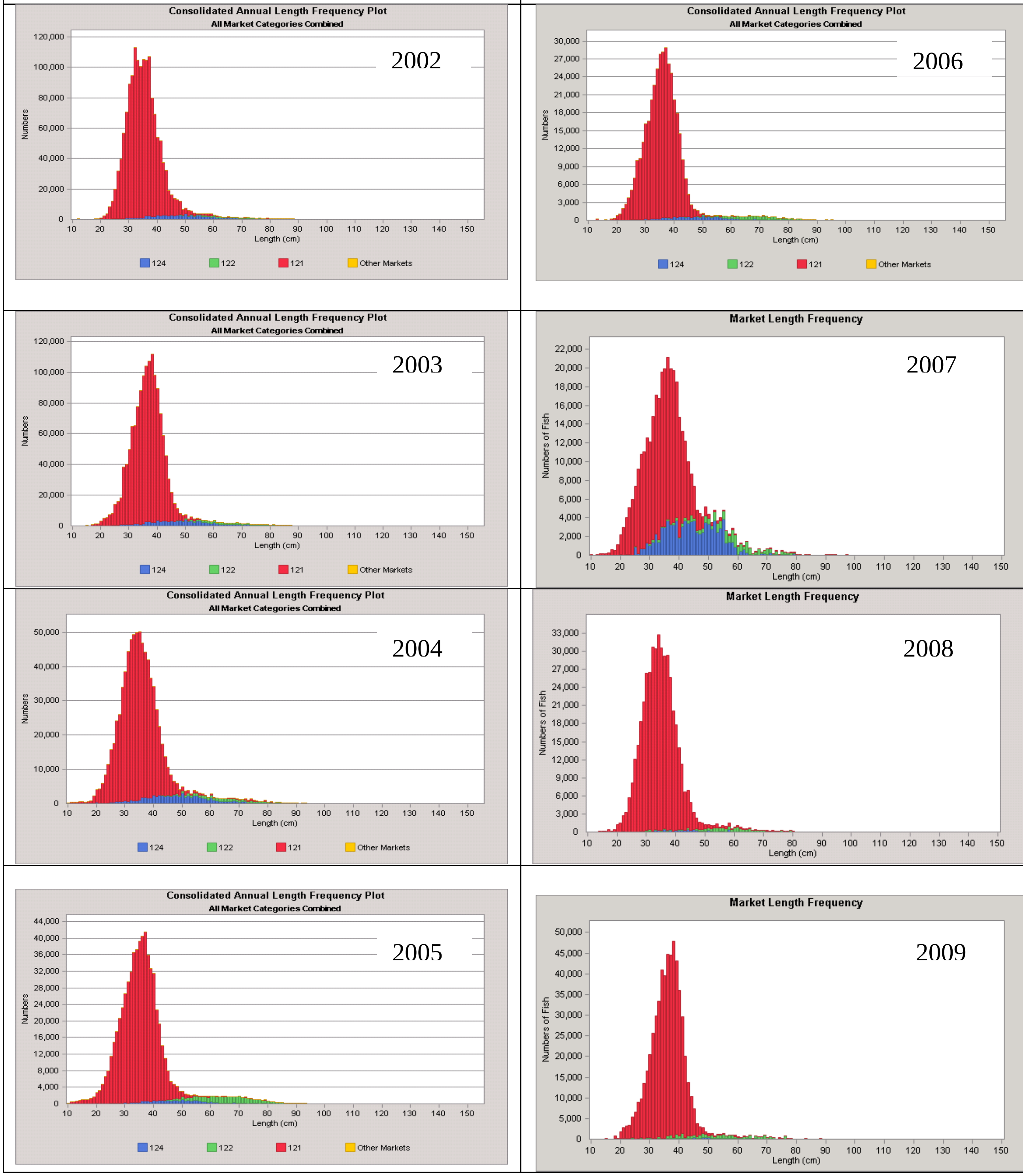


Figure A9, continued. Northern management area, discards at length by gear type, estimated using data from fishery observers. Red=trawls, green=gillnets, blue=dredges, gold=other.

South Discarded	South Discarded

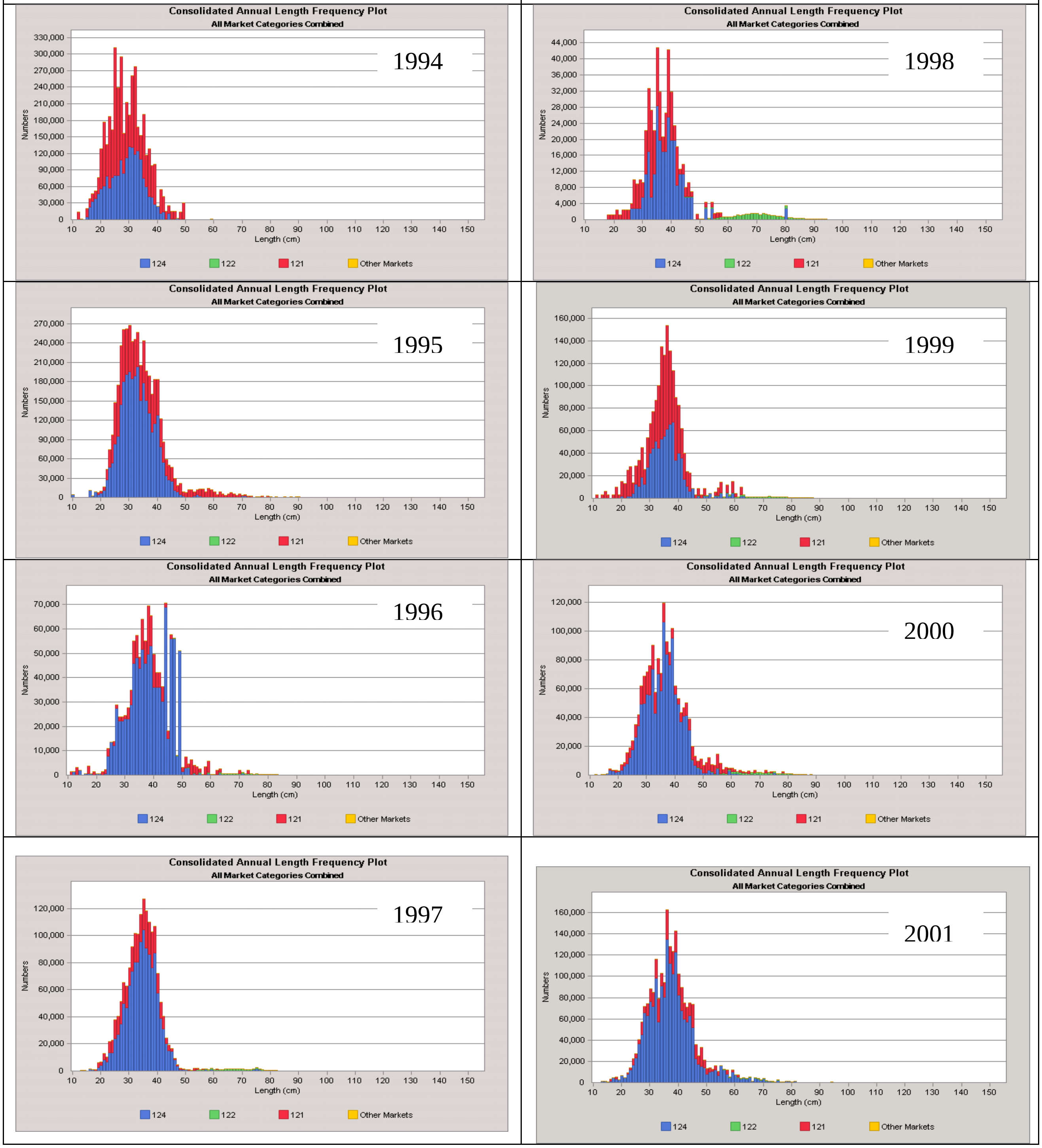


Figure A10. Southern management area, discards at length by gear type, estimated using data from fishery observers. Red=trawls, green=gillnets, blue=dredges, gold=other.

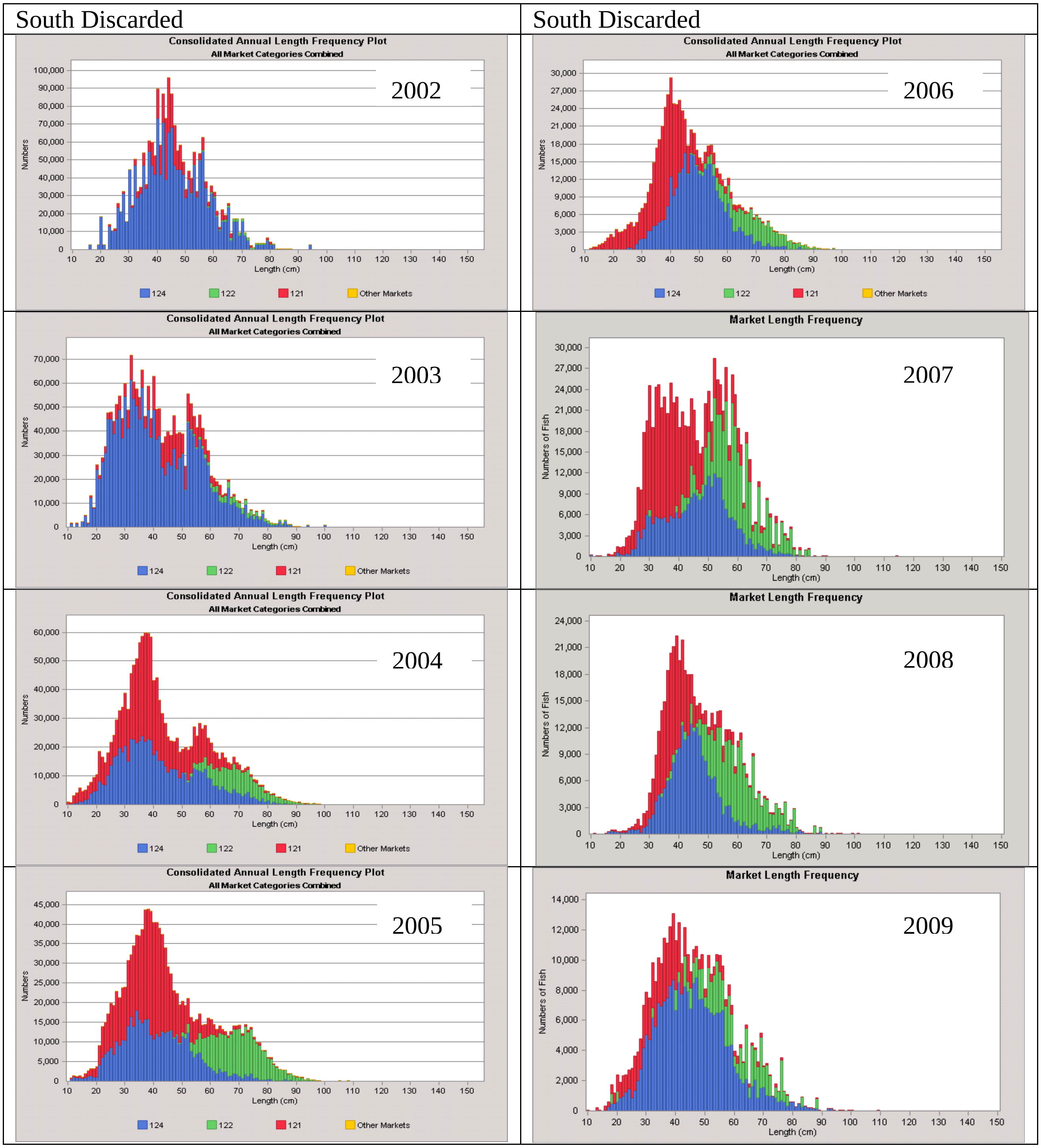


Figure A10, continued. Southern management area, discards at length by gear type, estimated using data from fishery observers. Red=trawls, green=gillnets, blue=dredges, gold=other.

NORTH

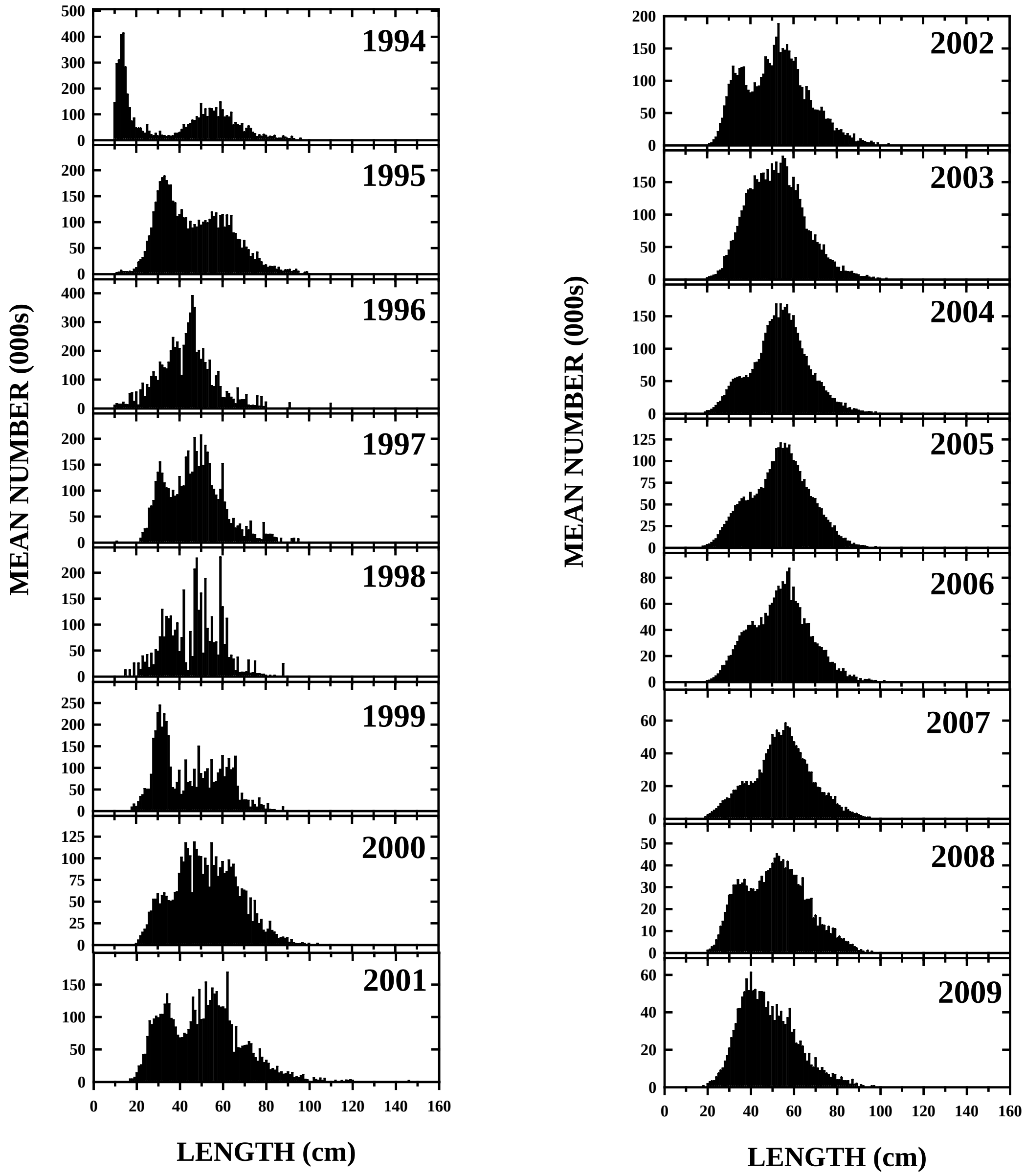


Figure A11. Length composition of commercial catch estimated from observed length samples in the northern management region.

SOUTH

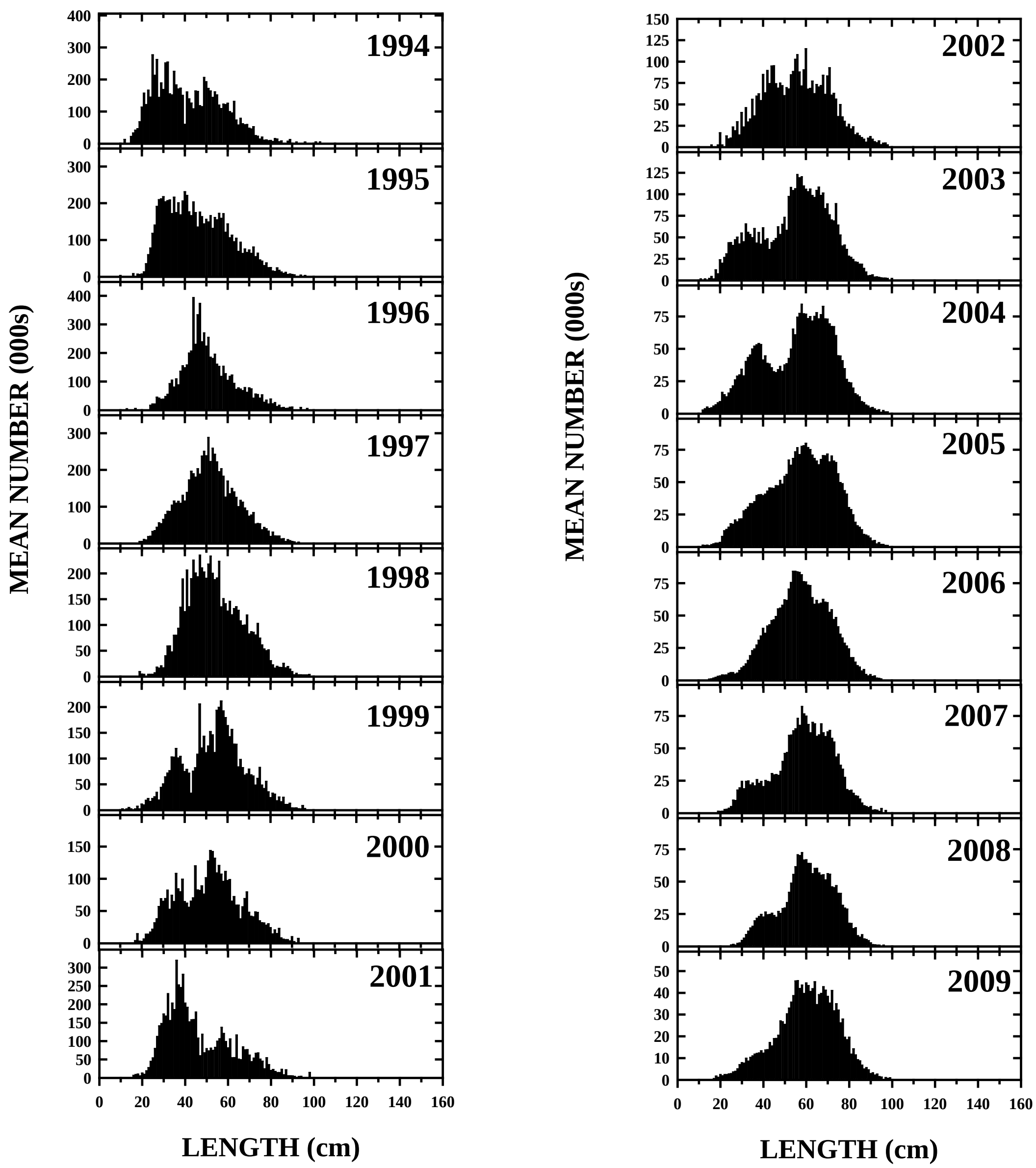


Figure A12. Length composition of commercial catch (discard estimates) estimated from observed length samples in the southern management region.

NORTH + SOUTH

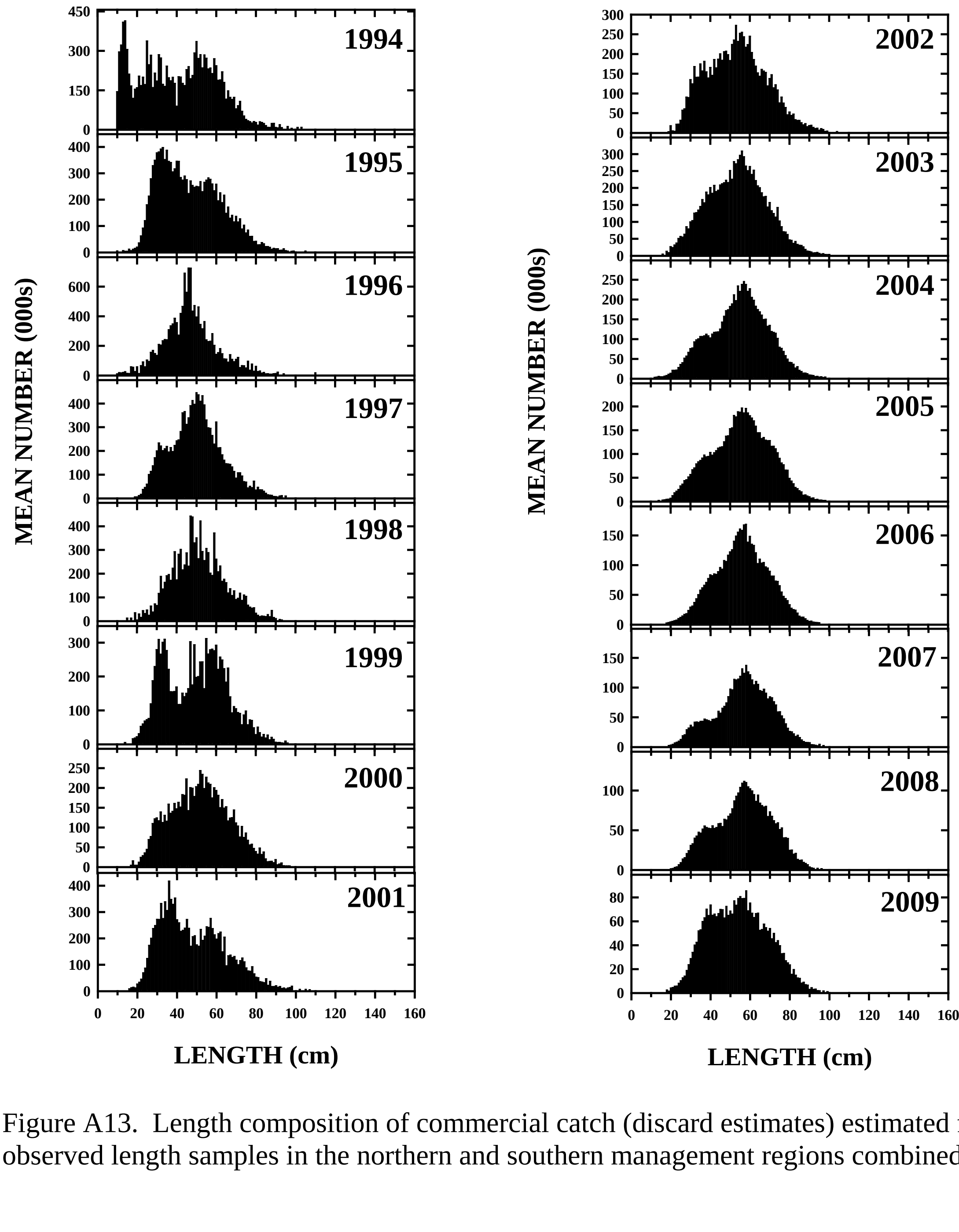


Figure A13. Length composition of commercial catch (discard estimates) estimated from observed length samples in the northern and southern management regions combined.

CPUE	Coefficient of Variation (CPUE)

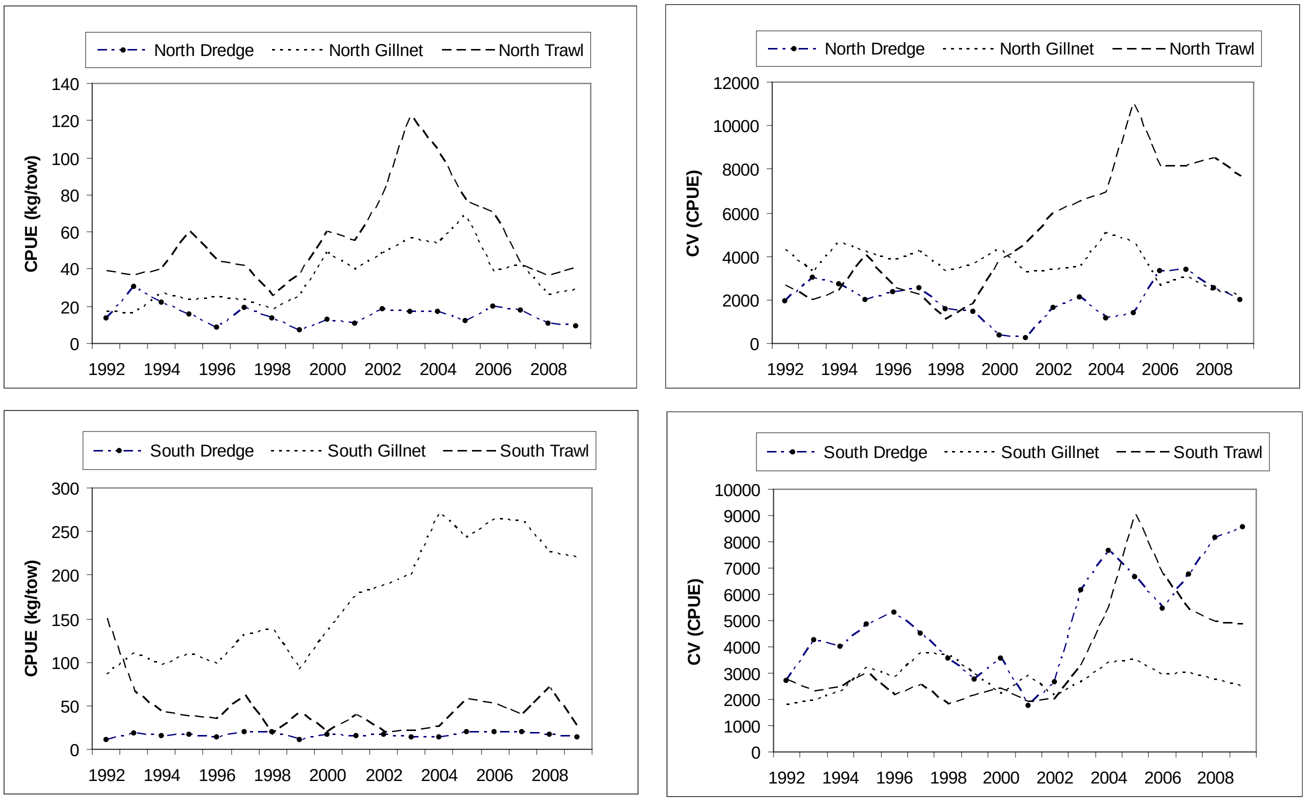


Figure A14. Catch rates of monkfish in the northern and southern management areas from observed tows that caught monkfish by gear-type. Left column, CPUE; right column, coefficient of variation of CPUE estimate.

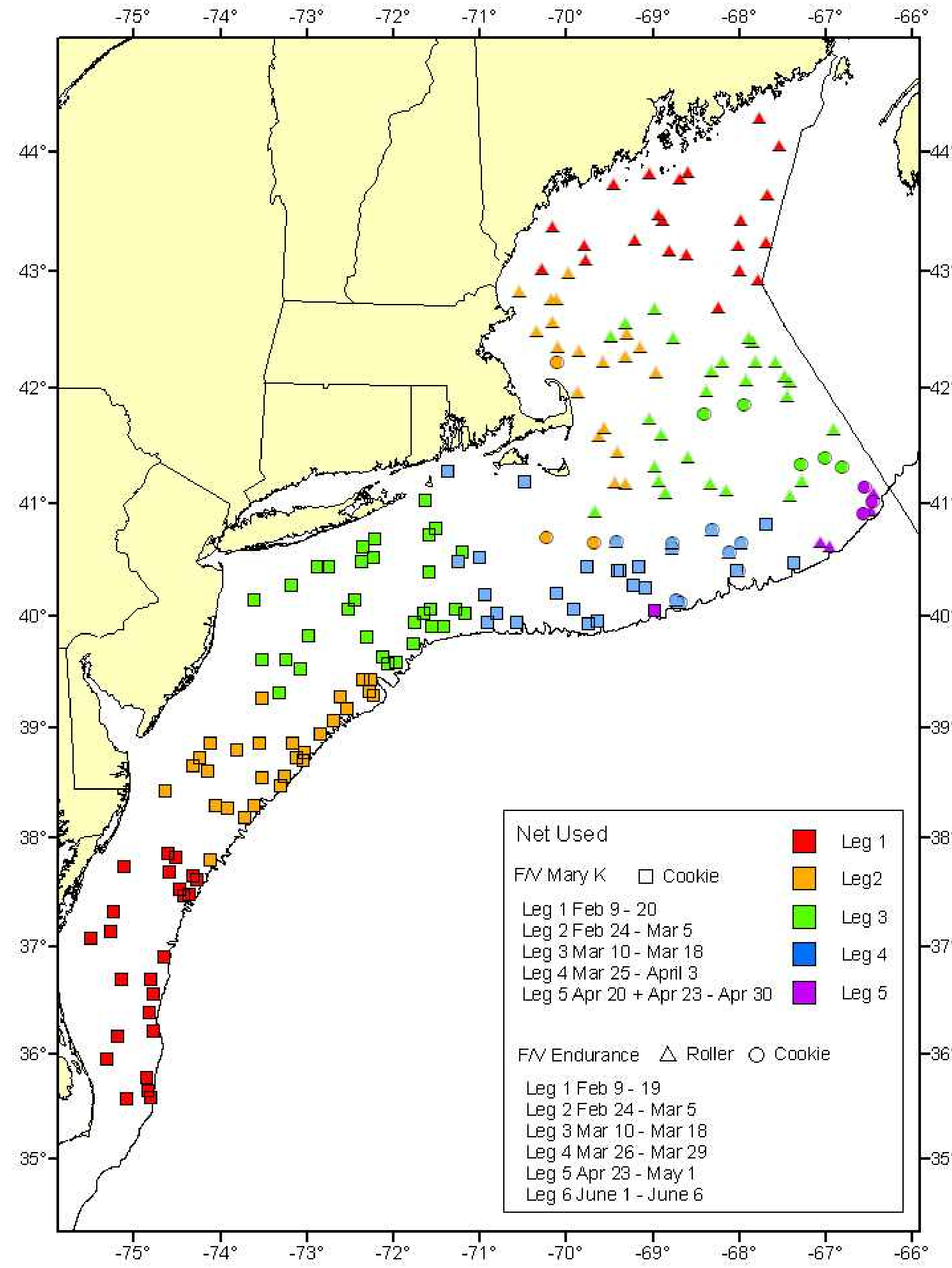


Figure A15. Location of successful survey stations sampled during 2009 cooperative monkfish survey, coded by net type and time of sampling (leg).

2008-2009
408 x 20 cm Fishing circle Trawl with 7"cookie sweep.
Design spread at end of bottom wing web 36 meters for a wing end angle of 24°.
Headrope 49 meters. Sweep 56 meters.
Ground gear 82 feet. End of ground gear to back straps' door attachments 36 feet.
Sensor to back straps' door attachments 6 feet.

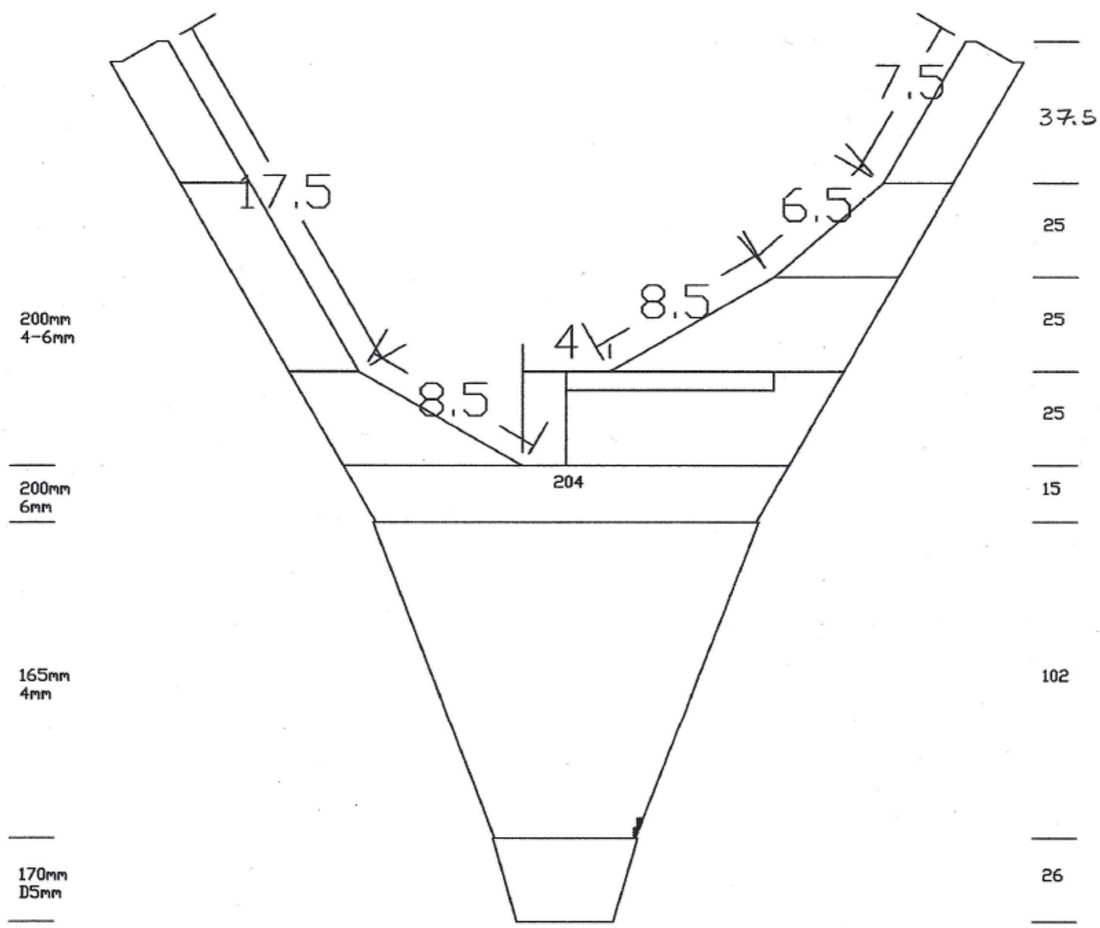


Figure A16. Plan for flat net used on F/V Endurance during 2009 cooperative survey.

F/V ENDURANCE
2008-2009
508 x 20 cm Fishing circle Trawl with rock hopper sweep.
Design spread 45.6 meters for a wing end angle of 23°.
Headrope 79 meters.
Sweep 86 meters (10.4 meters w/o web).
Center section 40 meters w/ 14" discs. Wing sections 22.7 meters w/ 12" discs. 30cm chain.
Ground gear 60 feet. End of ground gear to back straps' door attachment 36 feet.
Sensor to back straps' door attachment 6 feet.

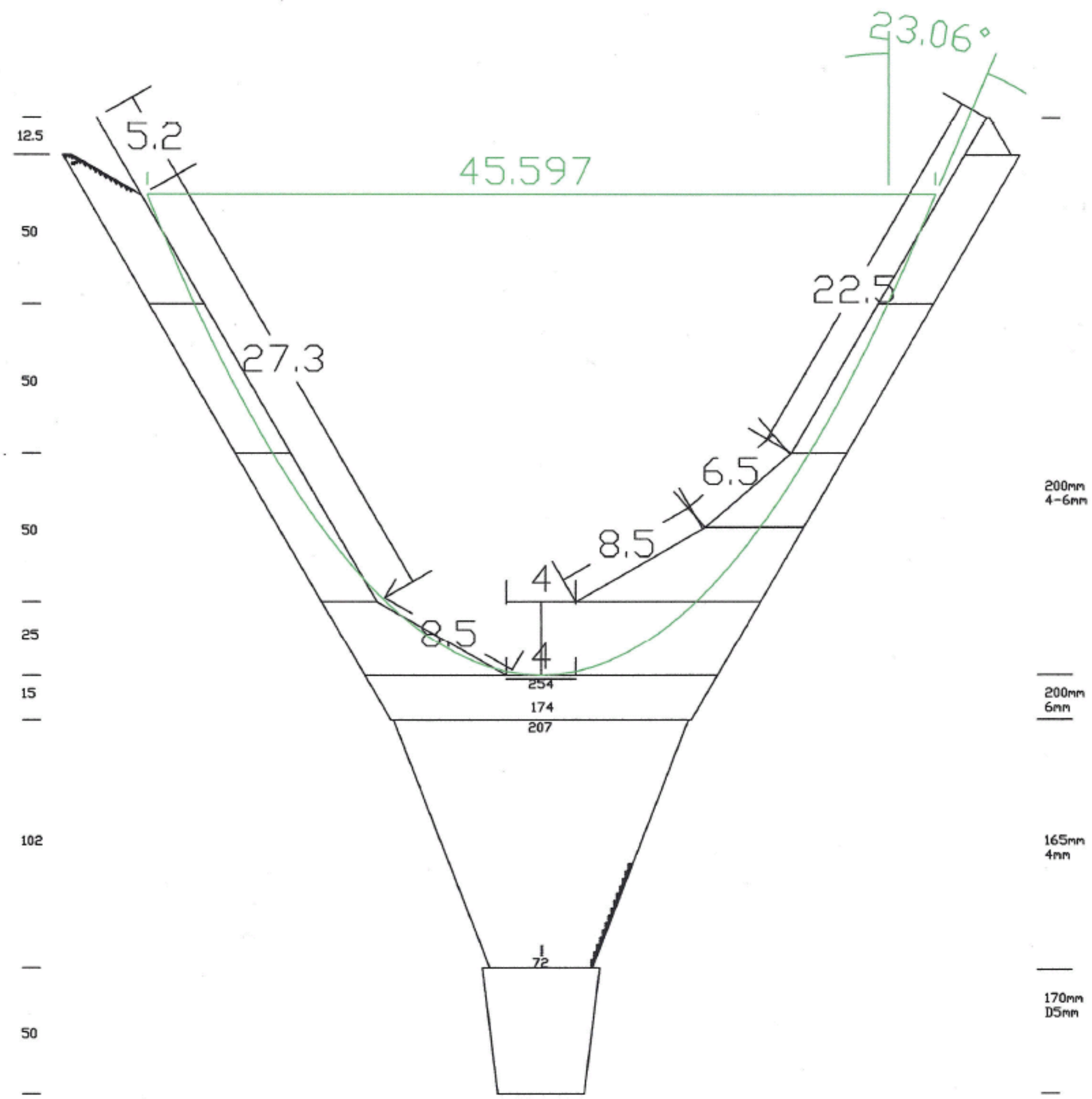


Figure A17. Plan for rockhopper net used on F/V Endurance during 2009 cooperative survey.

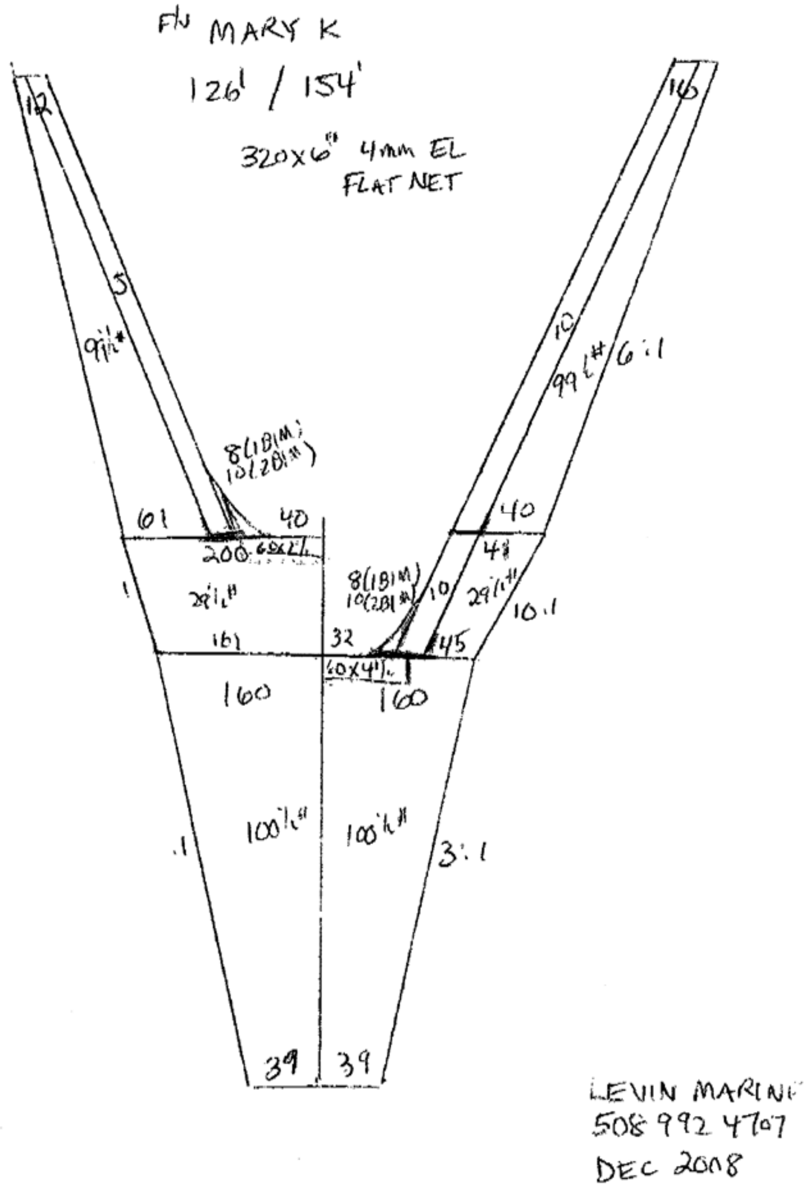
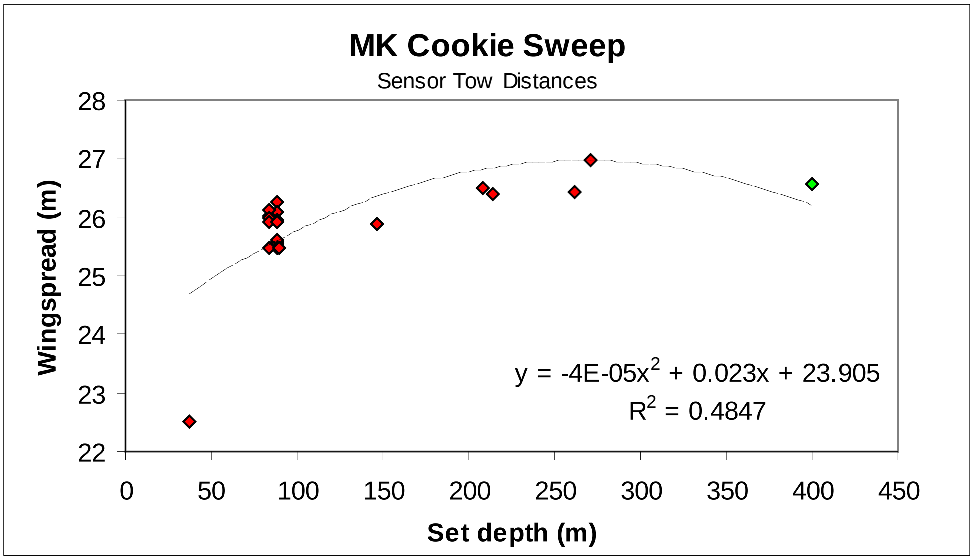


Figure A18. Plan for net used on F/V Mary K during 2009 cooperative survey.



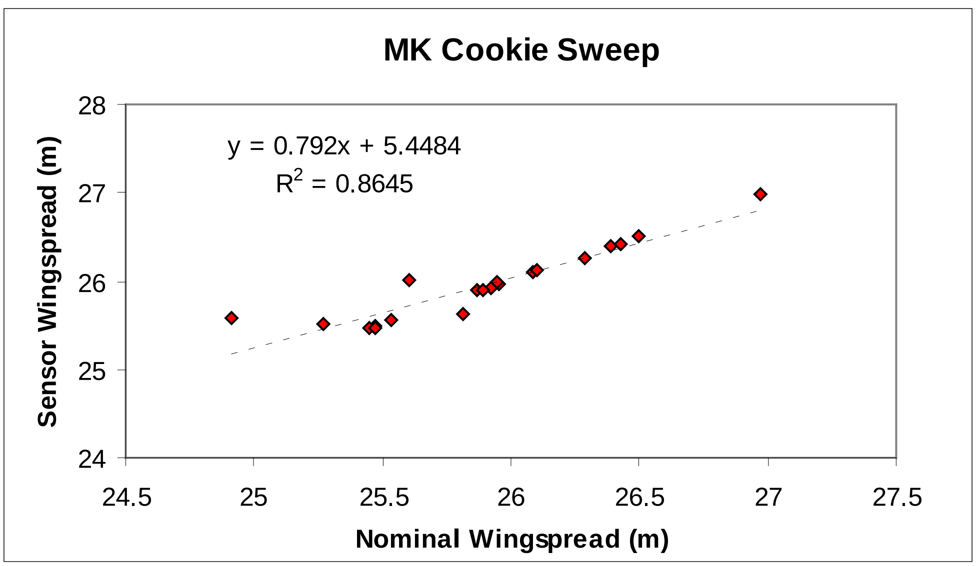


Figure A19. (A) Relationship between depth and wingspread for the cookie sweep net used on the Mary K, 2009 cooperative survey. Data are from mensuration tows and depletion experiments with good quality bottom contact and wingspread measurements, trimmed to sensor tow length before averaging for each tow. Point at 400 m is average wingspread for tows > 200 m set depth, not an observed value; maximum depth with observed wingspread was 271 m. Point at 37 m is based on only 6 wingspread readings. (B) relationship between average wingspread during nominal tow vs. sensor tow duration.

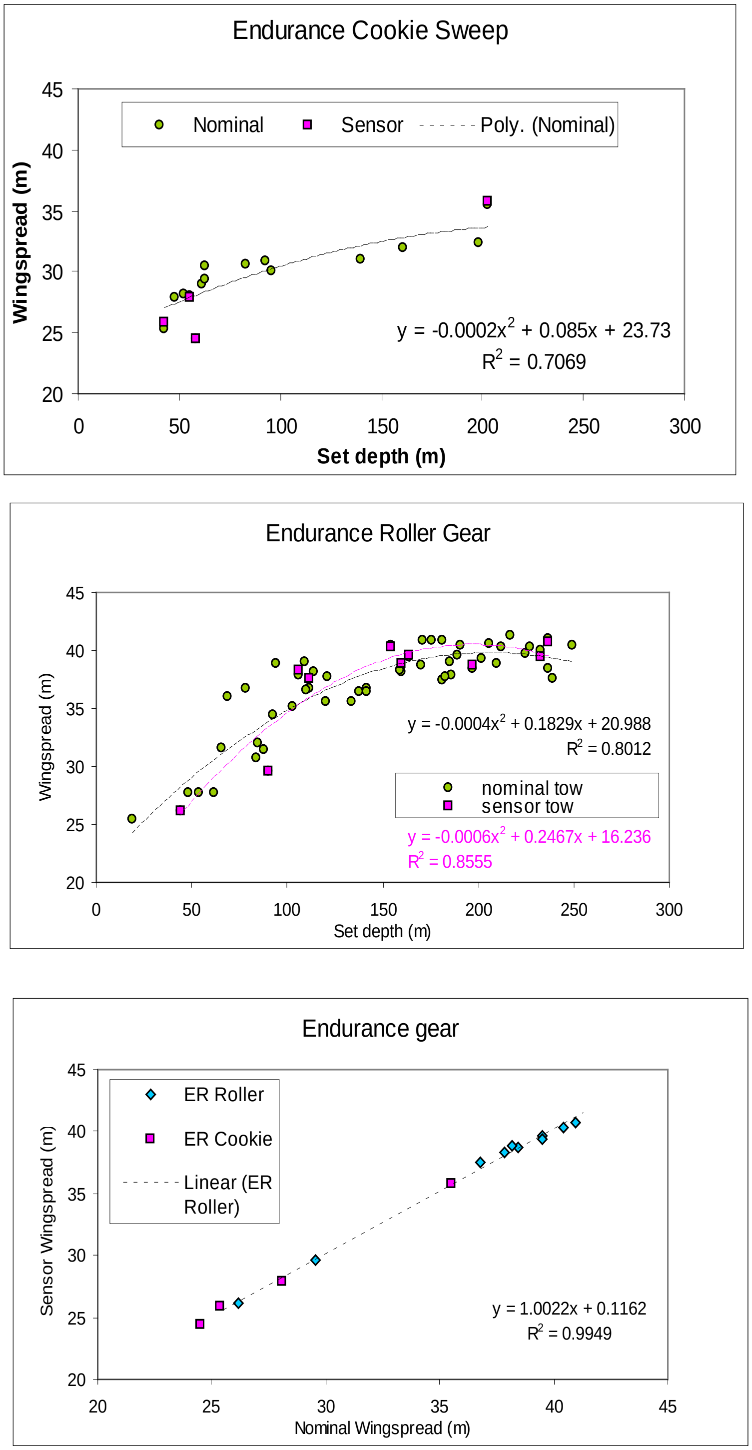
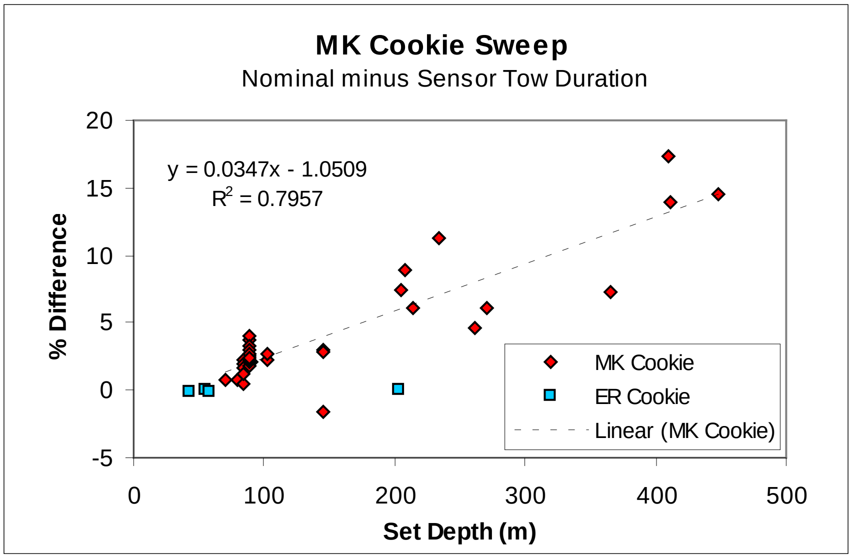


Figure A20. Wingspread-depth relationship for Endurance (A) cookie sweep net, (B) roller gear net, and (C) relationship between average wingspread during nominal tow vs. sensor tow duration.



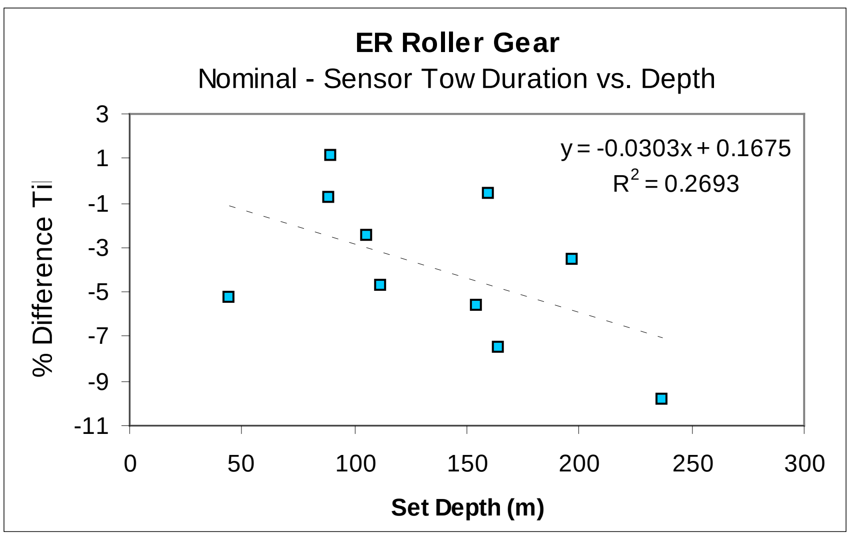


Figure A21. Relative difference between tow duration estimated from sensor data (tows with good bottom contact readings) and nominal tow duration for each net. (A) Endurance and Mary K cookie sweeps, (B) Endurance roller sweep.

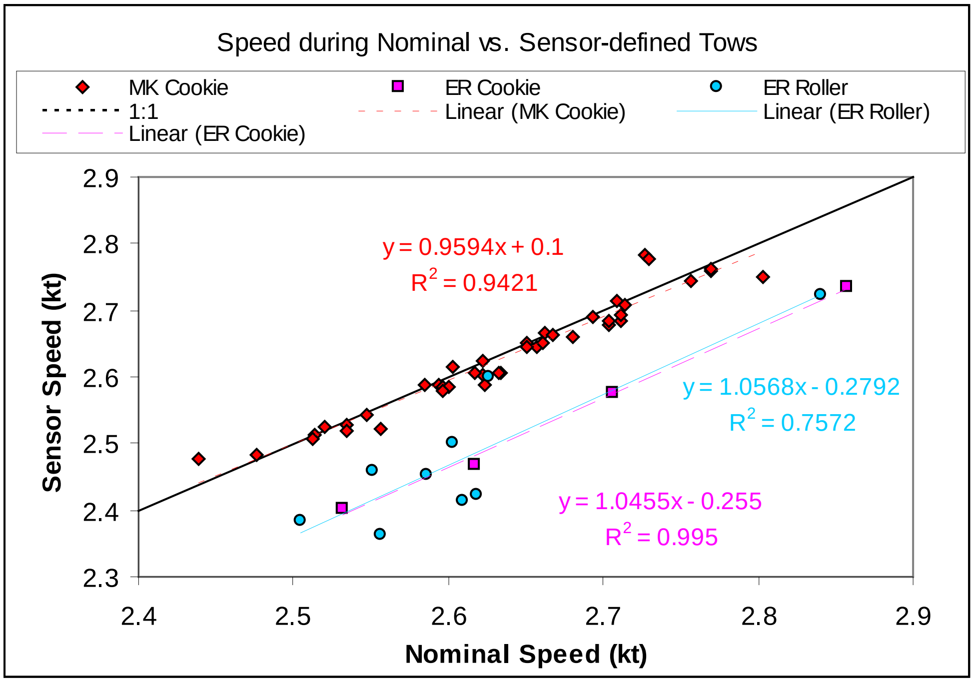


Figure A22. Adjustments to nominal average speed for tows with no bottom contact sensor data to define sensor tow length (and average sensor tow speed).

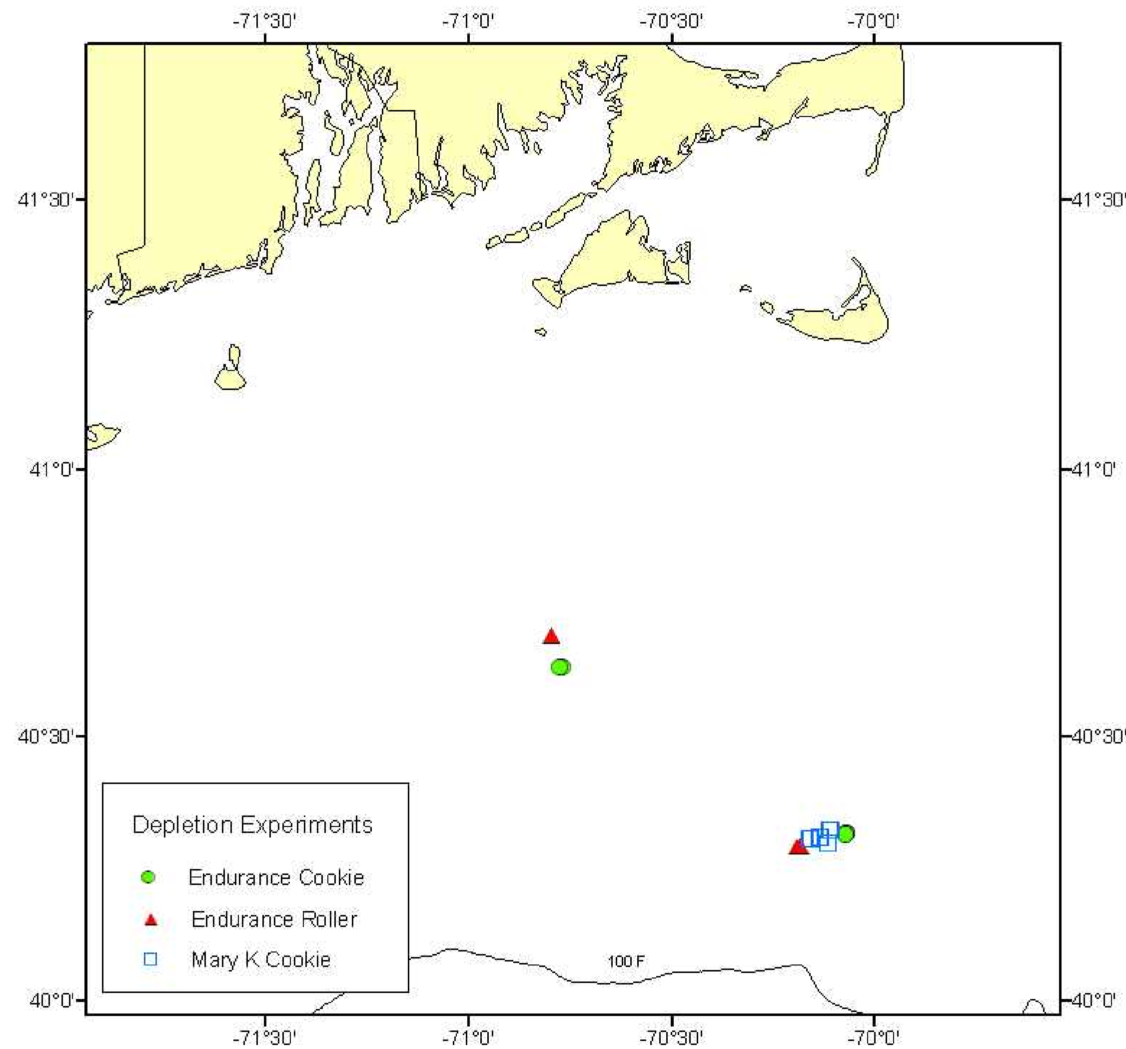


Figure A23. Location of depletion experiments for the 3 net types used in the 2009 cooperative monkfish survey.

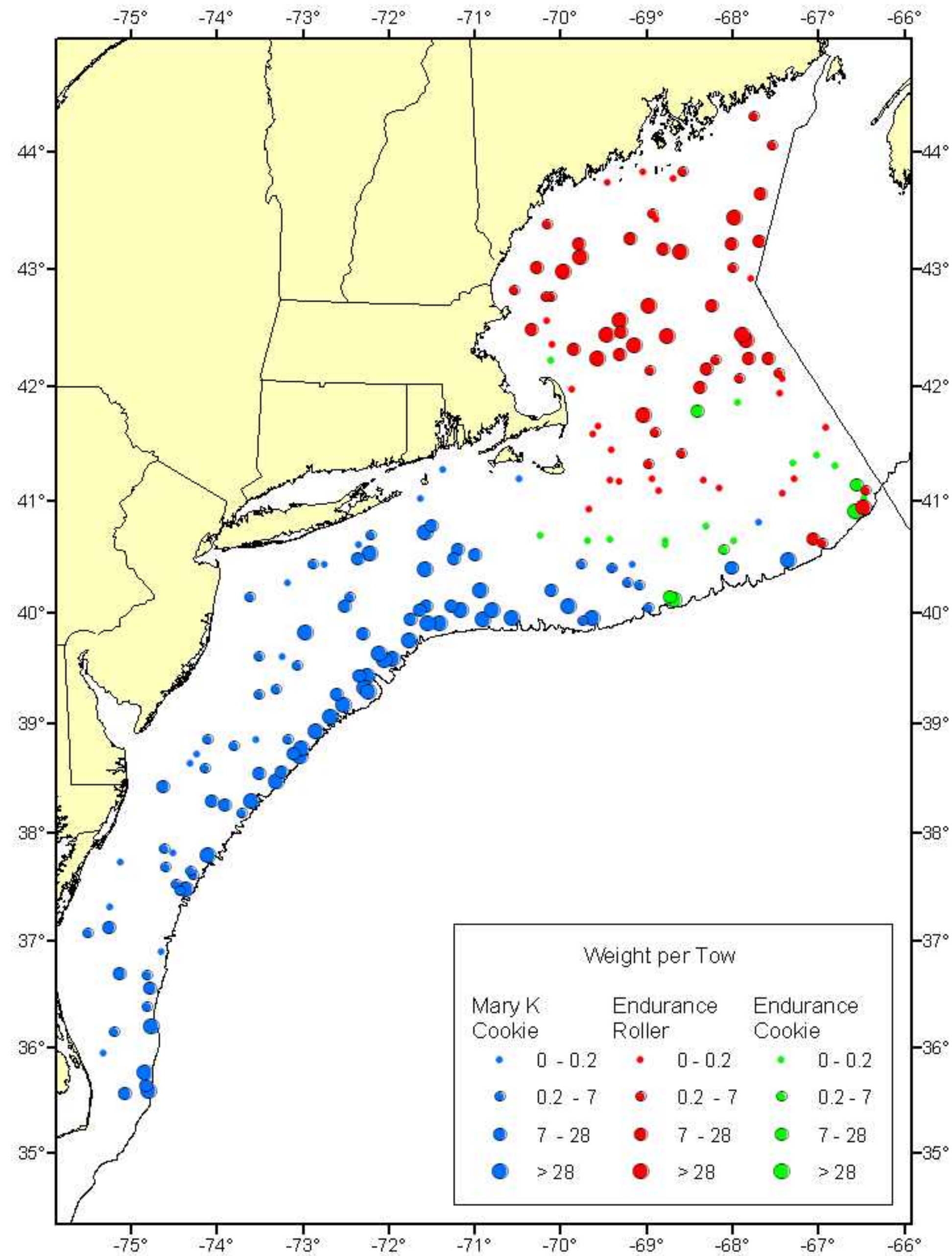


Figure A24. Nominal catch per tow (kg) coded by net type.

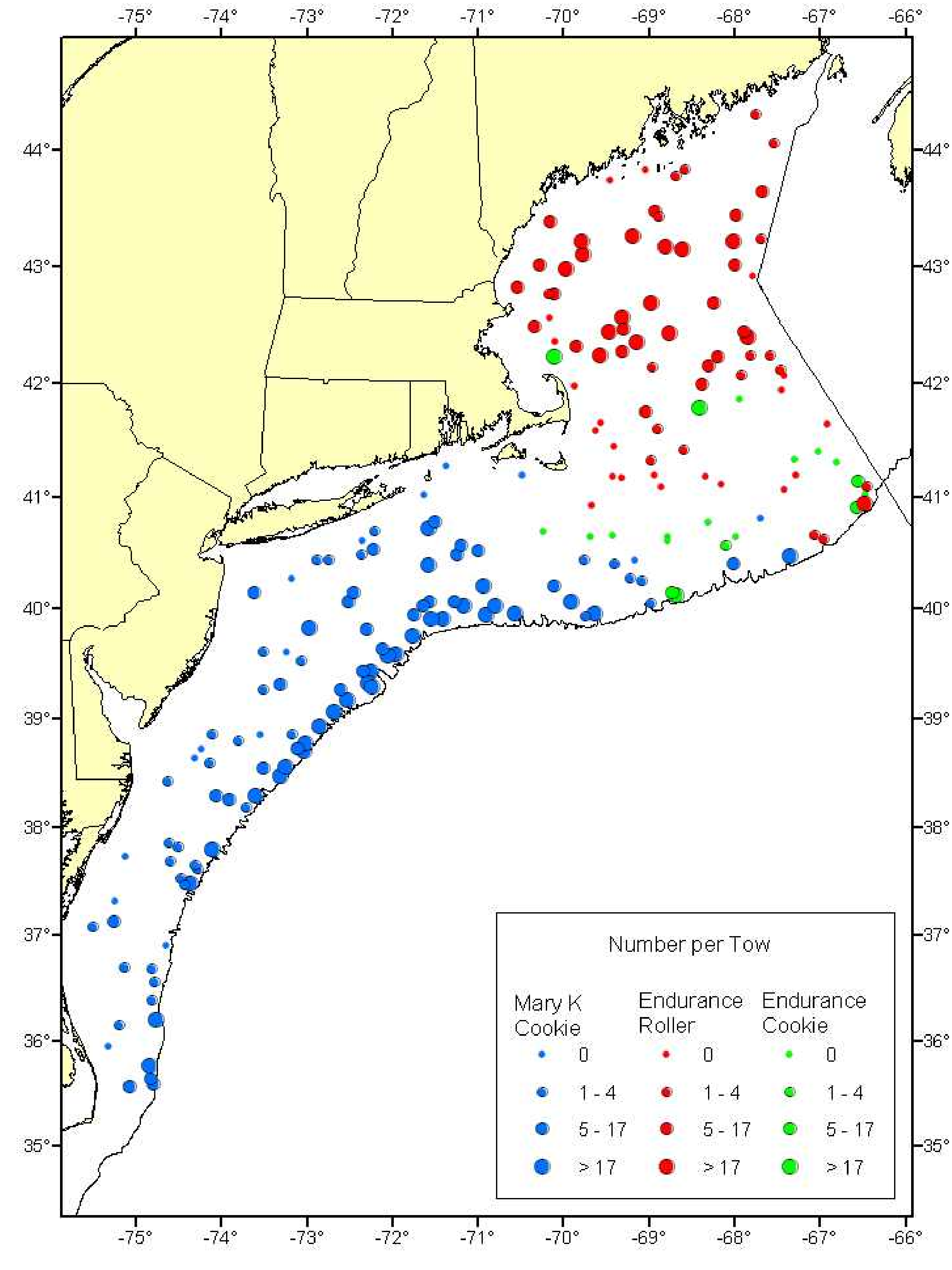
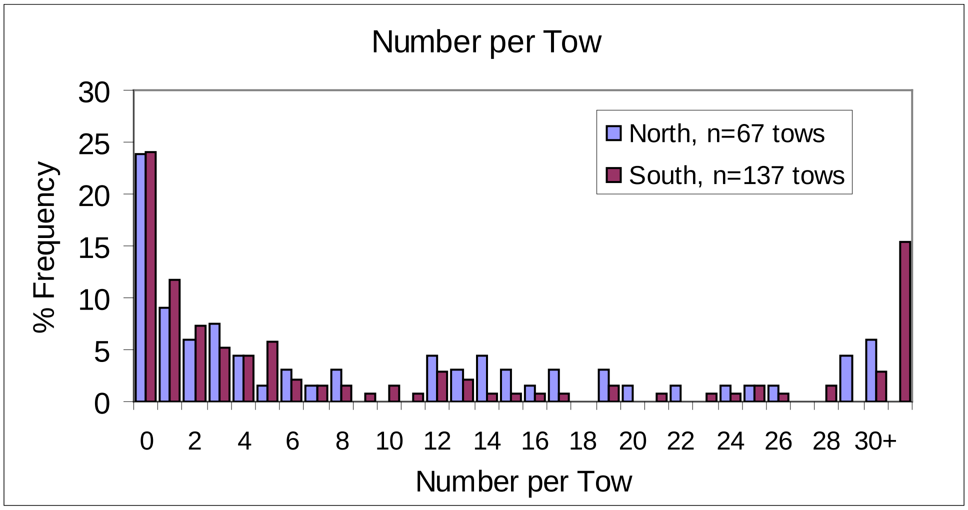


Figure A25. Nominal catch per tow (numbers) coded by net type.



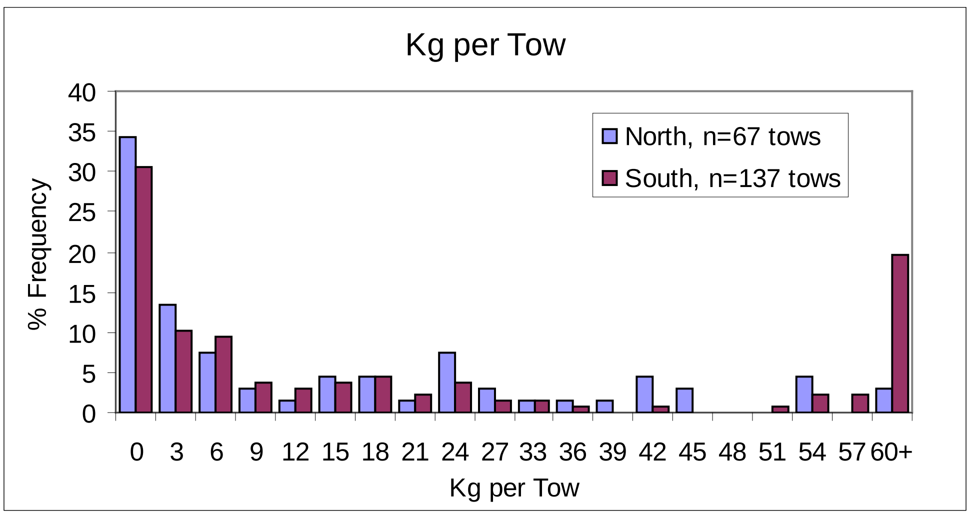


Figure A26. Relative frequency of catch per tow (number, kg), good survey tows.

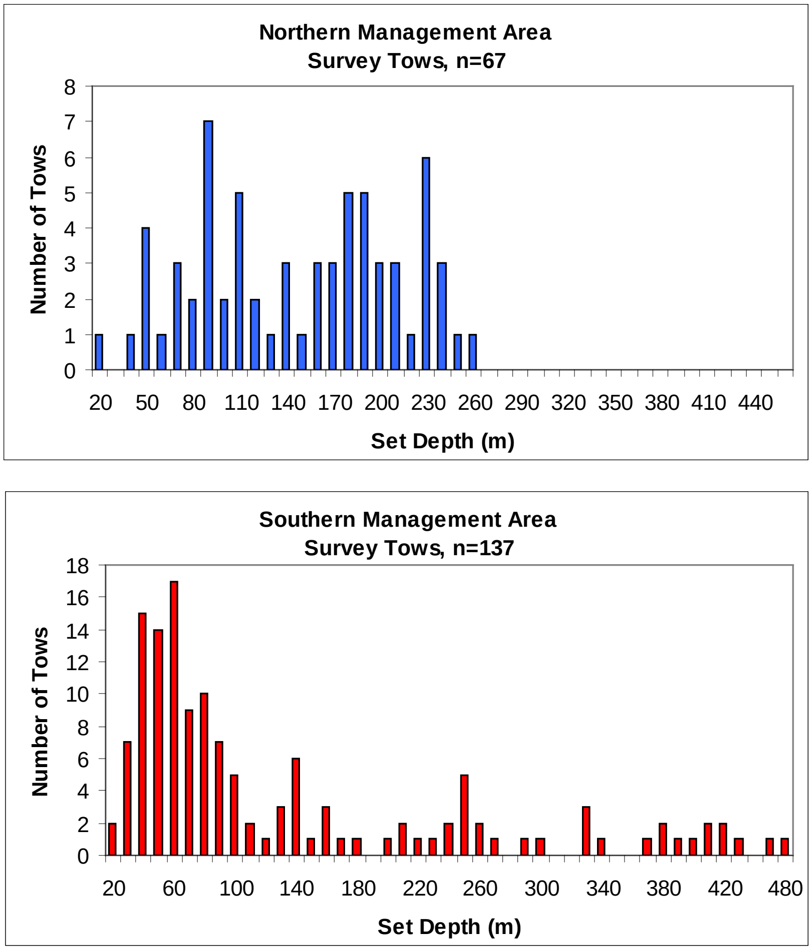


Figure A27. Depth distribution (binned by 10 m) of good survey tows from 2009 cooperative monkfish survey.

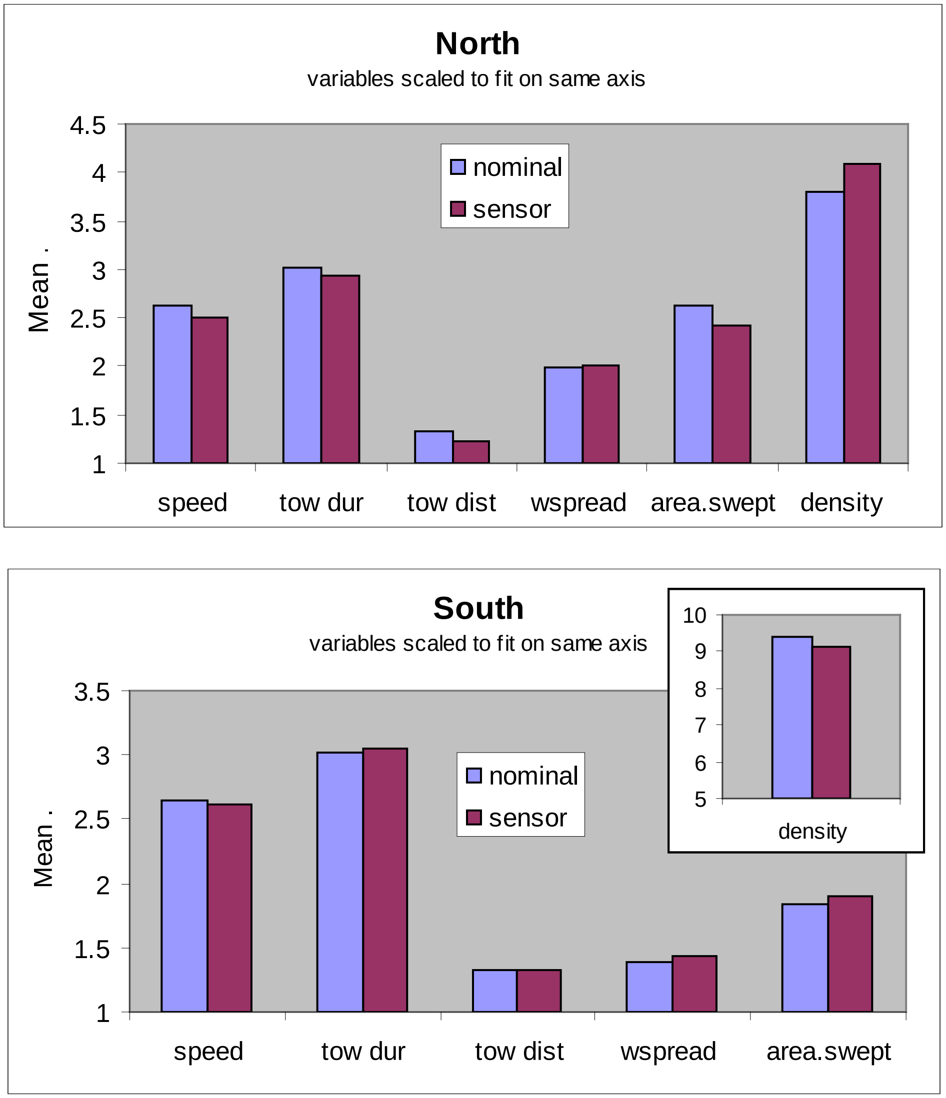
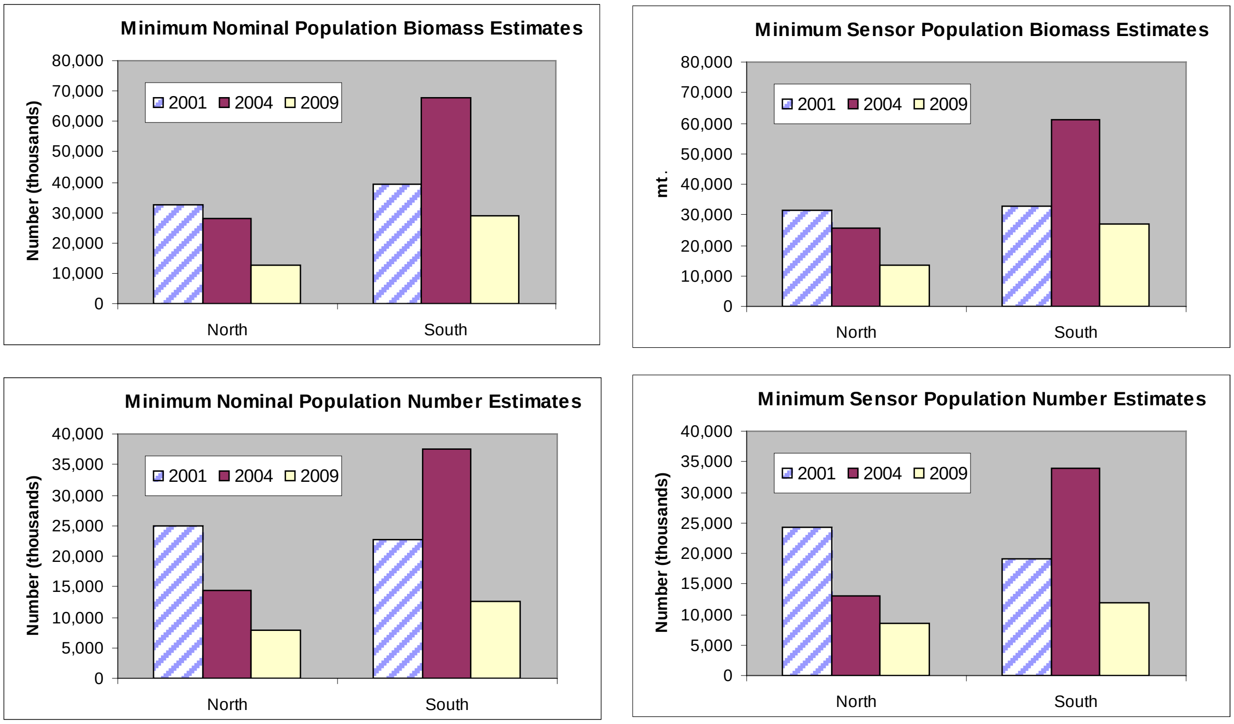


Figure A28. Effects of adjustments to derive sensor-based estimates, averaged over management area. Variables have been scaled to fit on the same x-axis. Density is number per nautical mile.

A.



B.

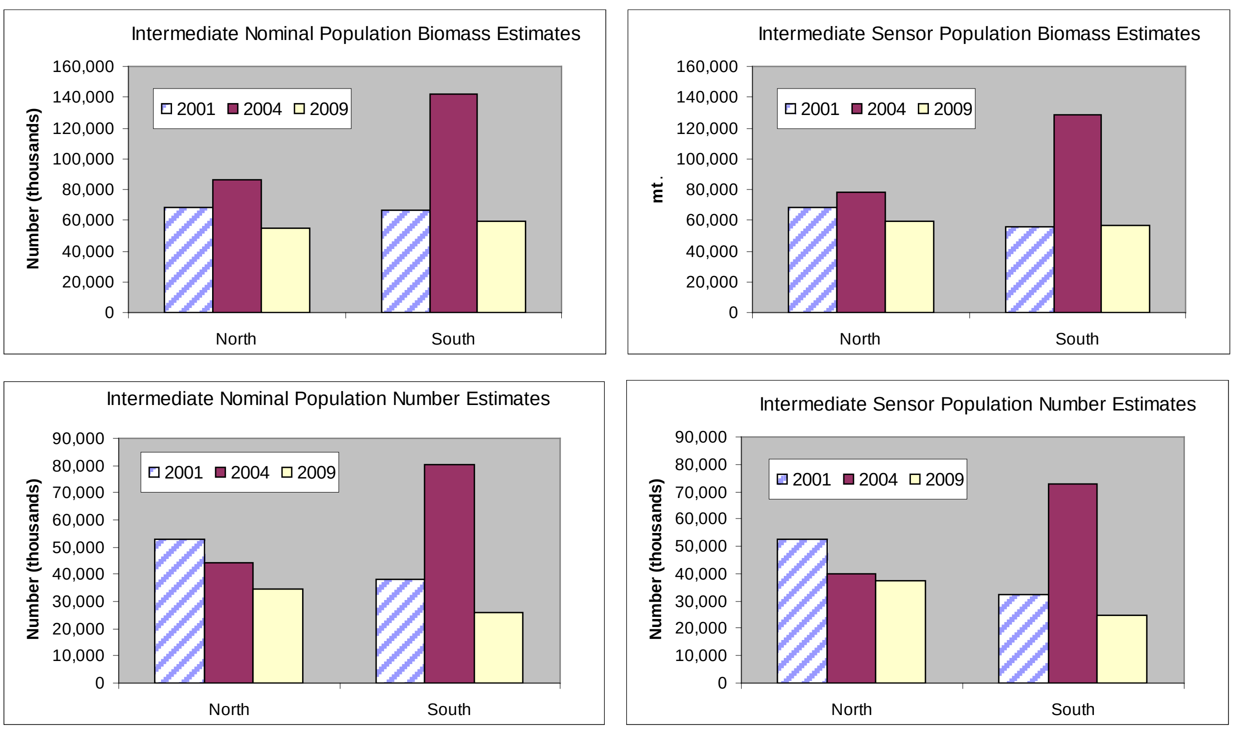


Figure A29. A. Minimum estimates (assuming 100% net efficiency) of population size and biomass based on nominal and sensor-defined tows from 2001, 2004 and 2009 cooperative surveys. B. Estimates assuming intermediate net efficiencies.

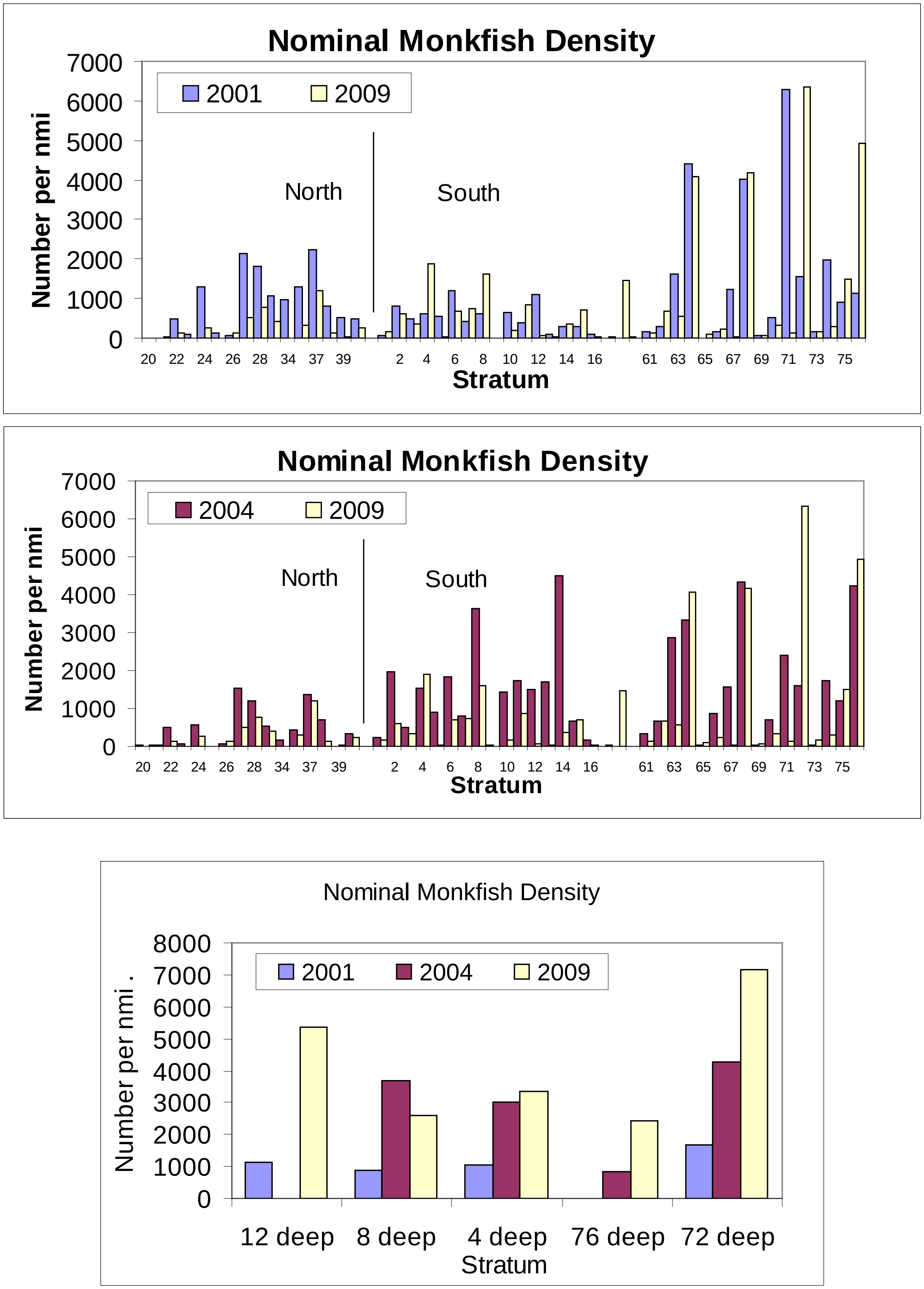


Figure A30. Monkfish density (nominal number per nmi swept) by stratum, 2001, 2004, and 2009 cooperative surveys. Bottom panel shows deep strata.

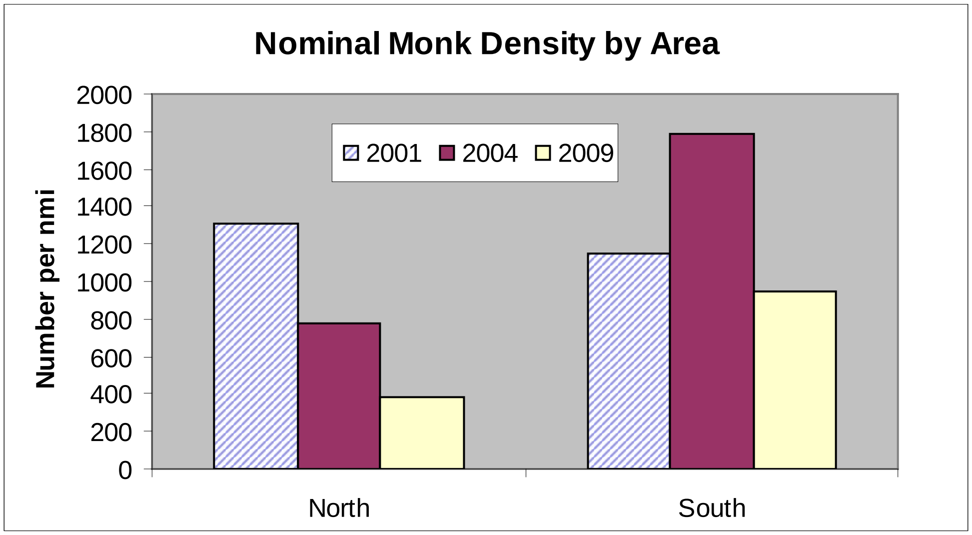
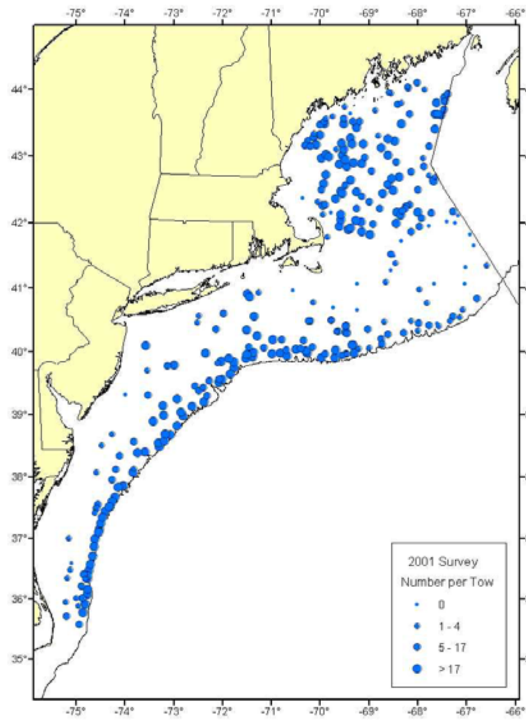
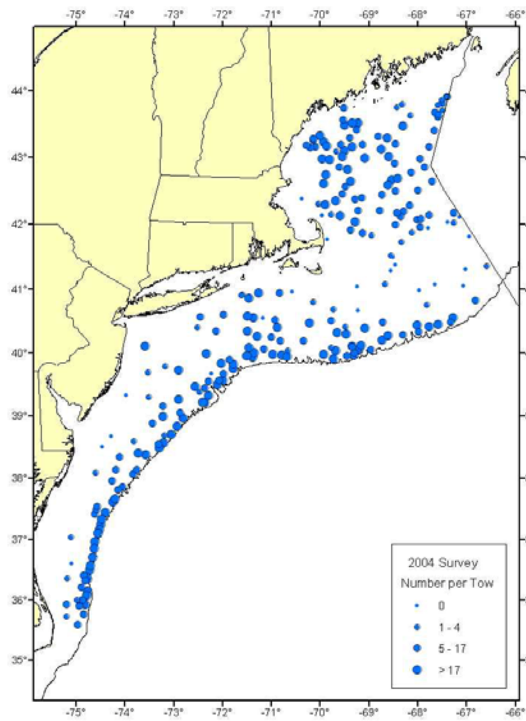


Figure A31. Nominal monkfish density by management region, 2001, 2004, 2009.


2001 Survey
Number per Tow
0
1 - 4
5 - 17
> 17


2004 Survey
Number per Tow
0
1 - 4
5 - 17
> 17

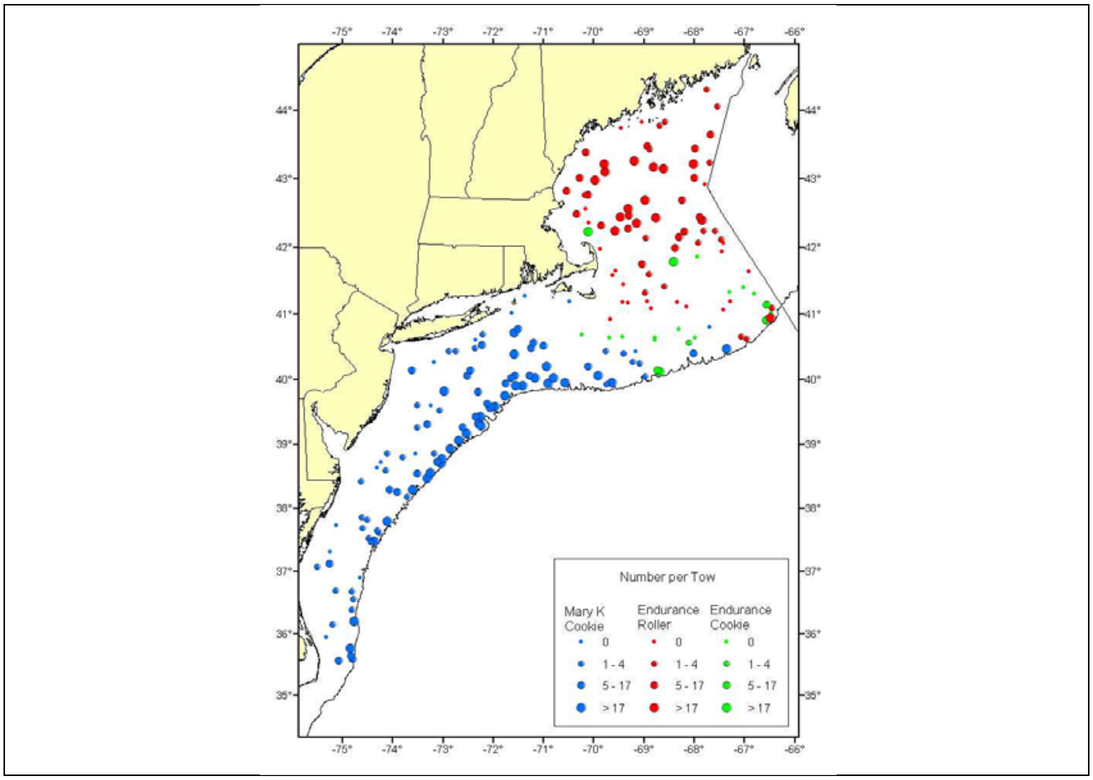


Figure A32. Distribution of catch rates (number per tow) in 2001, 2004 and 2009 cooperative surveys.

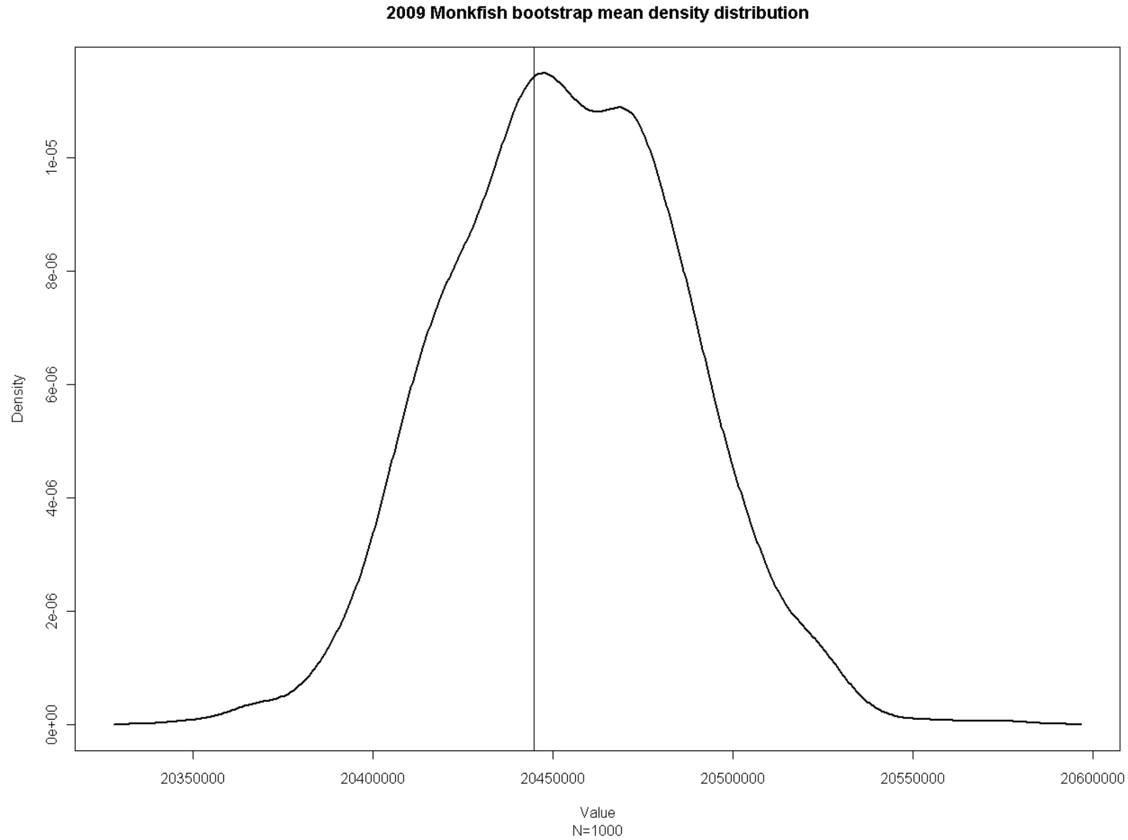
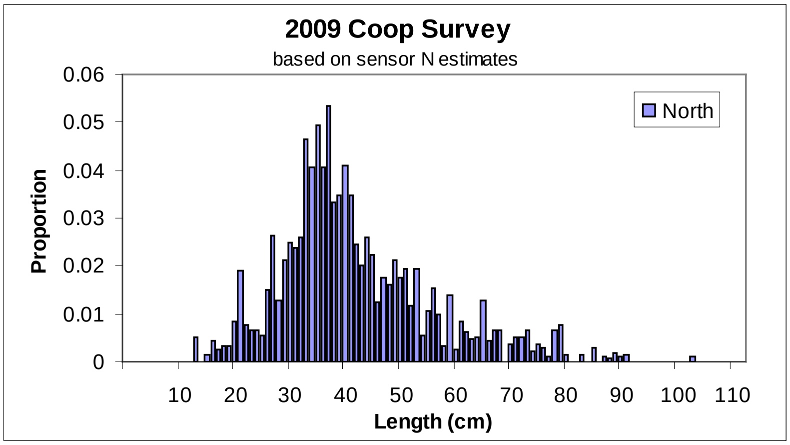
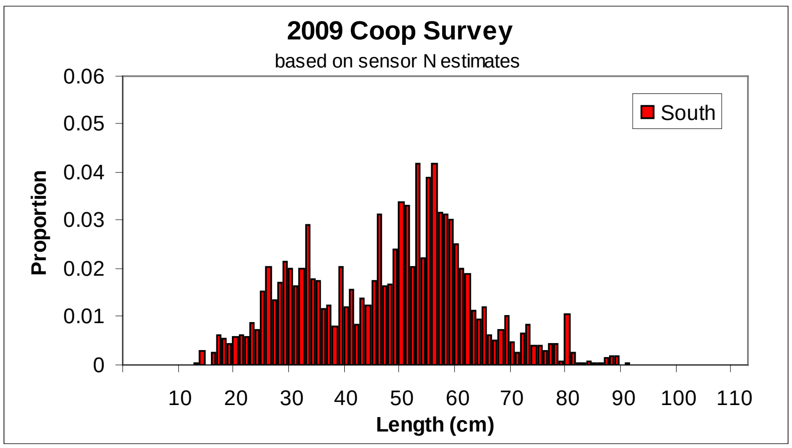
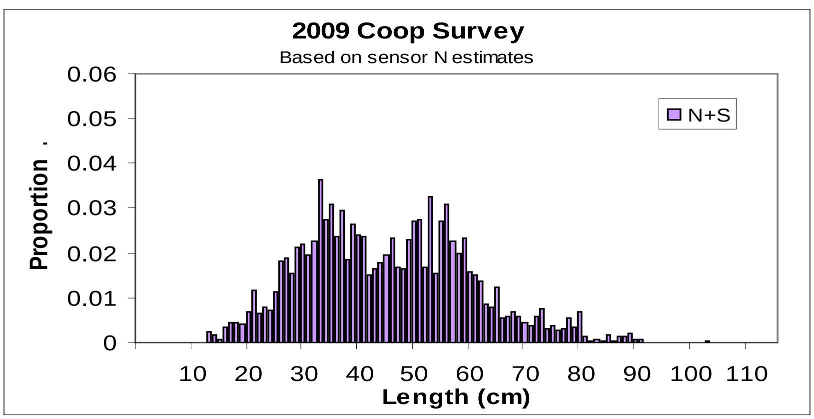


Figure A33. Results of bootstrapping analysis of monkfish catches in 2009 cooperative survey for the entire survey region based on 1,000 realizations.







Mean= 20,444,757
S.E. = 32,204.99
CV= 0.157522%

Figure A34. Proportion at length from the 2009 cooperative survey for northern, southern and combined management regions. Estimates were derived by applying proportion at length in each stratum to minimum sensor-based population numbers in that stratum, summing to numbers at length in each area and calculating the overall proportion at length.

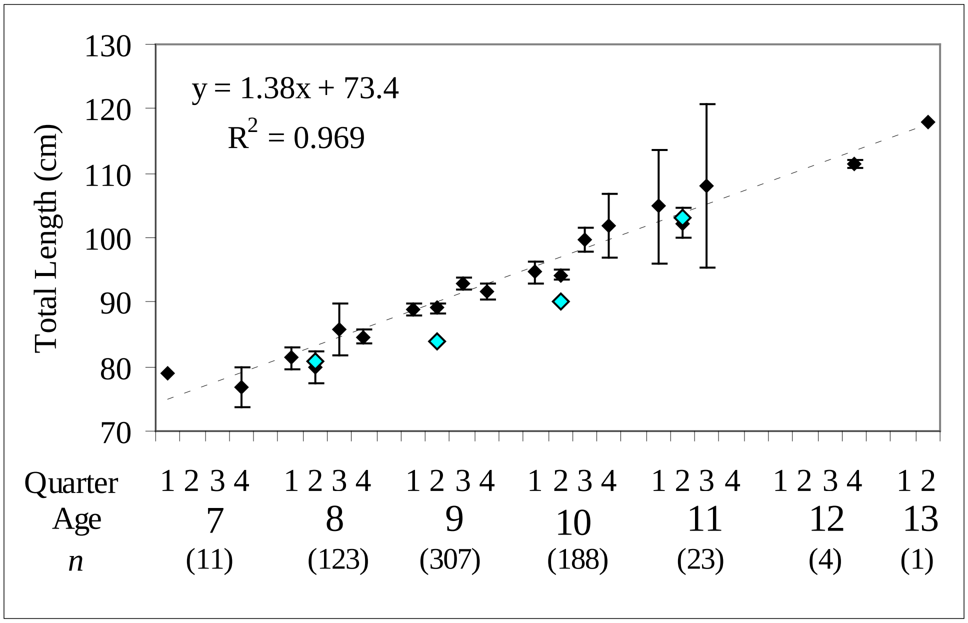


Figure A35. Mean length at age for samples from 2009 cooperative survey that were ≥ 80 cm (cyan diamonds) compared to mean length at age from NEFSC surveys and previous cooperative surveys (from Johnson et al. 2008). N for cooperative survey samples: age 8 = 4; age 9 = 17; age 10 = 3; age 11= 1.

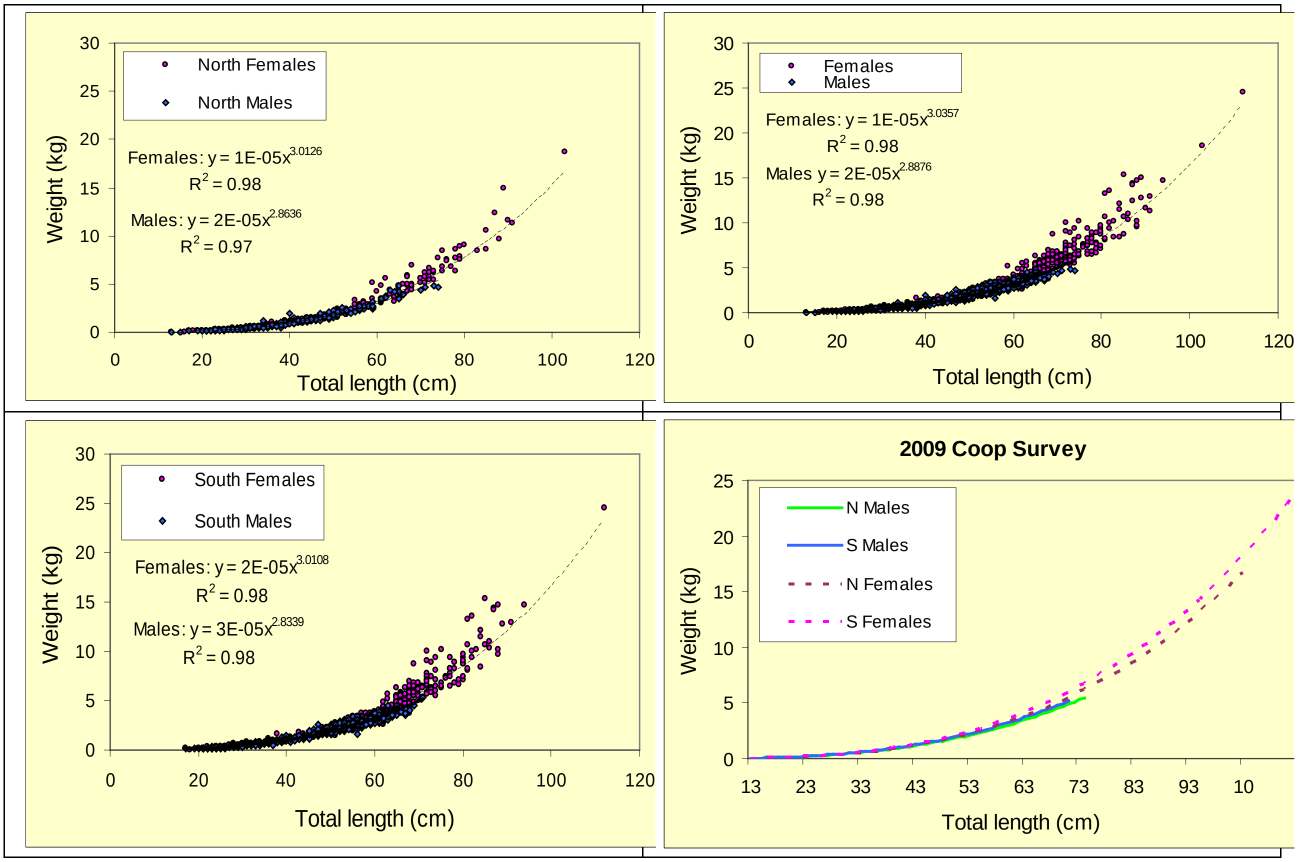


Figure A36. Length-weight relationships for male and female monkfish from northern and southern management areas, 2009 cooperative survey data.

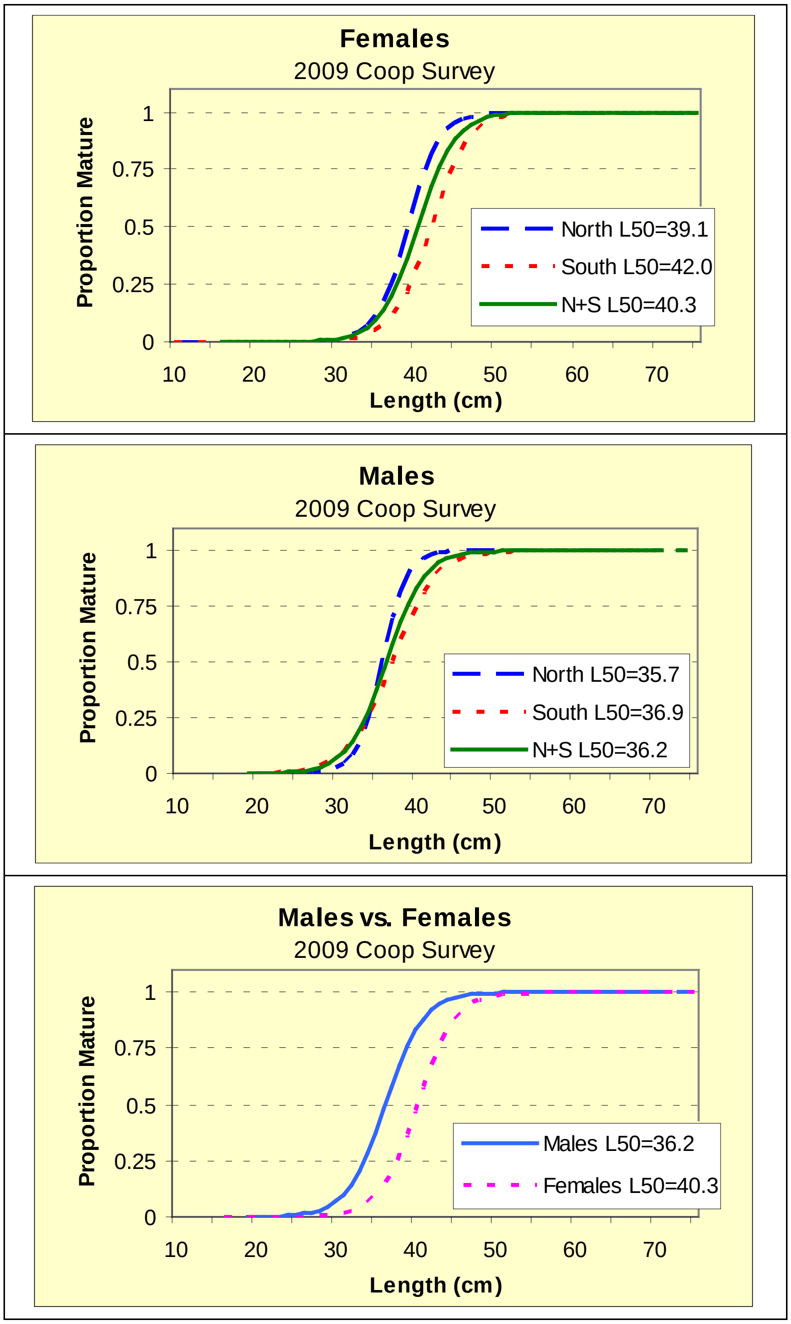


Figure A37. Maturity ogives for male and female monkfish from northern and southern management areas, 2009 cooperative survey data.

Figure A38. Catch rates (kg per tow) in 2009 cooperative monkfish survey and NEFSC 2009 spring survey.

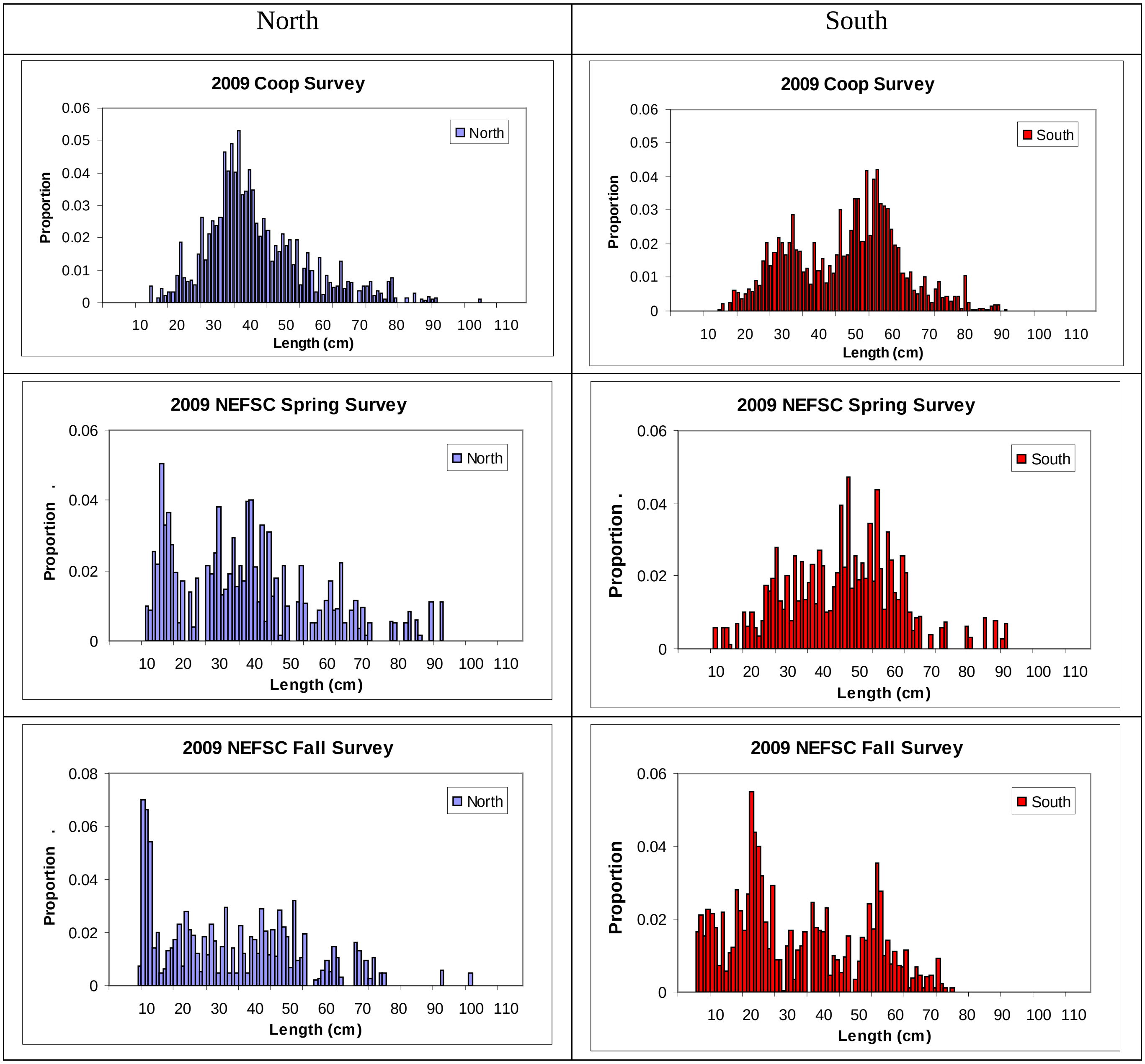


Figure A39. Proportion at length in NFMA and SFMA from the 2009 cooperative survey (top row), NEFSC 2009 spring survey (middle row) and NEFSC 2009 autumn survey (bottom row).

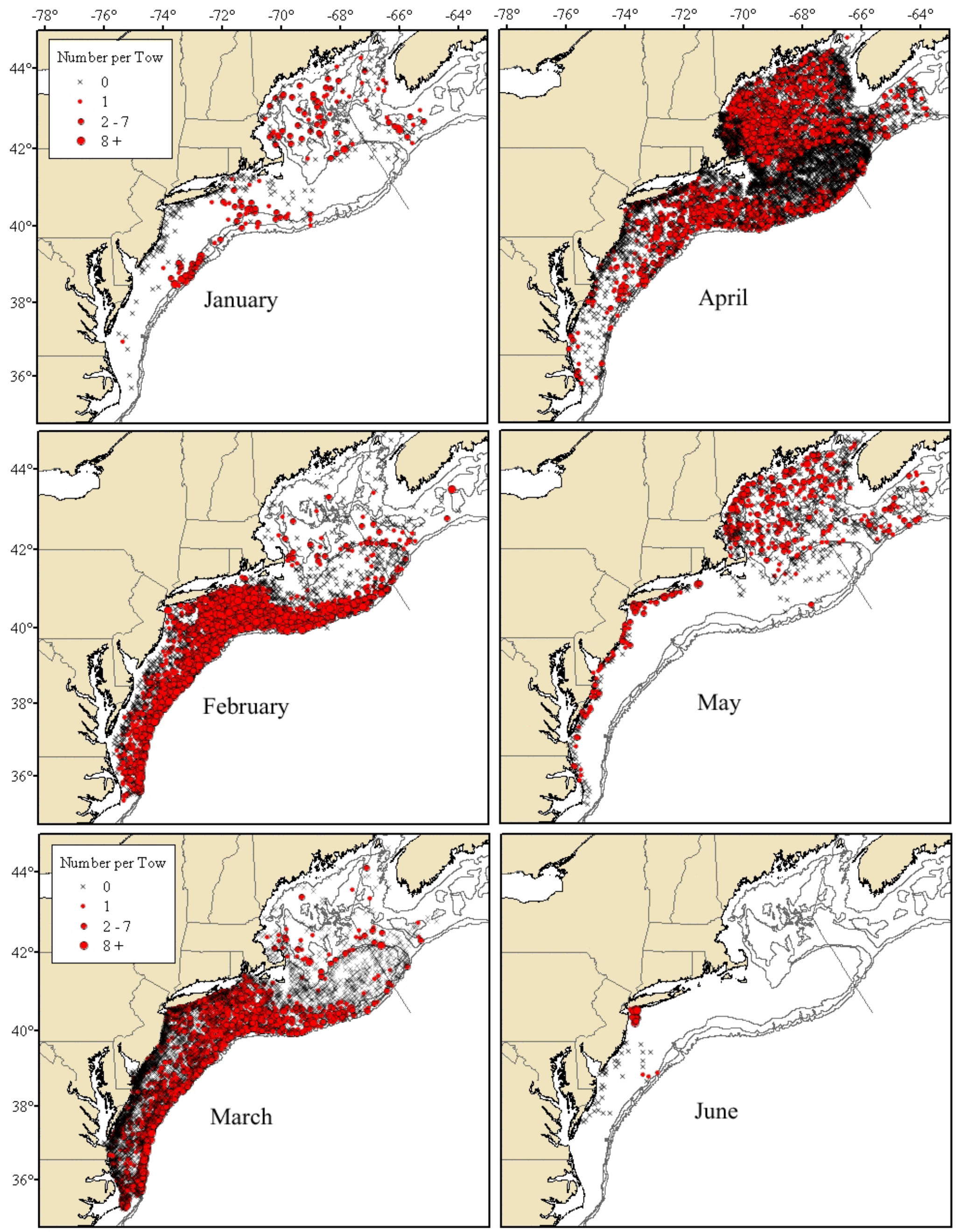


Figure A40. Monthly distribution plots for monkfish, January-December.

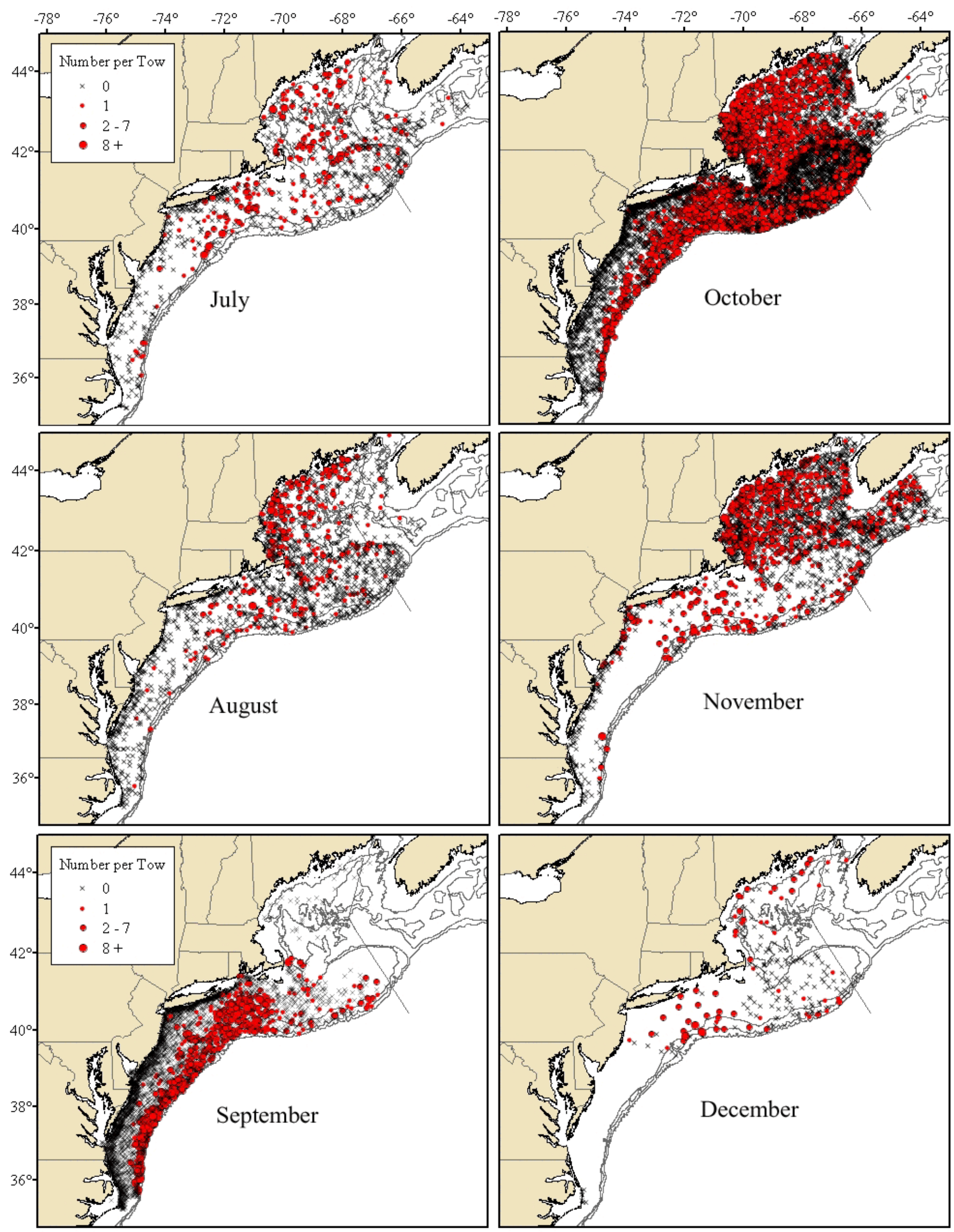


Figure A40, cont'd.

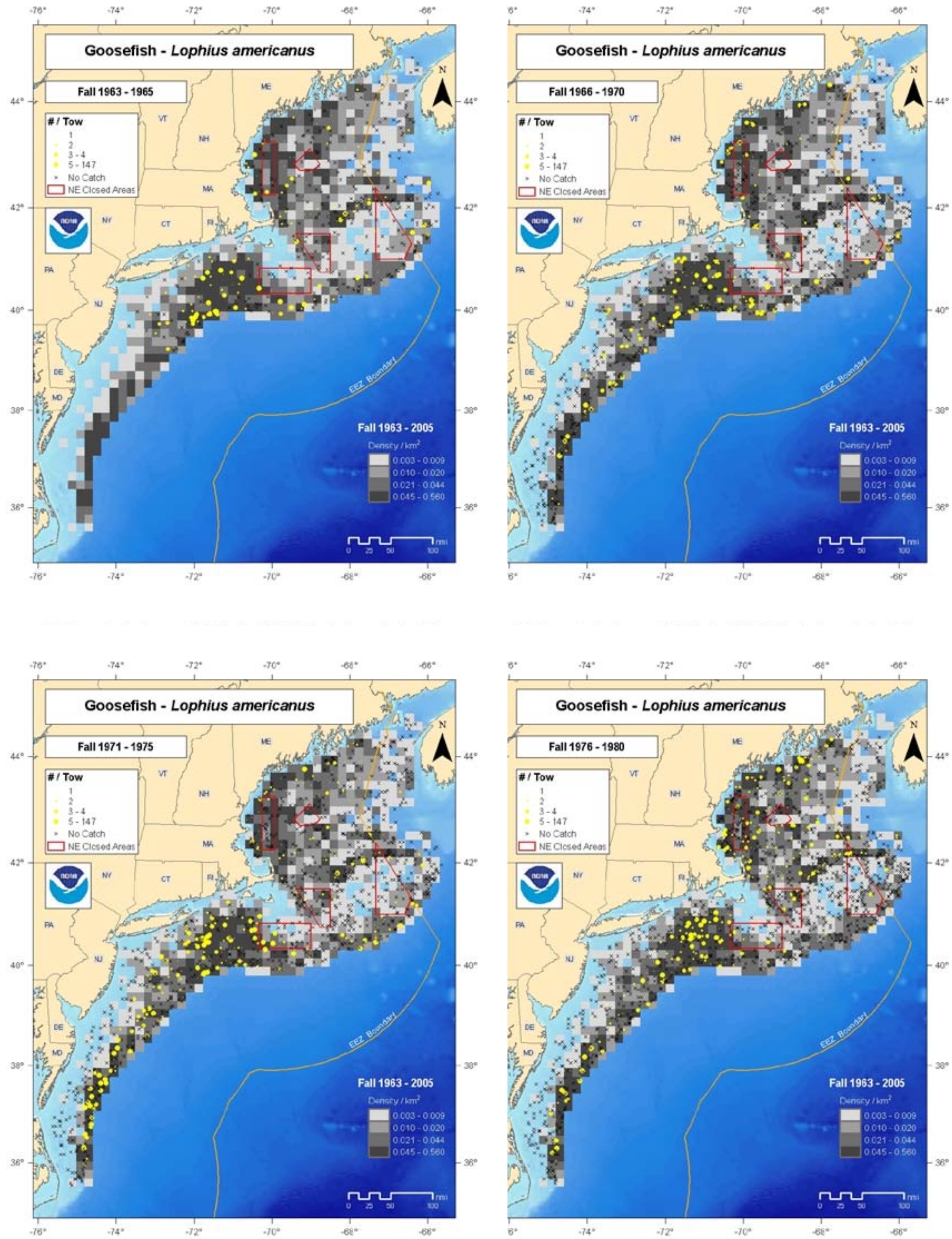


Figure A41. Distribution of monkfish from the NEFSC fall survey, 1963-2005 (from www.nefsc.noaa.gov/sos).

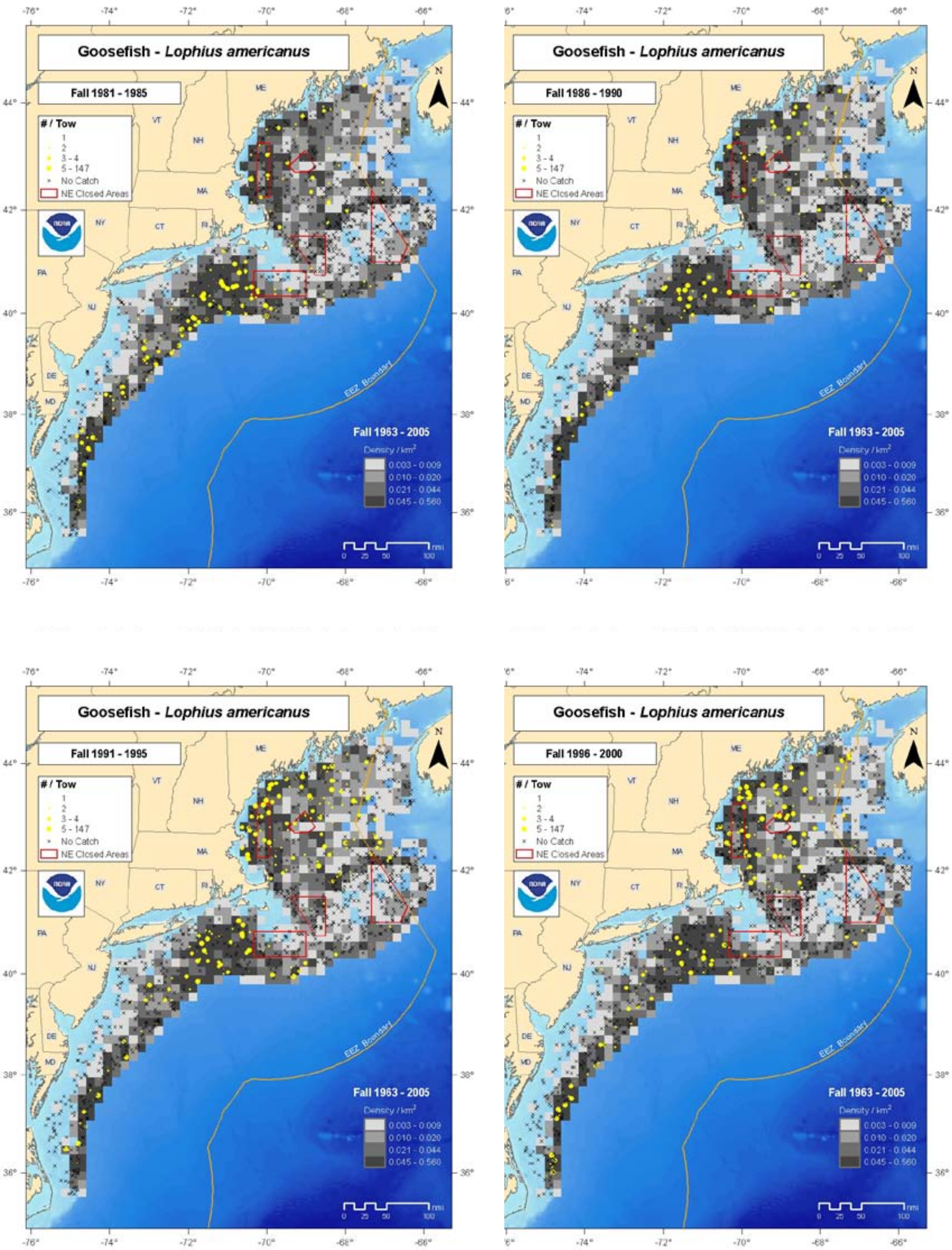


Figure A41. continued

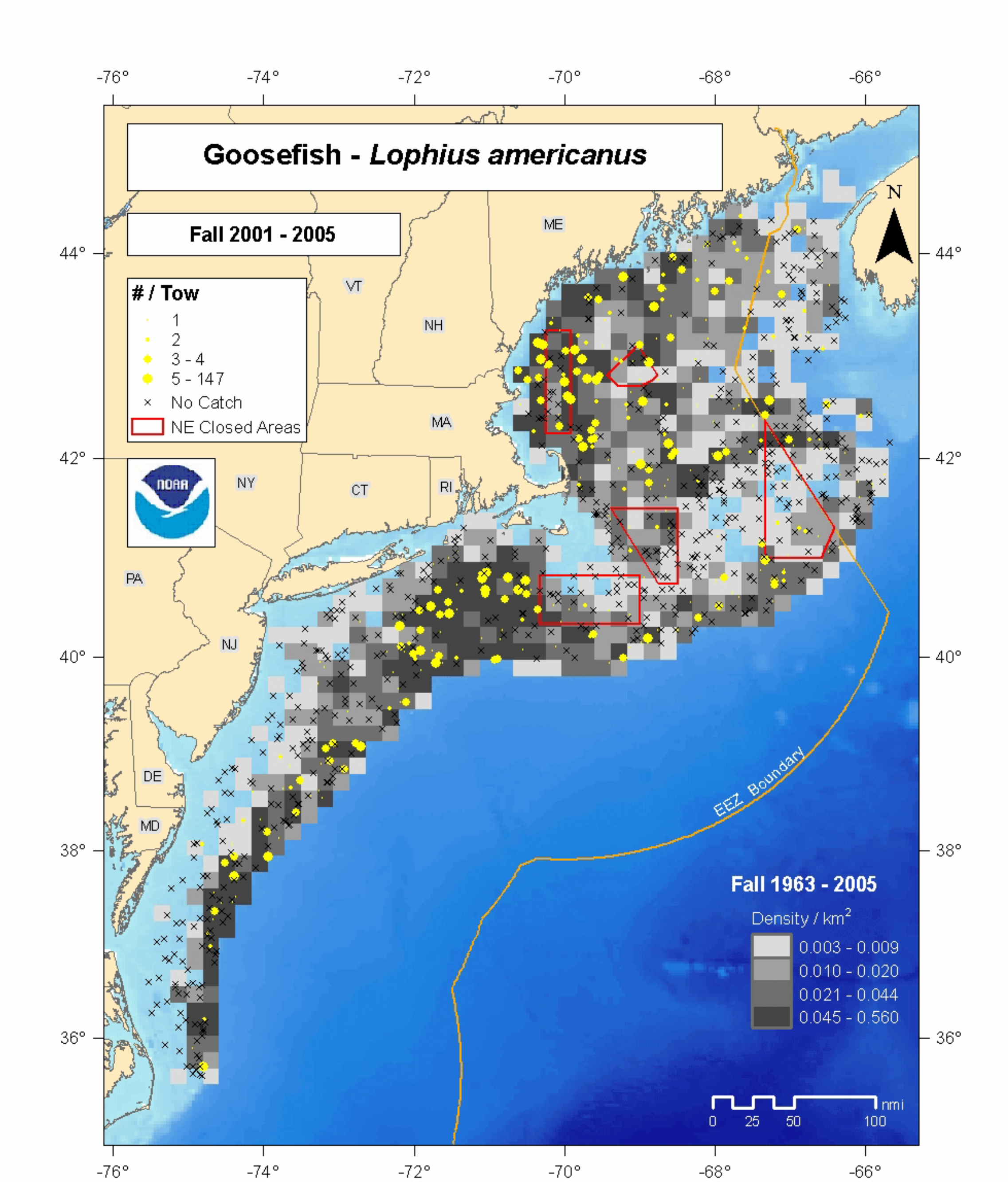
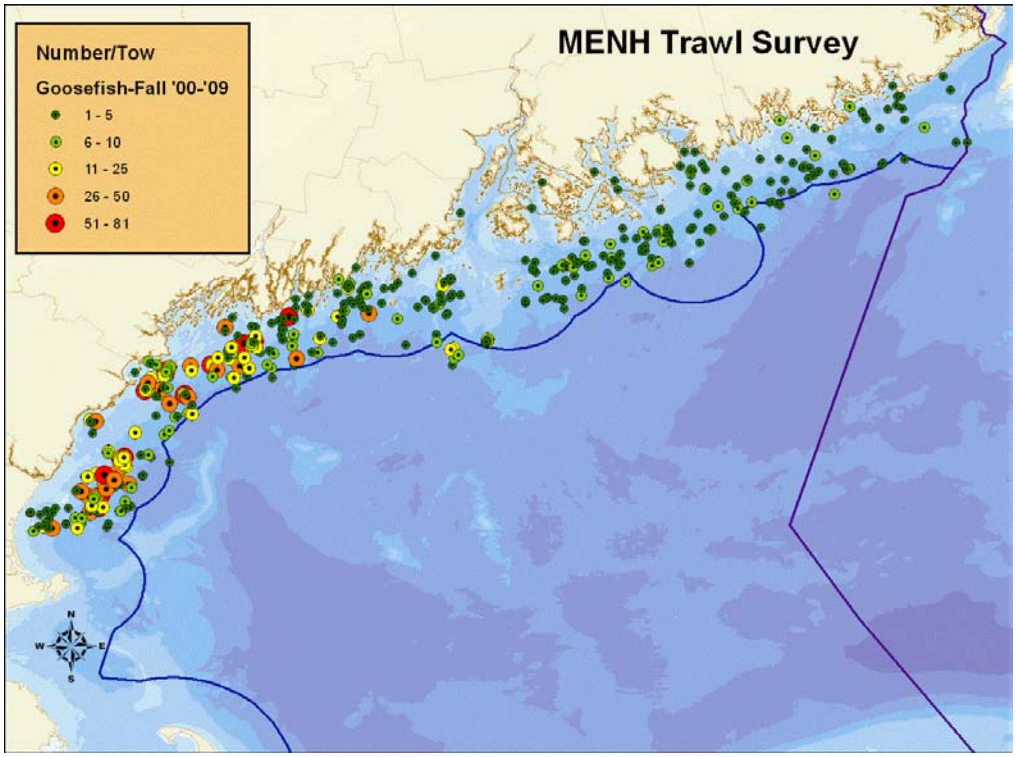


Figure A41. continued



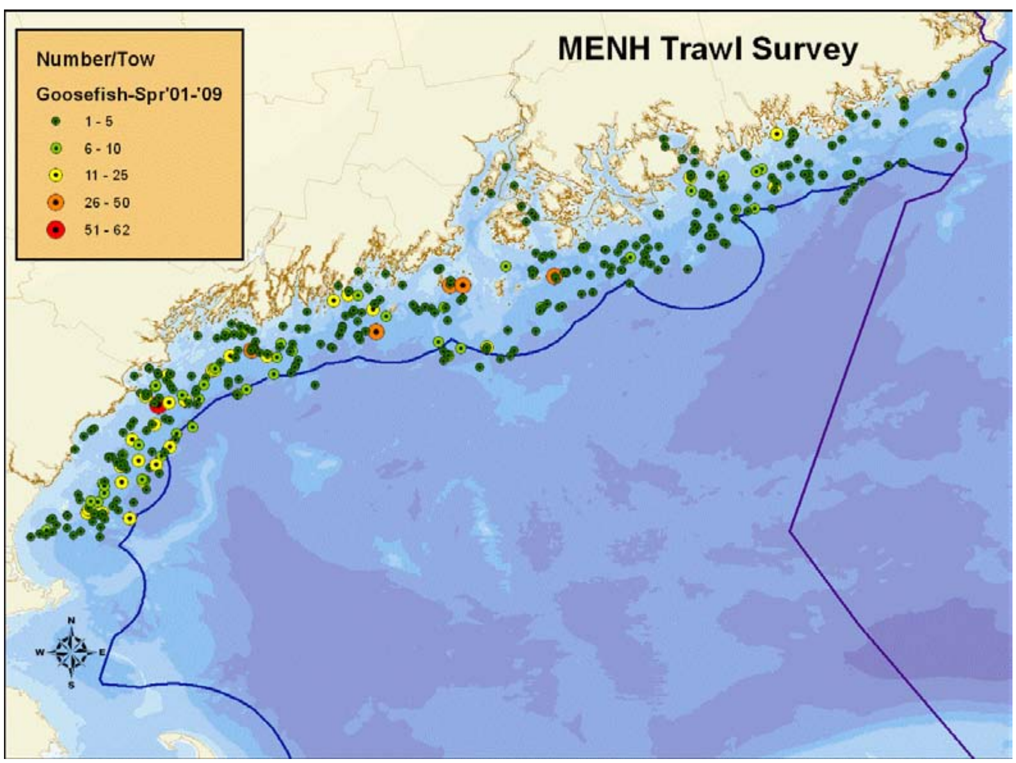
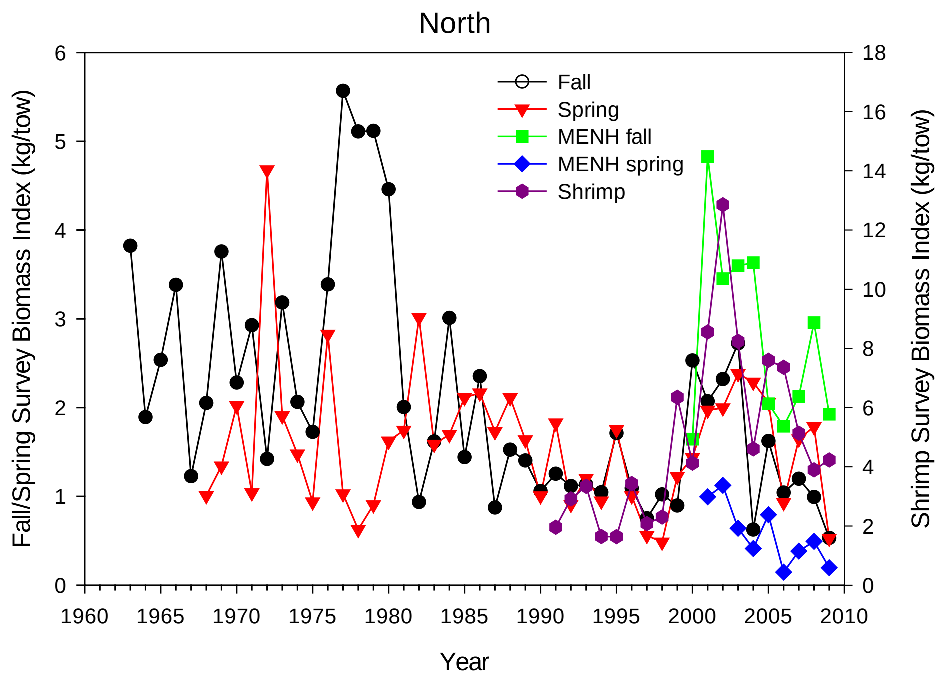


Figure A42. Geographic distribution of catches in fall (top panel) and spring (bottom panel) ME-NH inshore trawl surveys. Outer limit of survey (bold dark blue line) is 200 m.



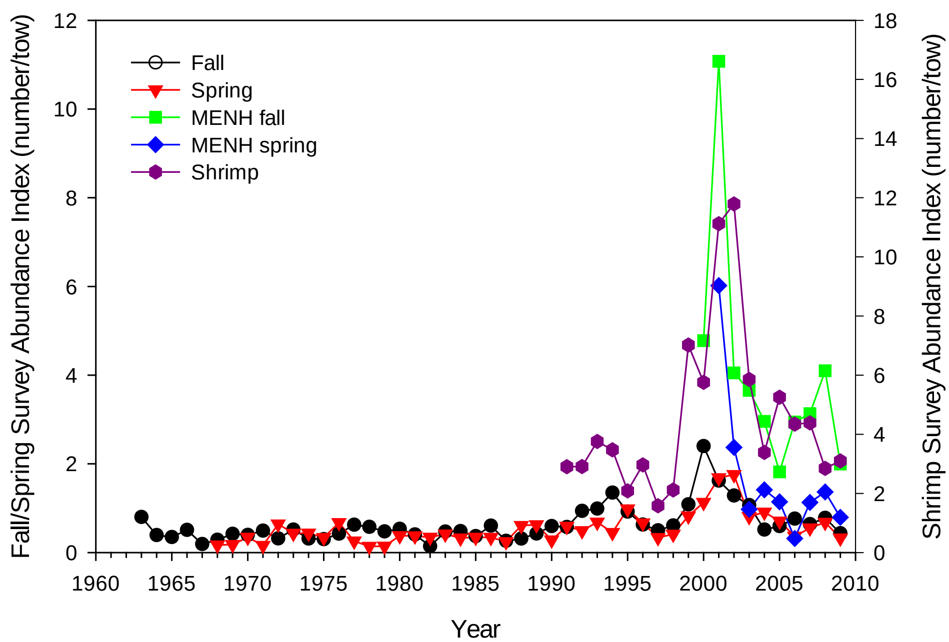


Figure A43. NEFSC spring and autumn surveys of monkfish biomass and abundance in the northern management region.

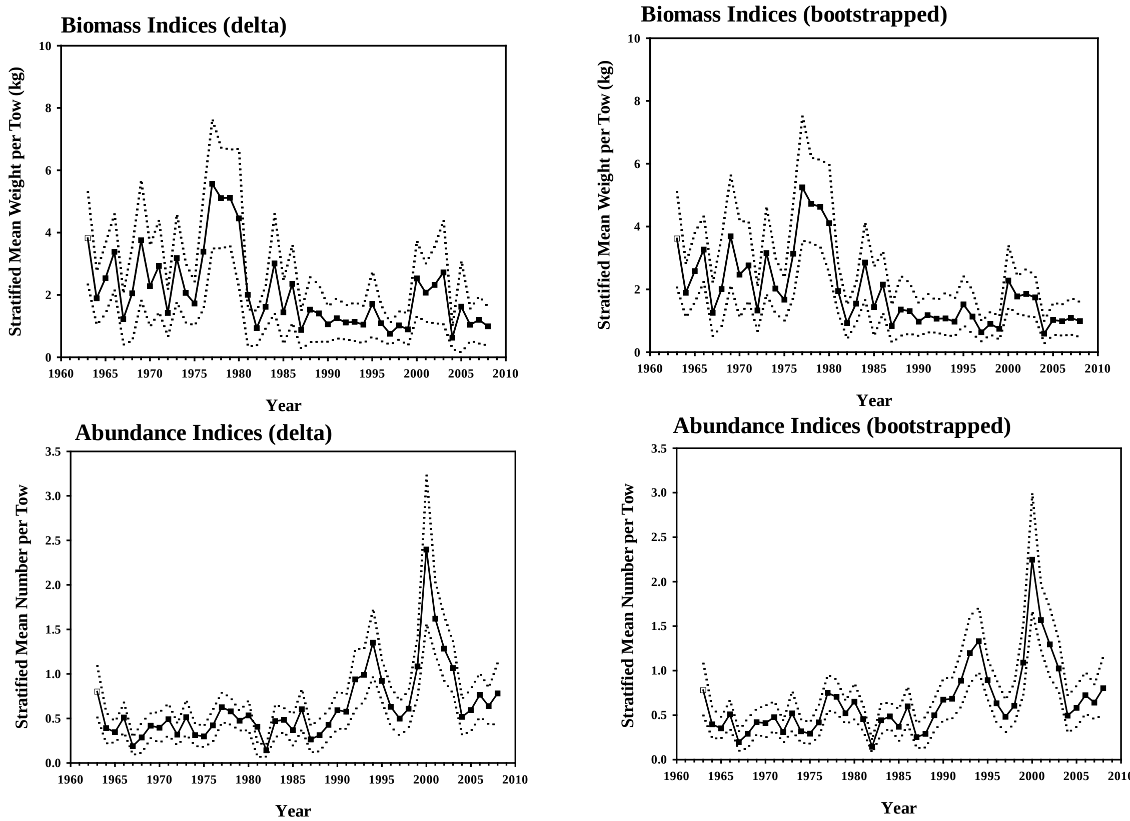


Figure A44. Delta distribution (parametric) and bootstrapped (arithmetic) biomass and abundance indices from the NEFSC autumn bottom trawl survey for the northern management region from 1963-2008. Data prior to 1971 have been revised following an audit of historical data. The 95% confidence limits are shown by the dashed line.

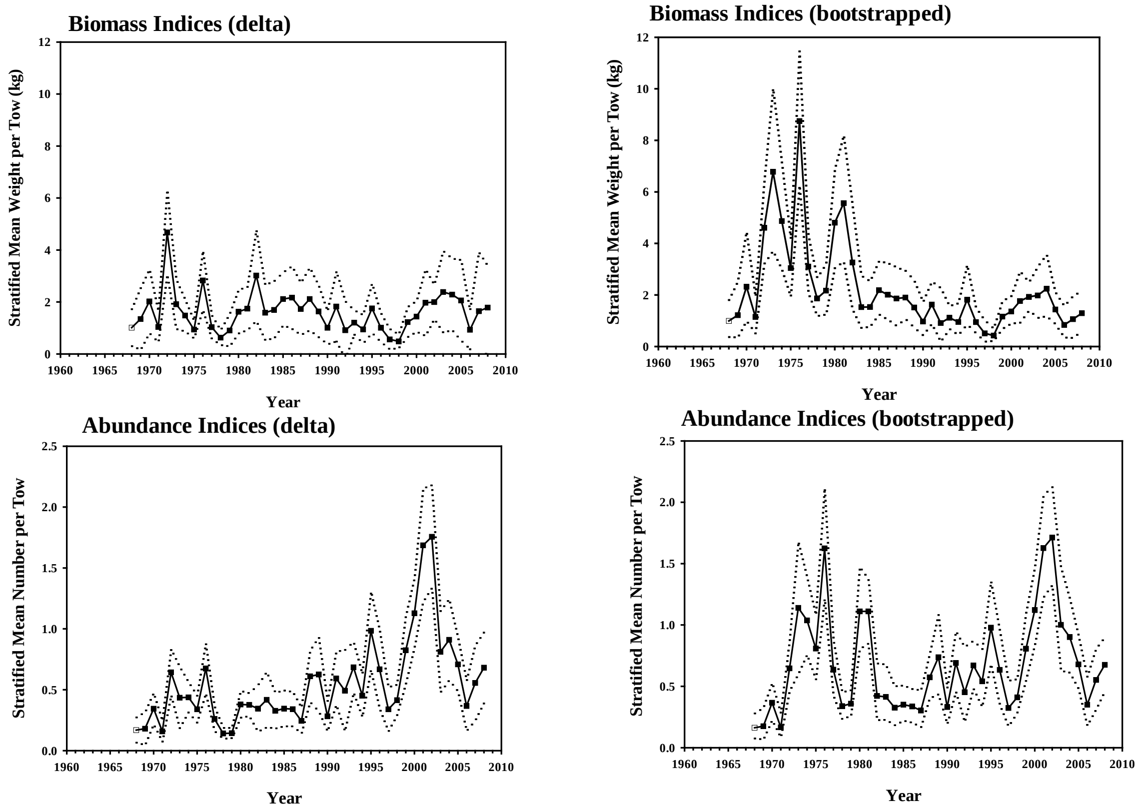


Figure A45. Delta distribution (parametric) and bootstrapped (arithmetic) biomass and abundance indices from the NEFSC spring bottom trawl survey for the northern management region from 1968-2008. Data prior to 1971 have been revised following an audit of historical data. The 95% confidence limits are shown by the dashed line.

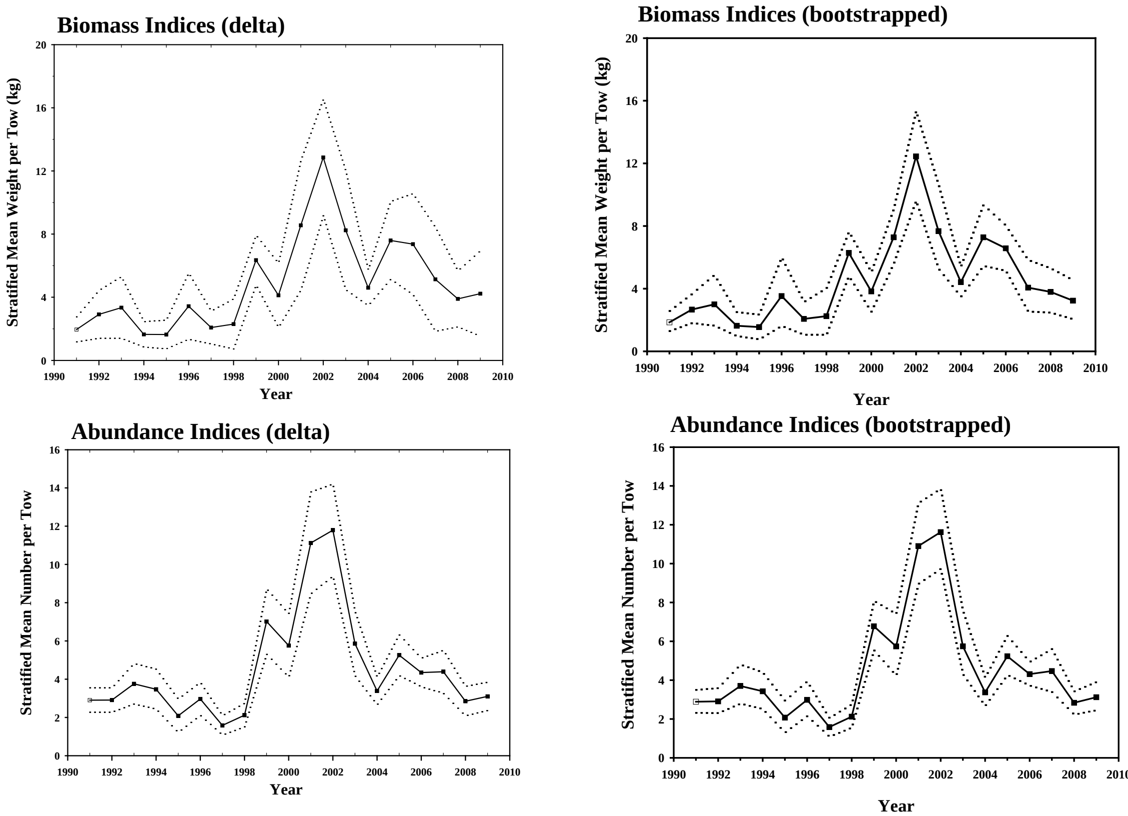
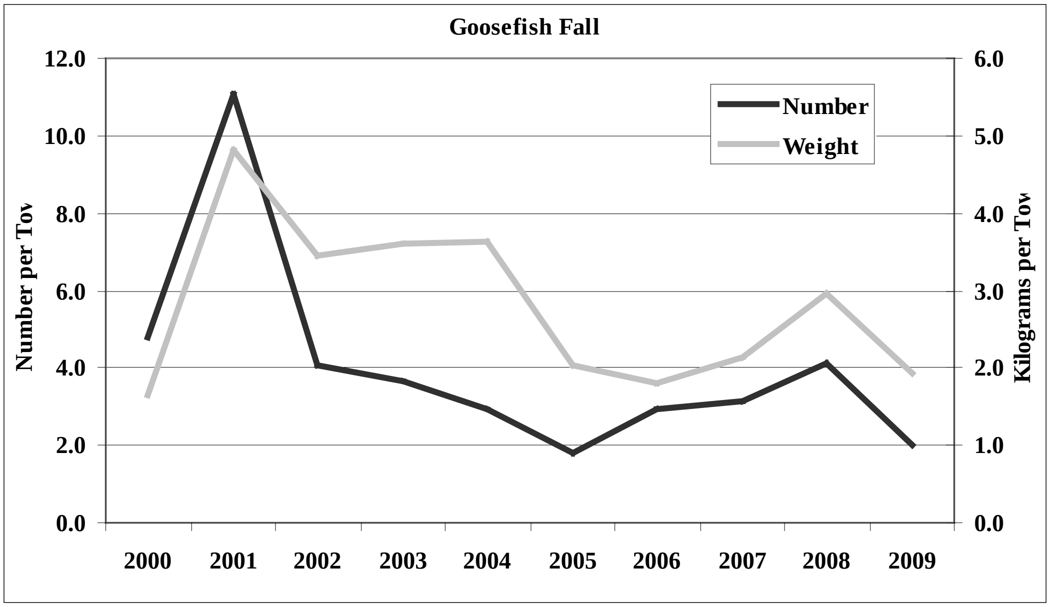


Figure A46. Delta distribution (parametric) and bootstrapped (arithmetic) biomass and abundance indices from the NEFSC shrimp survey for the northern management region from 1991-2009. Data prior to 1971 have been revised following an audit of historical data. The 95% confidence limits are shown by the dashed line.



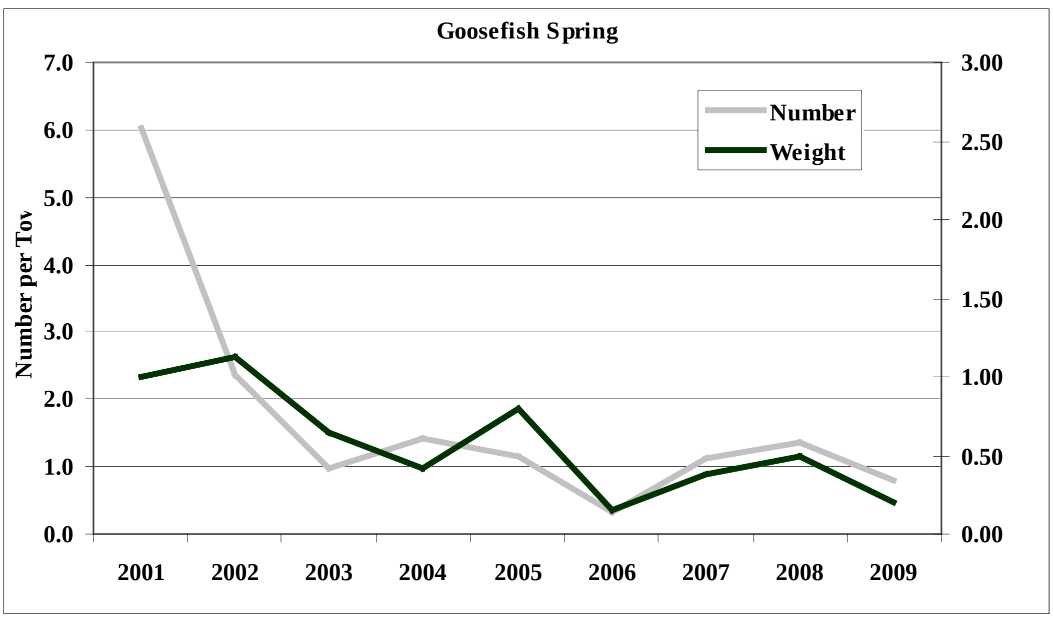


Figure A47. Survey indices from ME-NH inshore trawl surveys, NFMA.

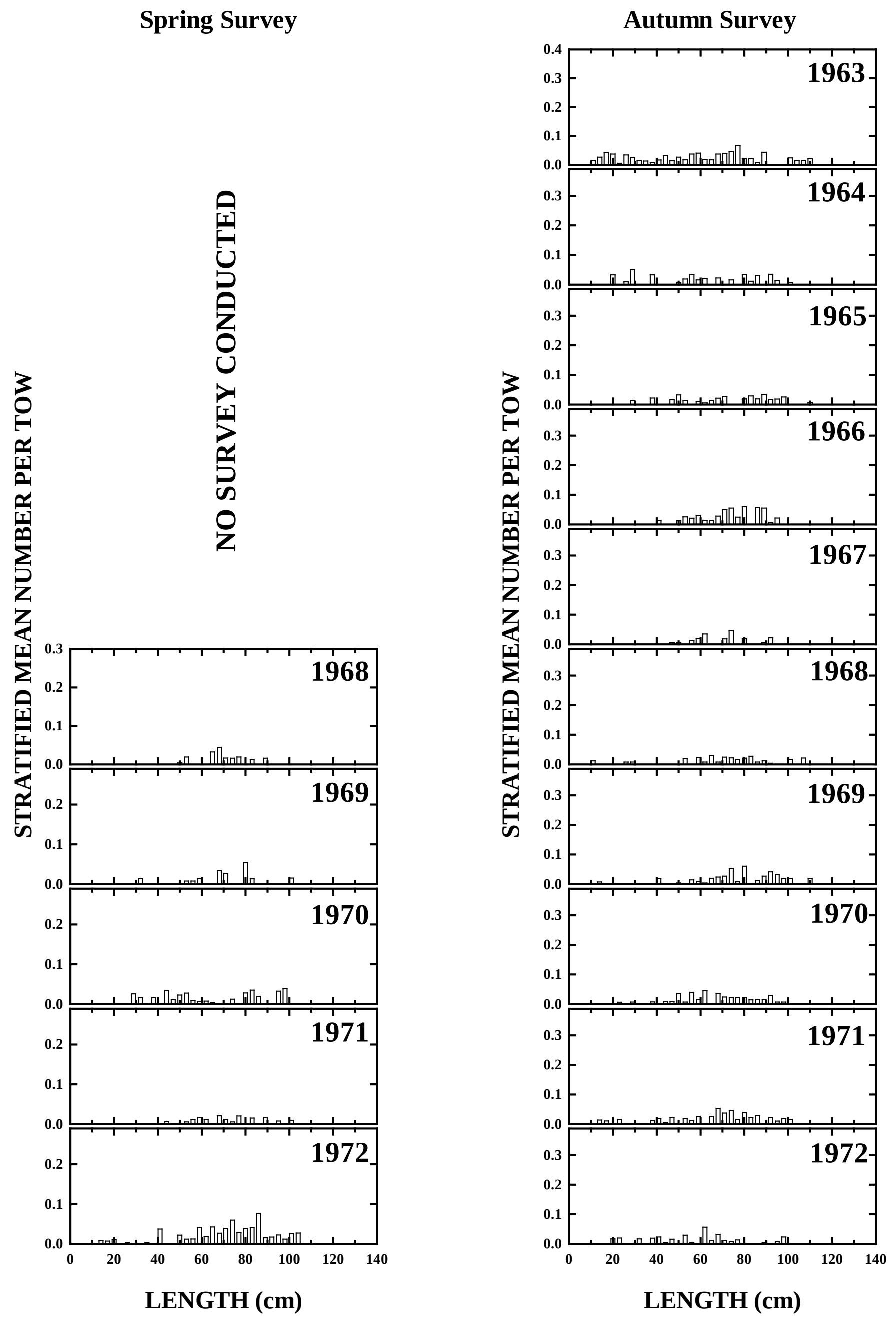


Figure A48. Goosefish length composition from the NEFSC spring and autumn bottom trawl surveys in the northern management region,

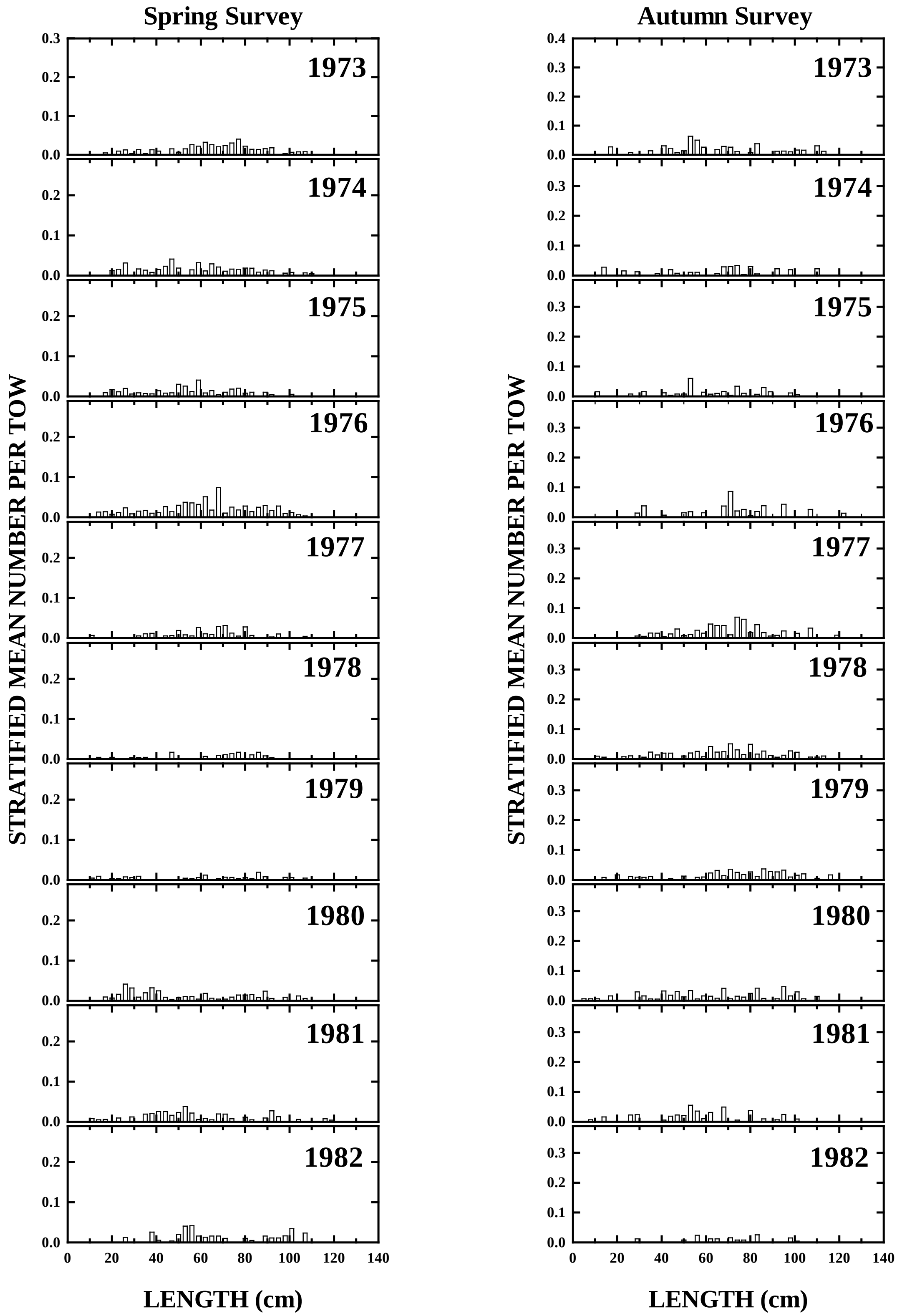


Figure A48, continued

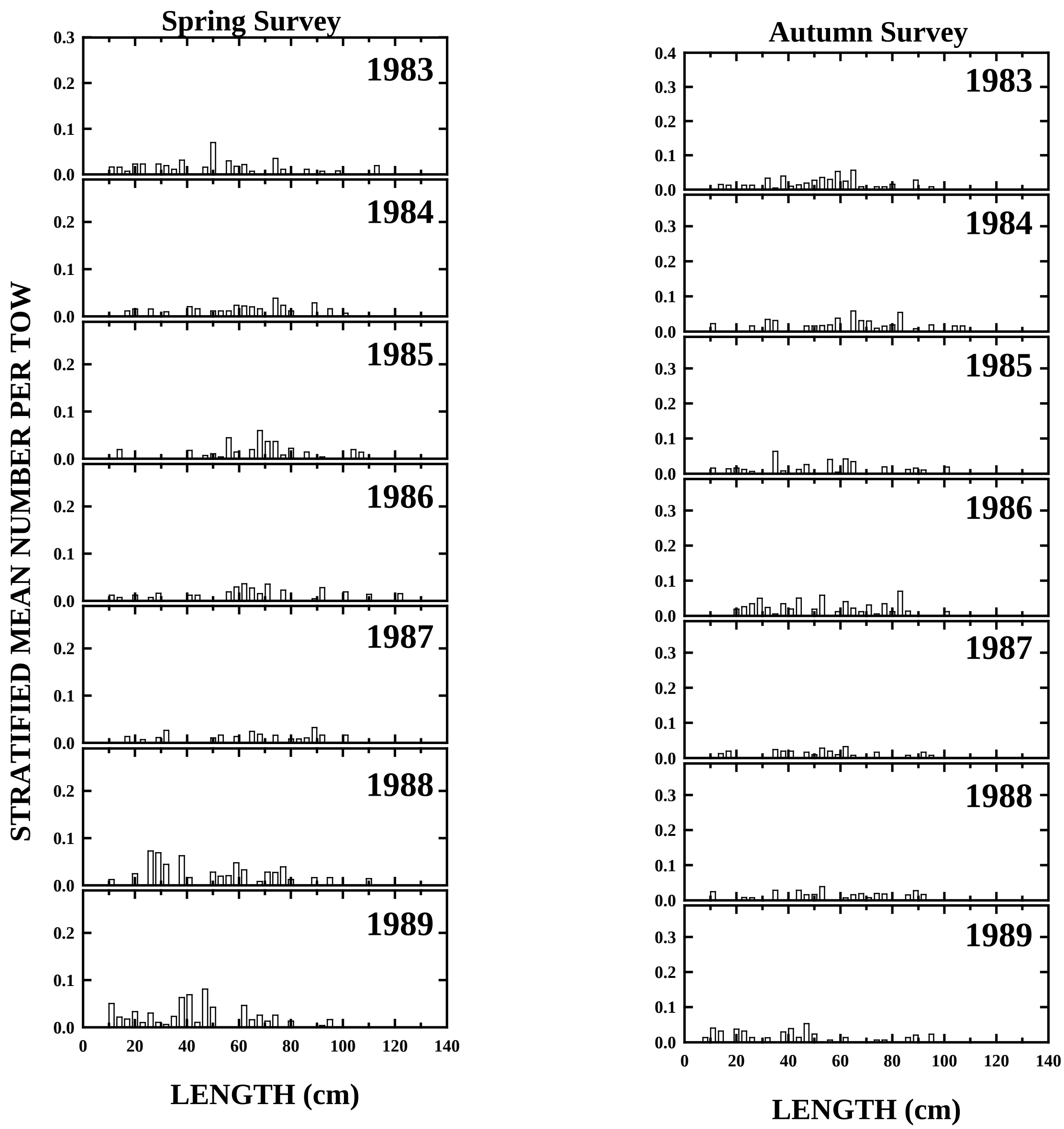
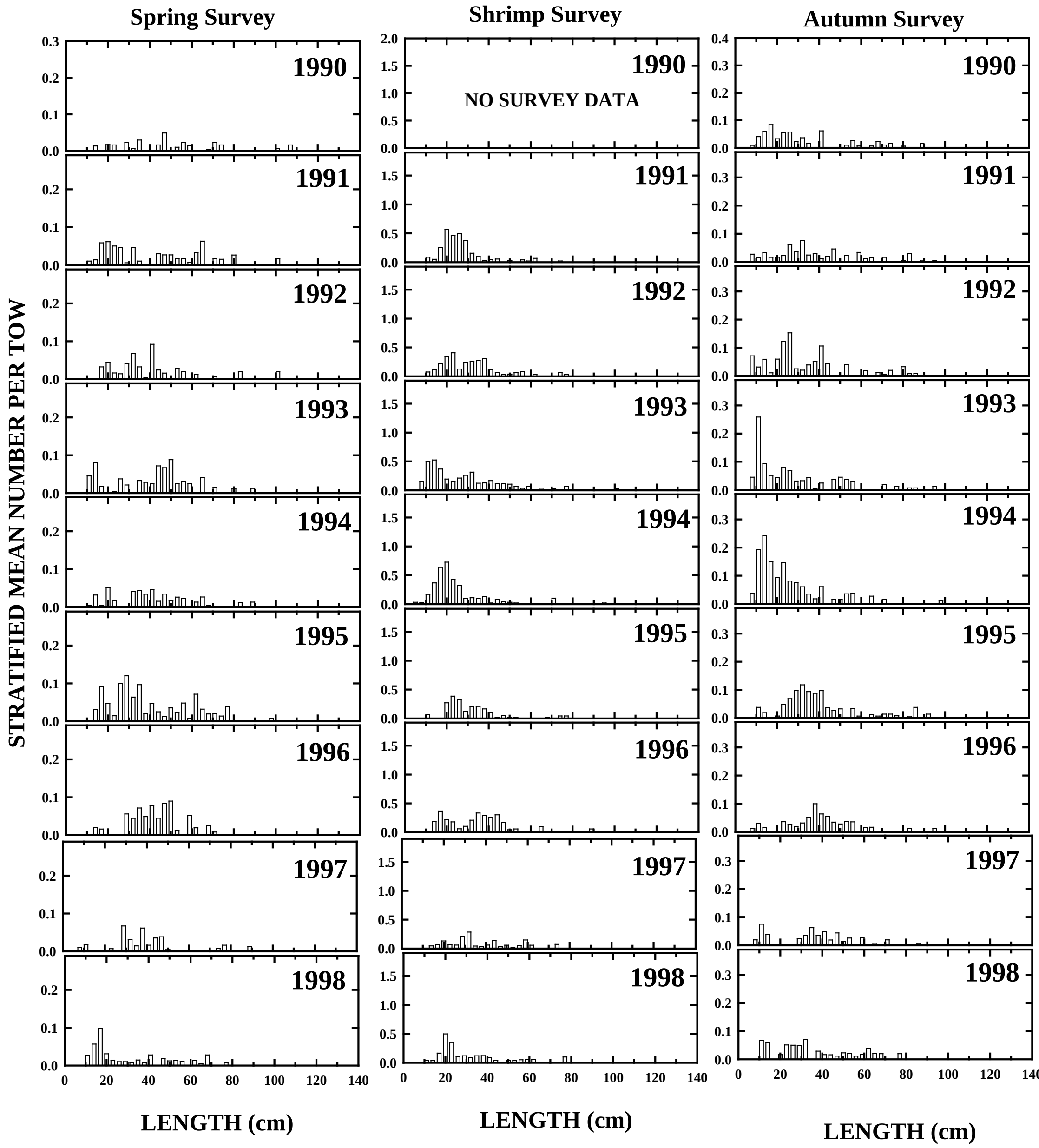


Figure A48, continued.

NOTE: Y-AXIS SCALE CHANGES ON THIS PAGE



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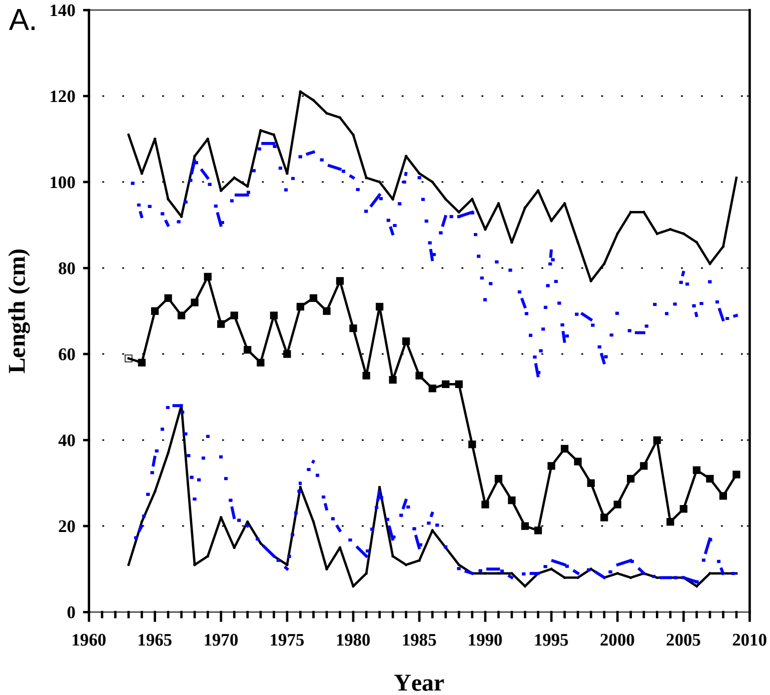


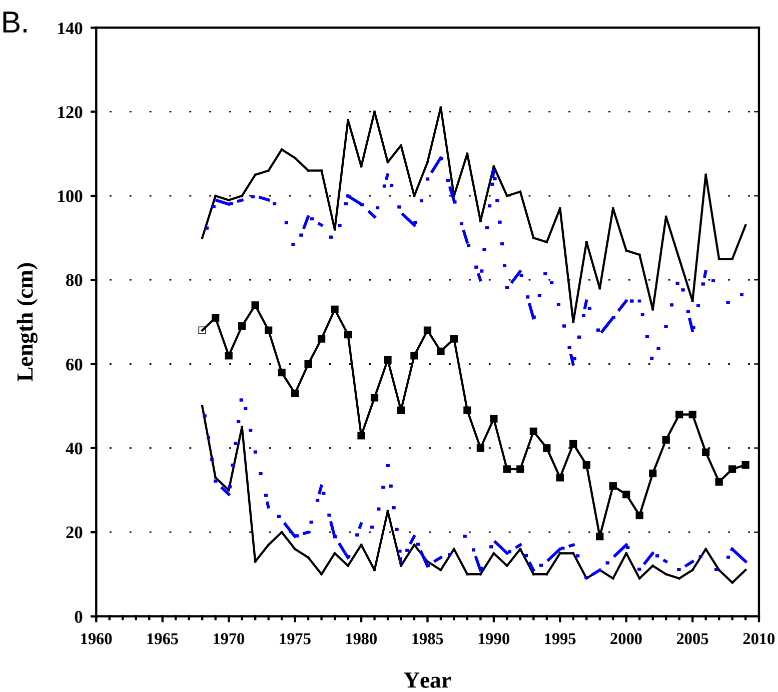


Figure A49. Minimum, median, and, maximum lengths for the northern management region from (A) NEFSC autumn surveys and (B) NEFSC spring surveys

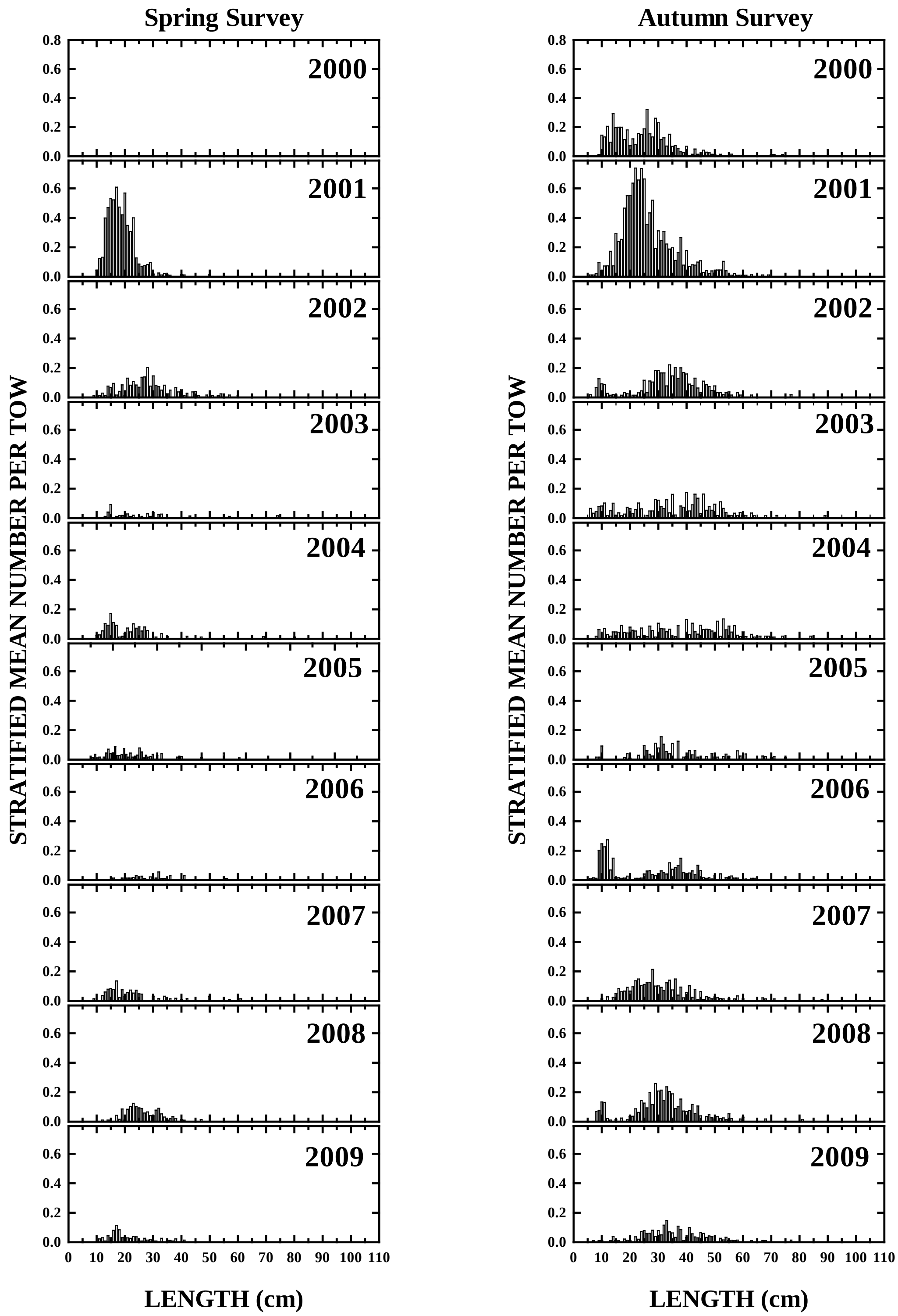
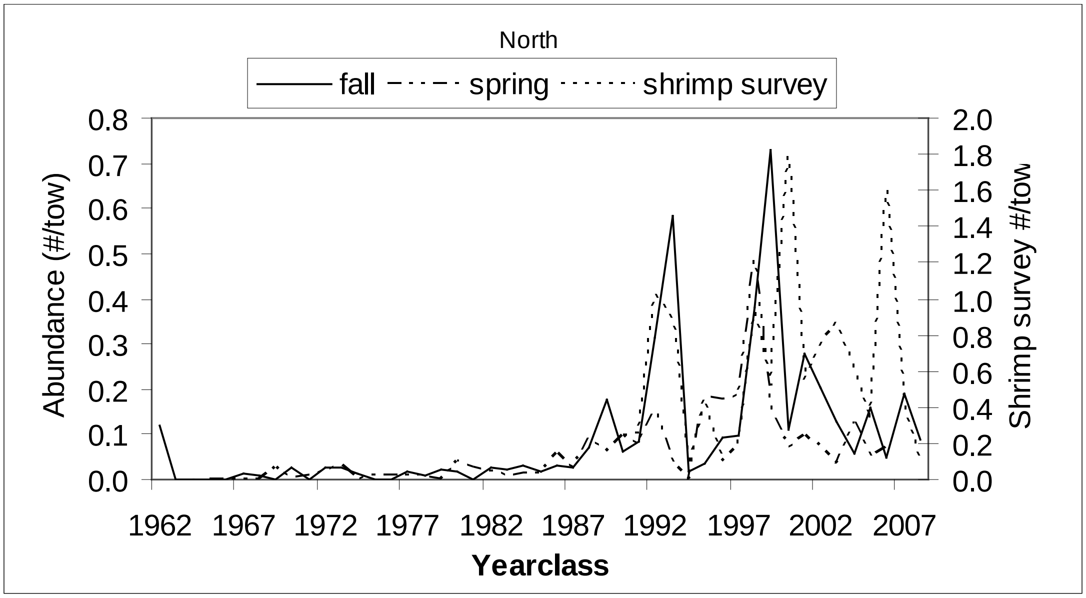


Figure A50. ME-NH inshore survey length frequency plots, 2000-2009.



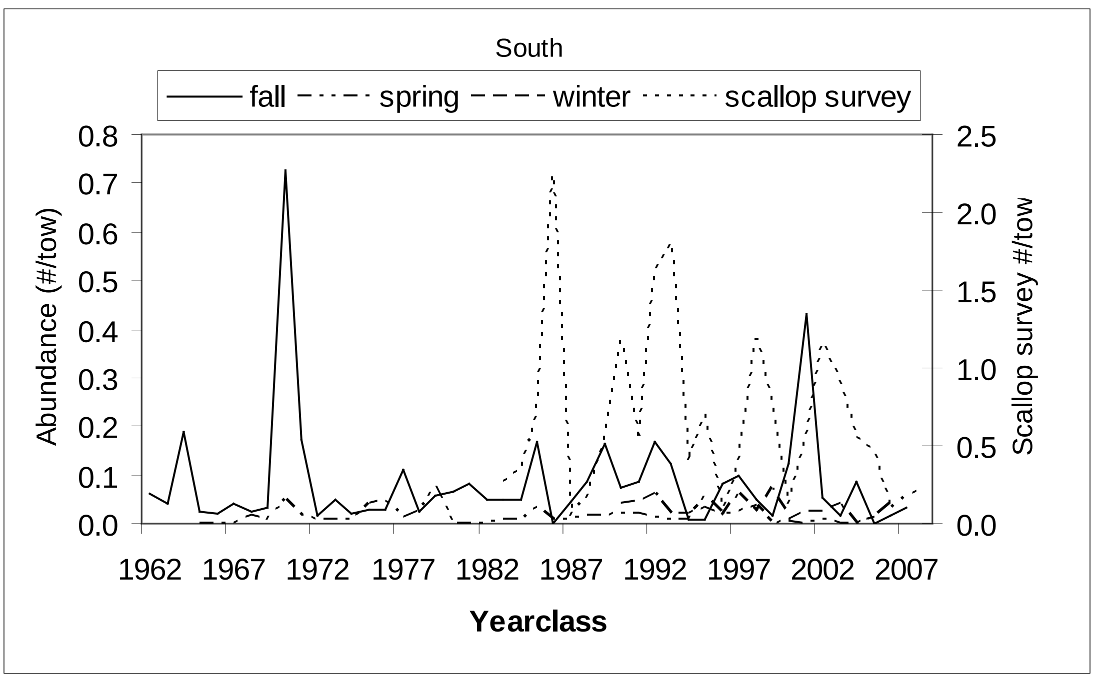


Figure A51. Abundance indices for approximate age 1 (shrimp, scallop and autumn surveys) and age 2 (winter and spring surveys) by yearclass. 2009 FSV Bigelow indices were corrected using calibration coefficient for numbers.

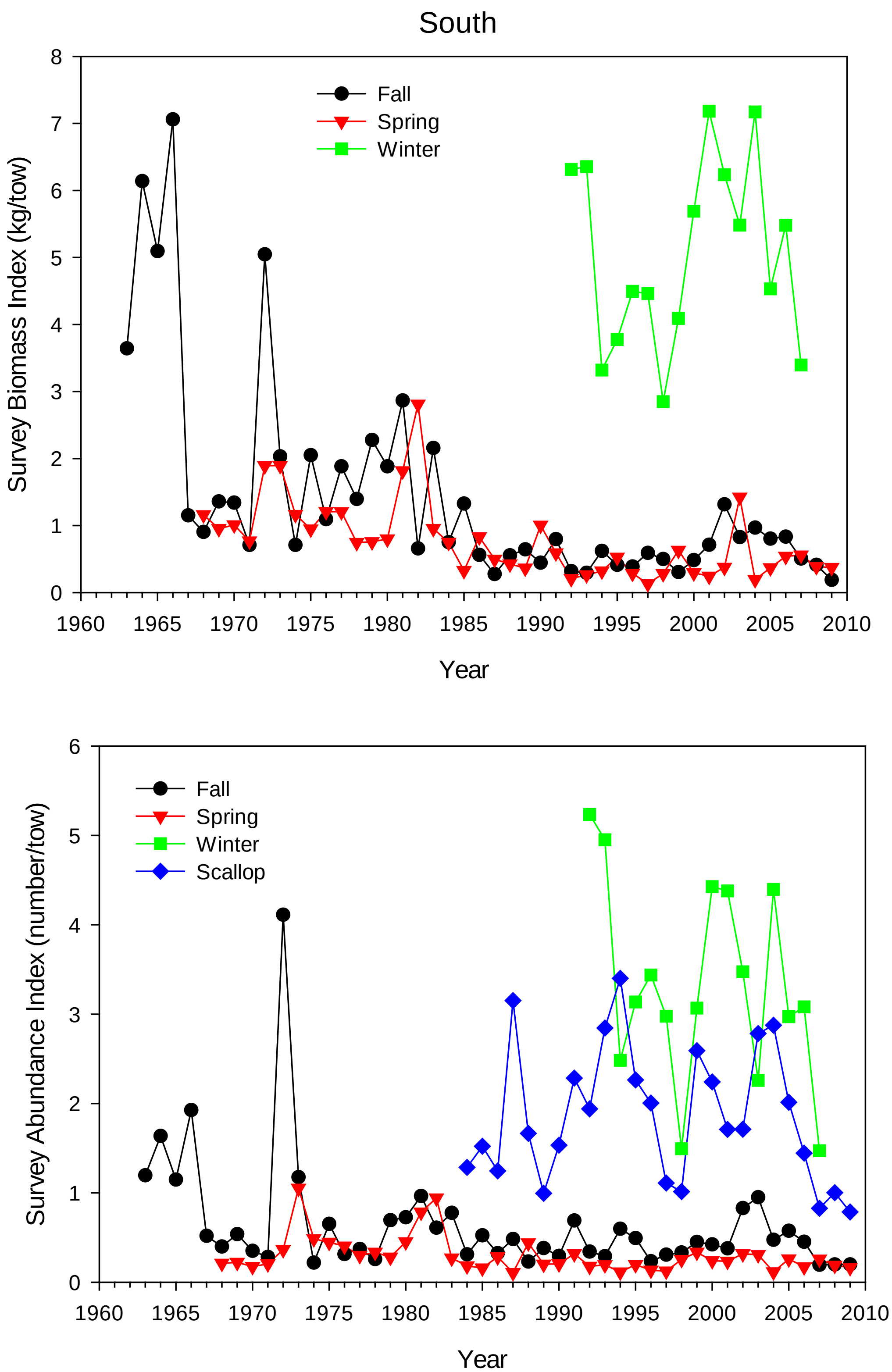


Figure A52. NEFSC spring and autumn surveys of monkfish biomass and abundance in the southern management region.

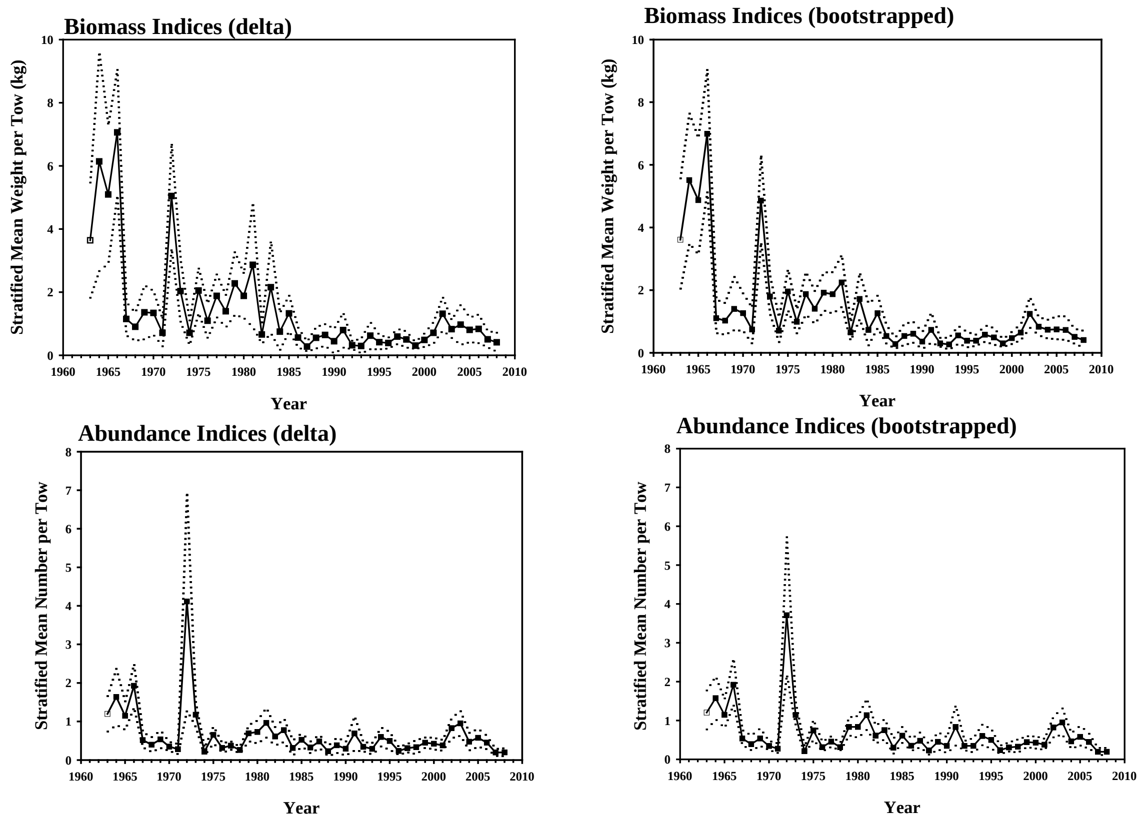


Figure A53. Delta distribution (parametric) and bootstrapped (arithmetic) biomass and abundance indices from the NEFSC autumn bottom trawl survey for the southern management region from 1963-2008. Data prior to 1971 have been revised following an audit of historical data. The 95% confidence limits are shown by the dashed line.

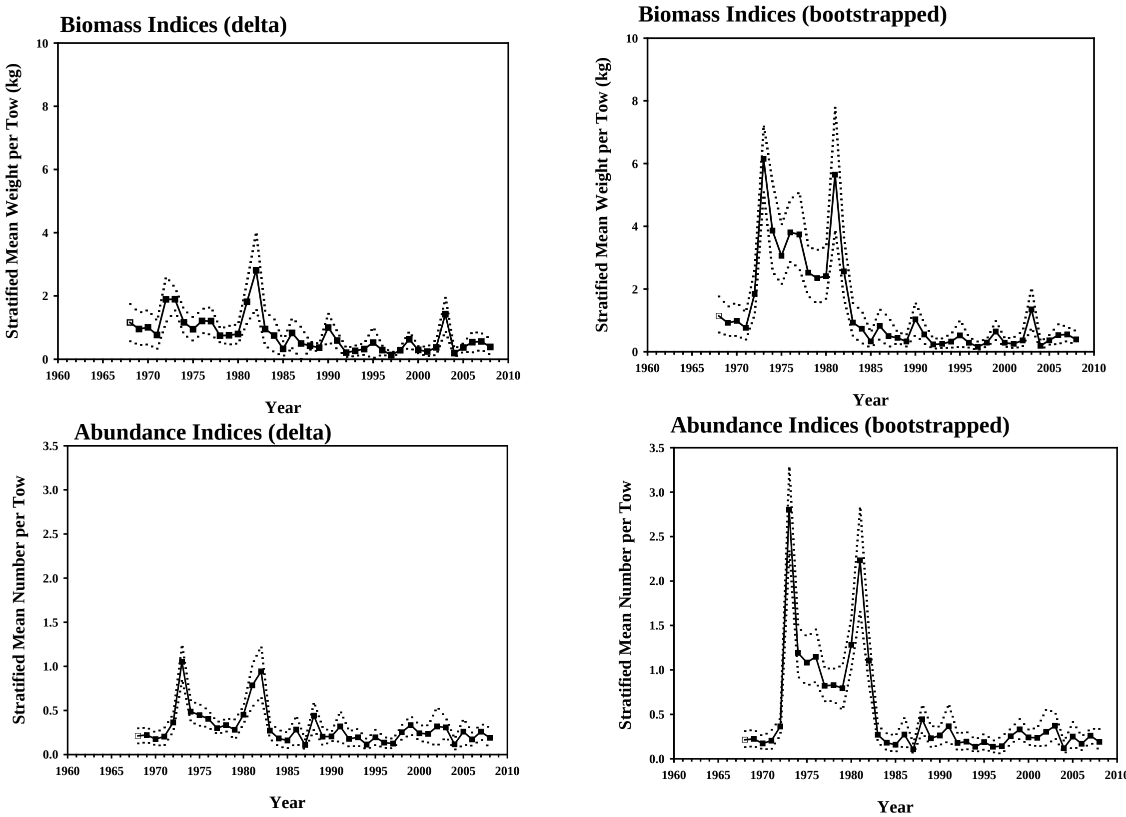


Figure A54. Delta distribution (parametric) and bootstrapped (arithmetic) biomass and abundance indices from the NEFSC spring bottom trawl survey for the southern management region from 1968-2008. Data prior to 1971 have been revised following an audit of historical data. The 95% confidence limits are shown by the dashed line.

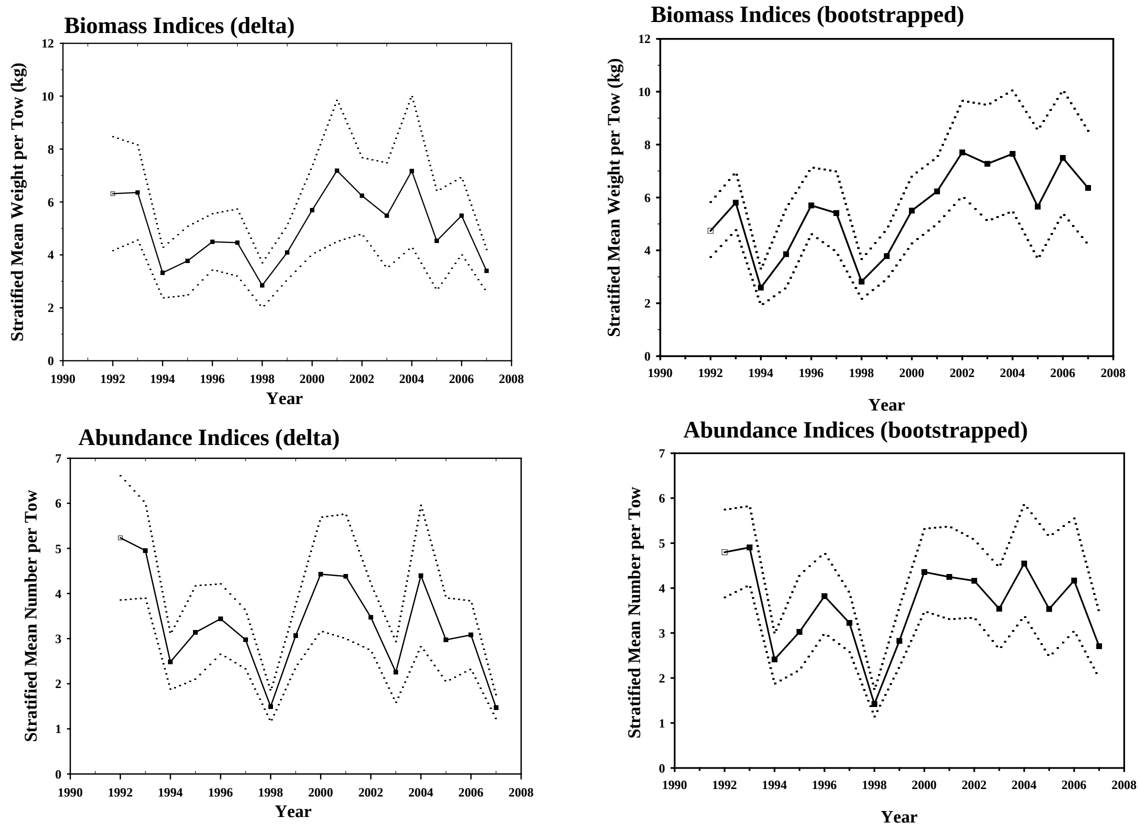


Figure A55. Delta distribution (parametric) and bootstrapped (arithmetic) biomass and abundance indices from the NEFSC winter survey for the southern management region from 1992-2007. Data prior to 1971 have been revised following an audit of historical data. The 95% confidence limits are shown by the dashed line.

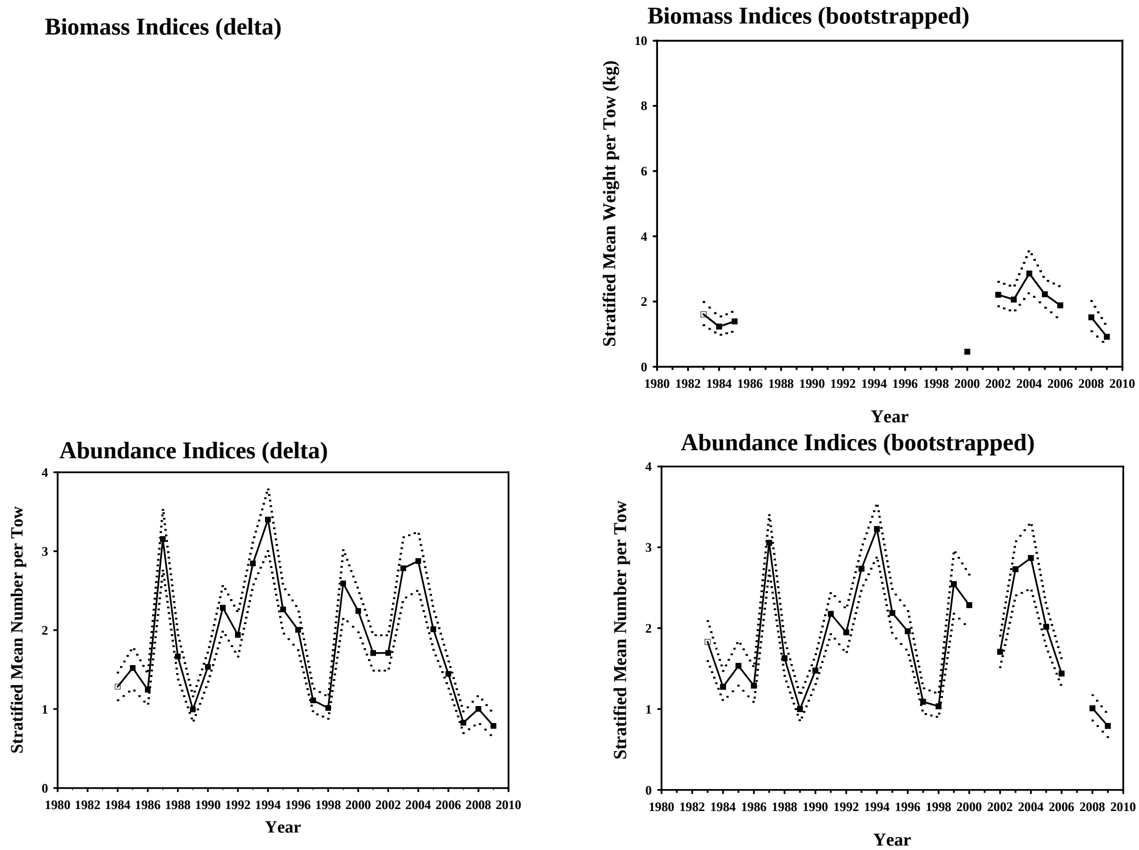


Figure A56. Delta distribution (parametric) and bootstrapped (arithmetic) biomass and abundance indices from the NEFSC scallop survey for the southern management region from 1983-2009. Data prior to 1971 have been revised following an audit of historical data. The 95% confidence limits are shown by the dashed line.

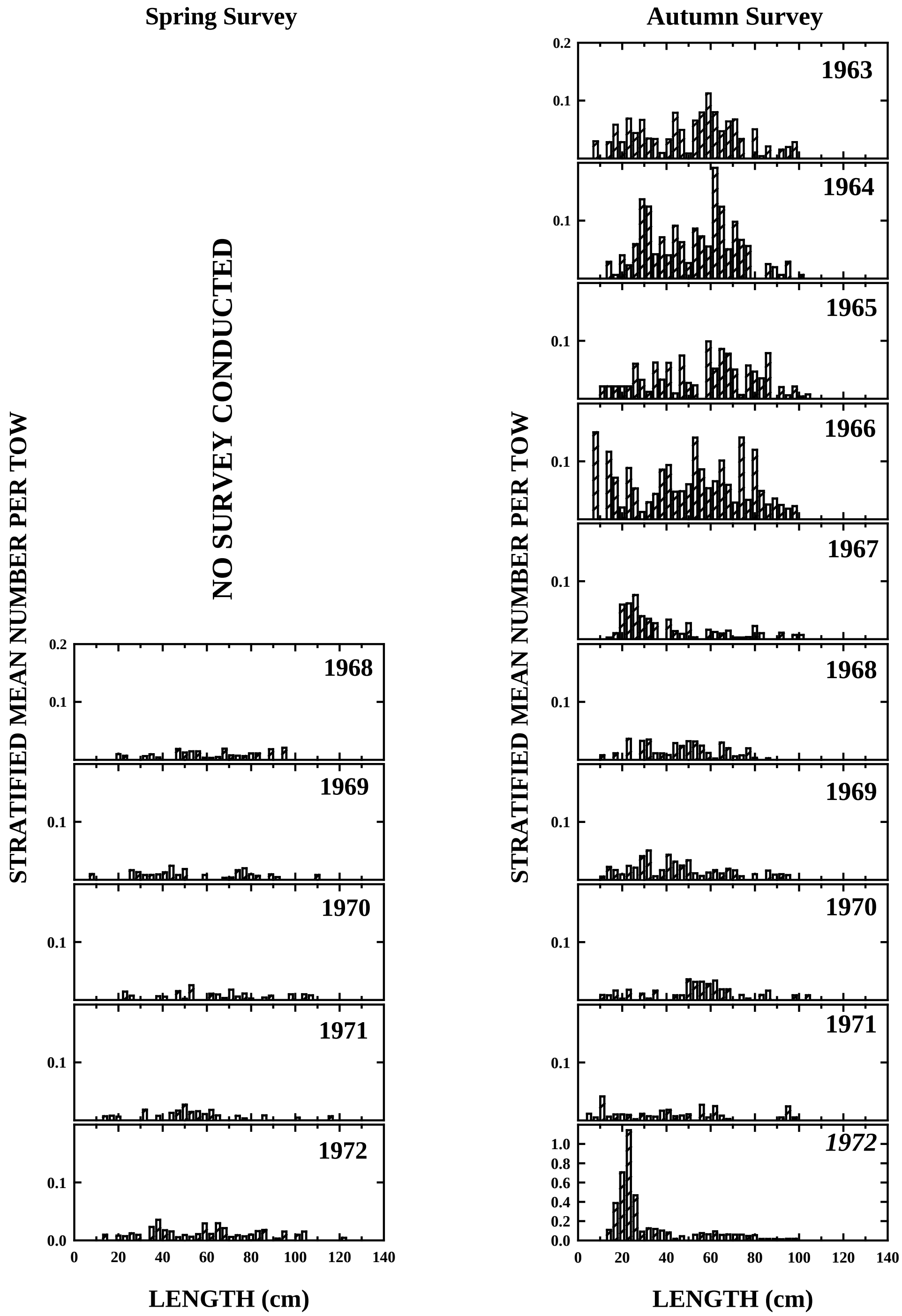


Figure A57, continued

Figure A57. Goosefish length composition from the NEFSC spring bottom trawl (March-April), winter flatfish (February), summer scallop (July-August), and autumn (September-October) bottom trawl surveys in the southern management region, 1963-2009. Note: 1963-1966 sampled reduced strata set

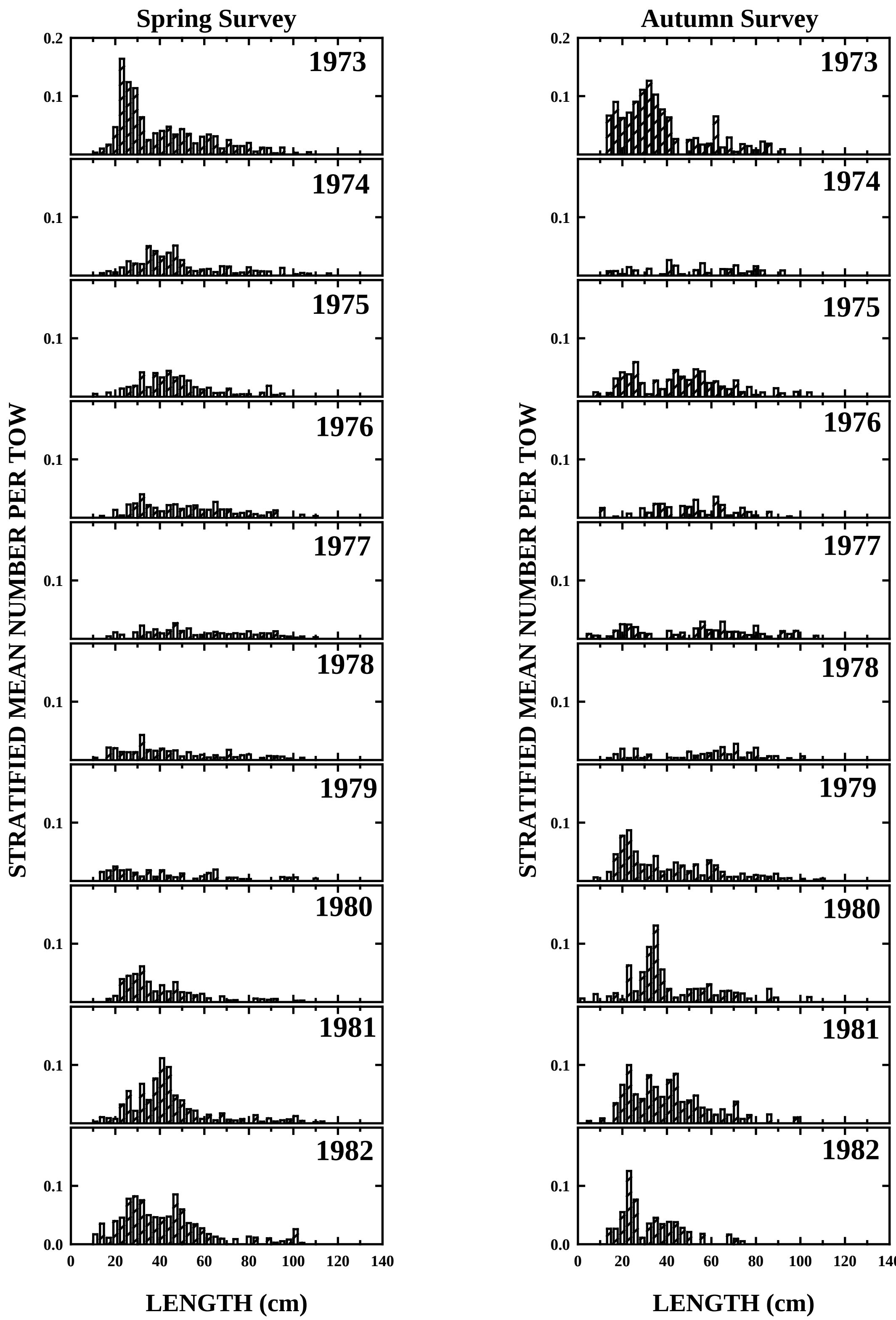


Figure A57, continued

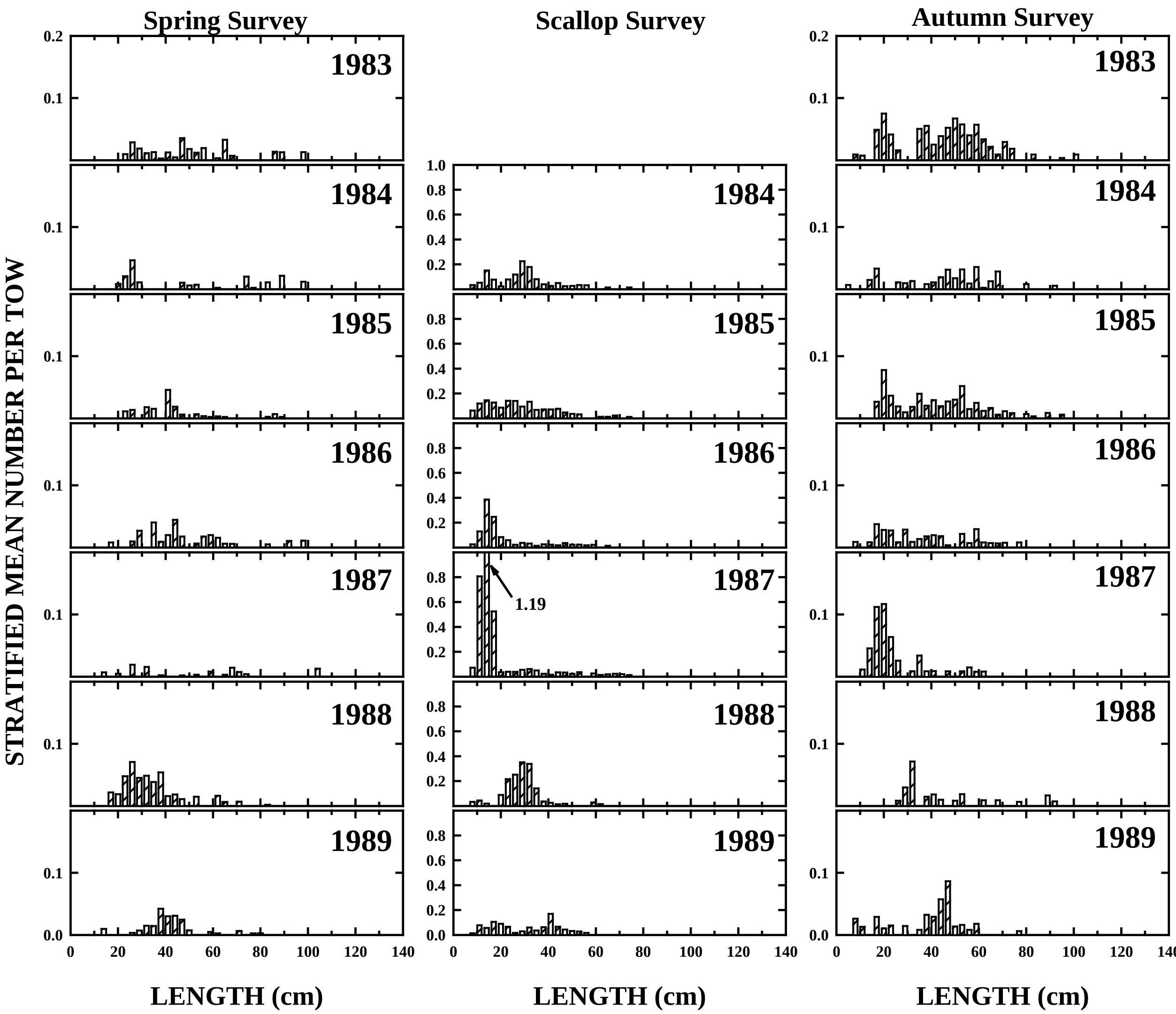
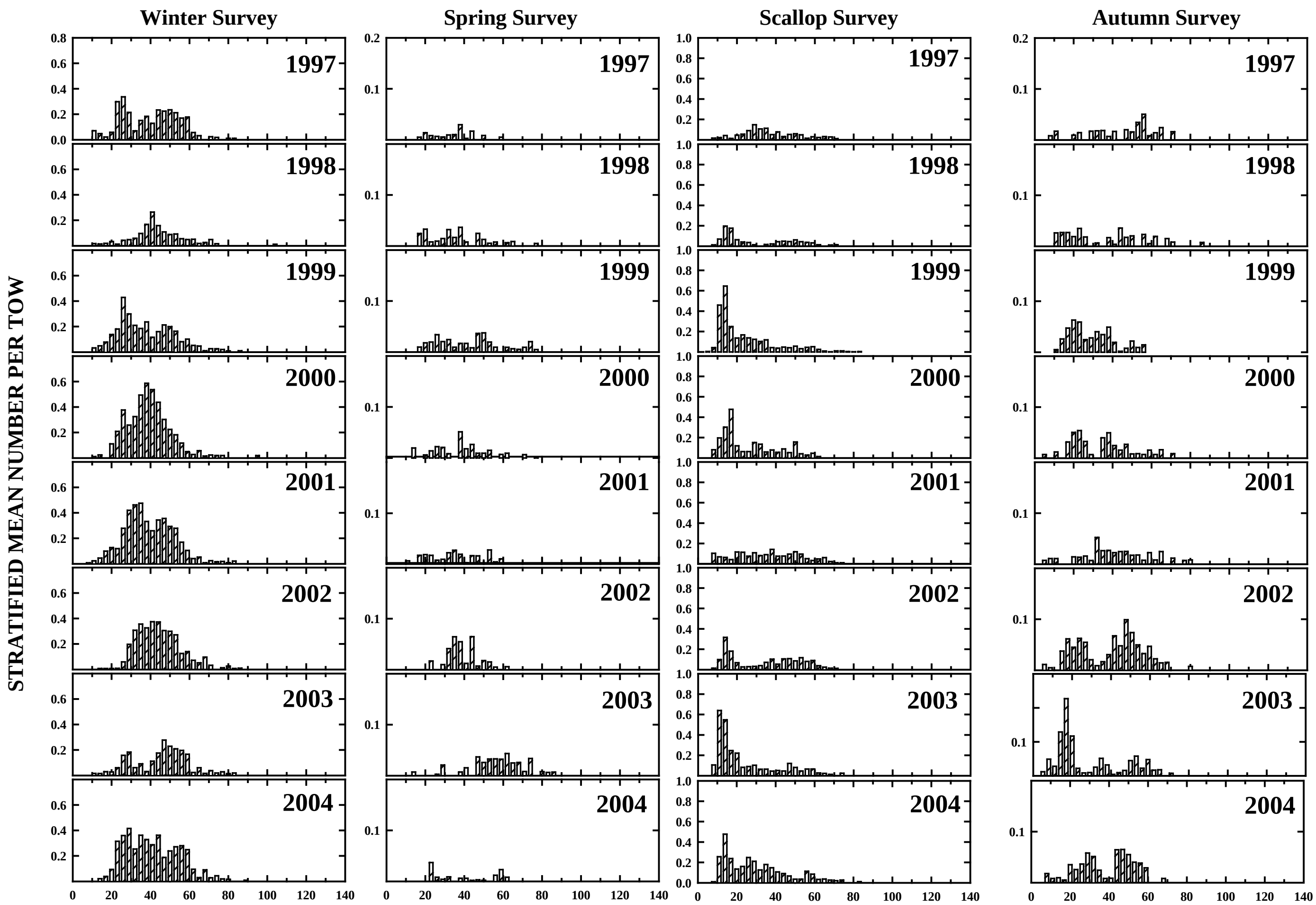


Figure A57, continued



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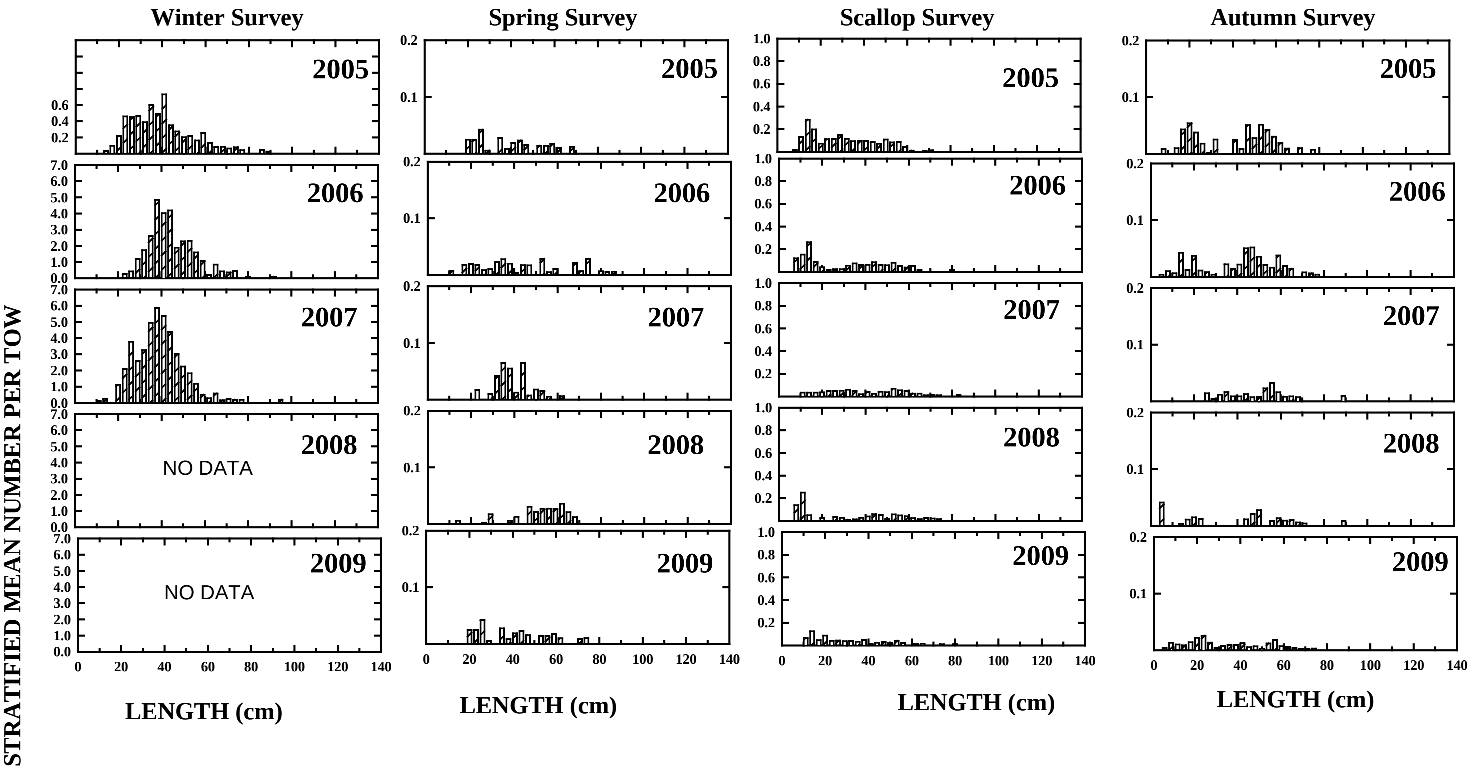
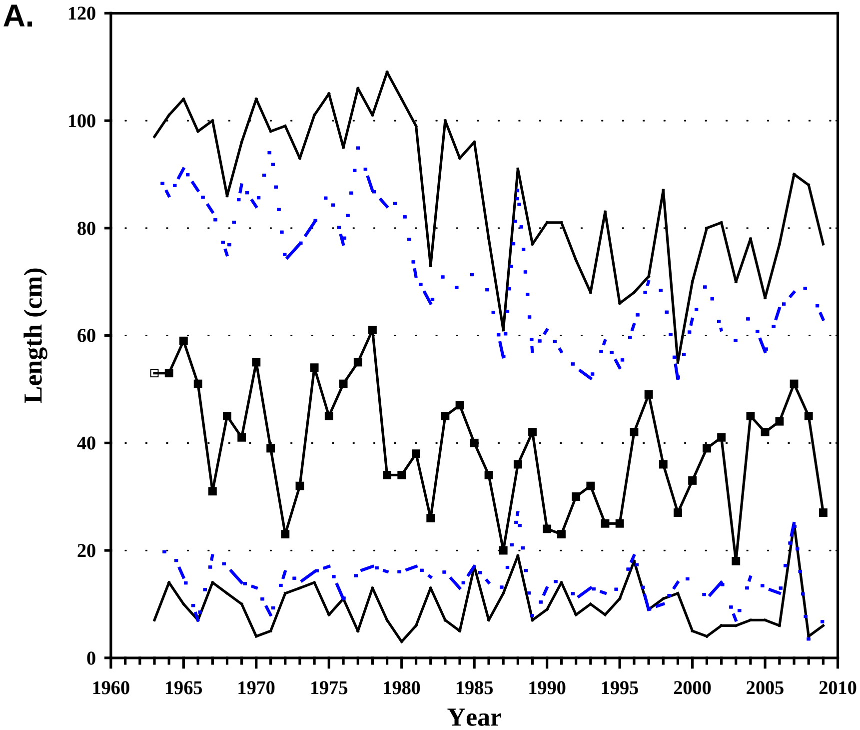


Figure A57, continued

A.



B.

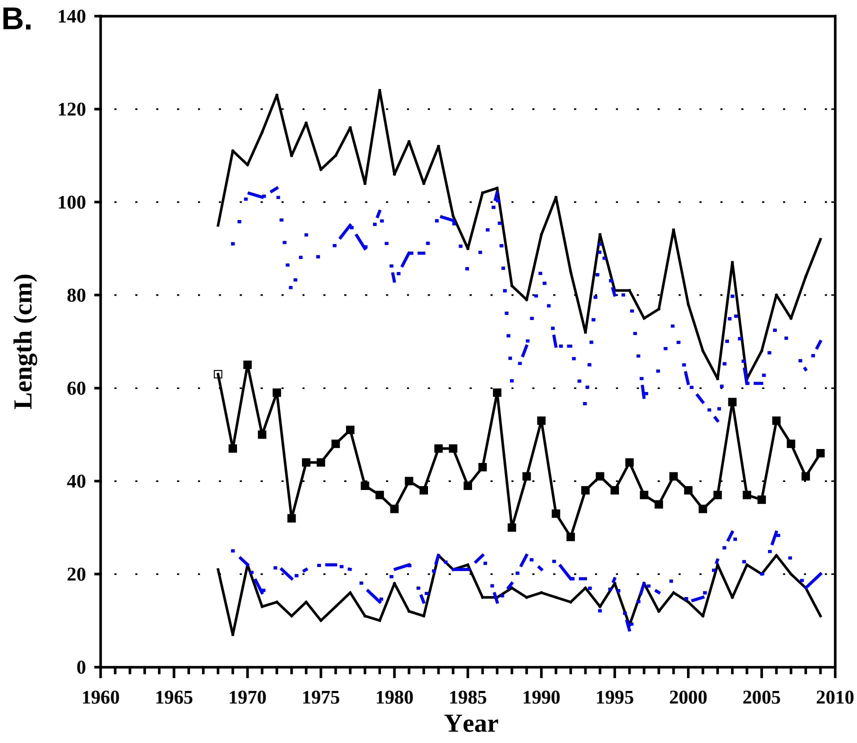


Figure A58. Minimum, median, and, maximum lengths for the southern management region from (A) NEFSC autumn surveys and (B) NEFSC spring surveys.

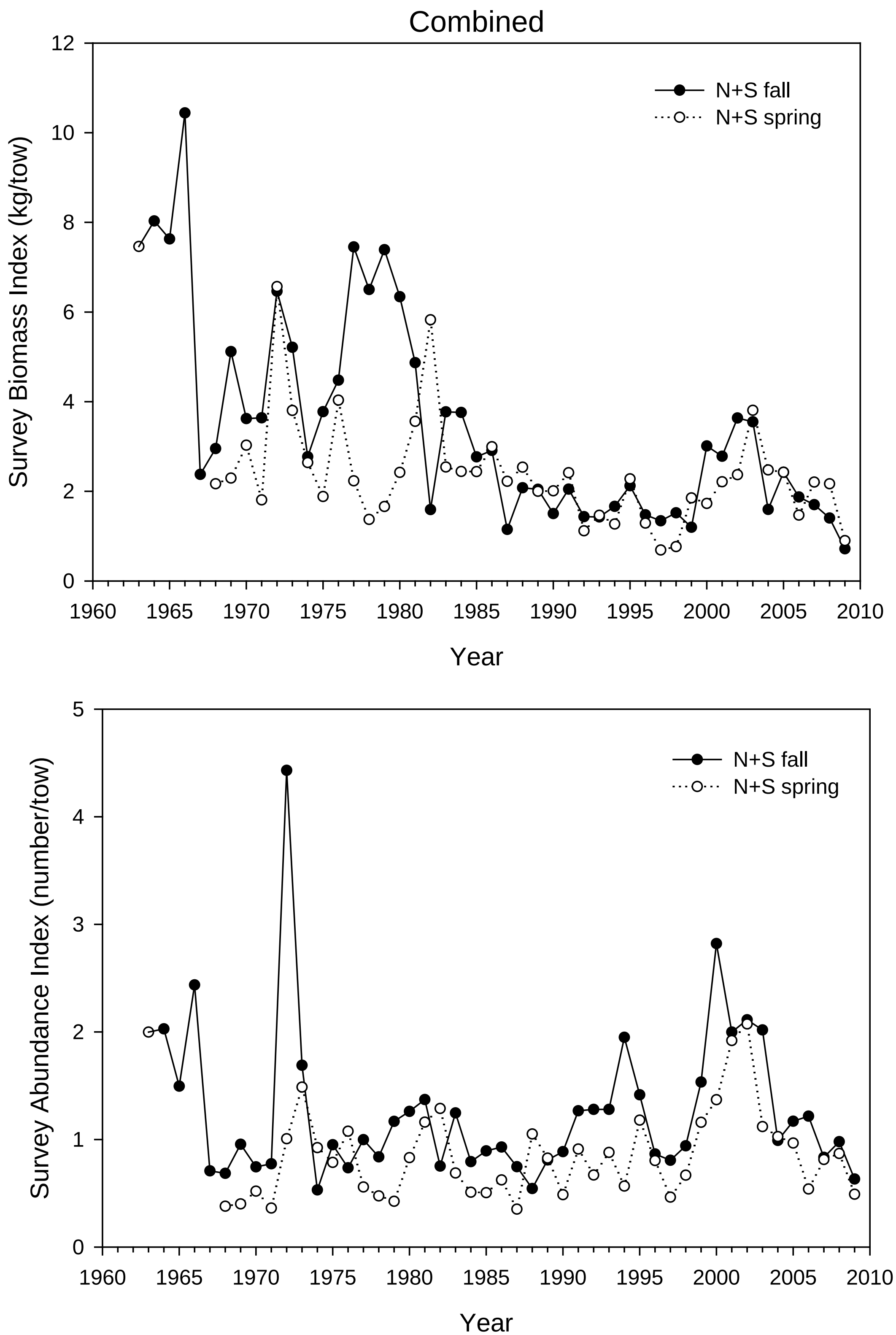


Figure A59. NEFSC spring and autumn surveys of monkfish biomass and abundance in both the northern and southern management regions

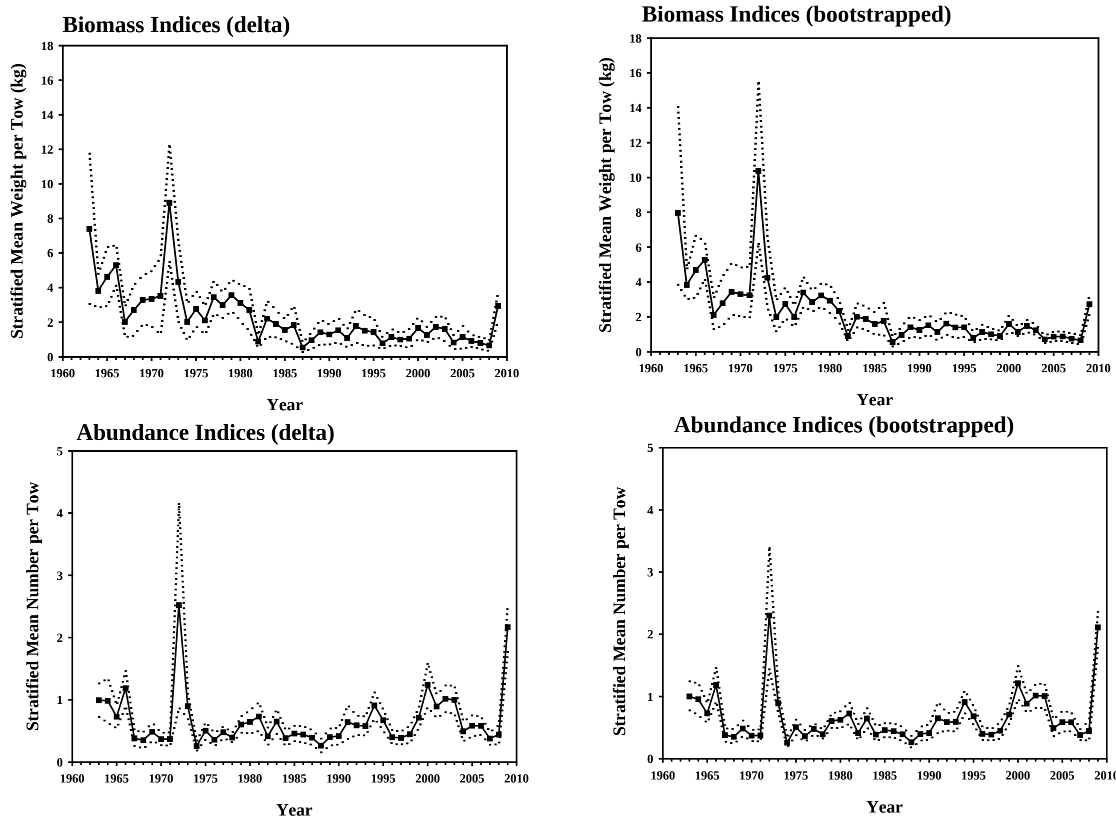


Figure A60. Delta distribution (parametric) and bootstrapped (arithmetic) biomass and abundance indices from the NEFSC autumn bottom trawl survey for combined management regions from 1963-2009. Data prior to 1971 have been revised following an audit of historical data. The 95% confidence limits are shown by the dashed line.

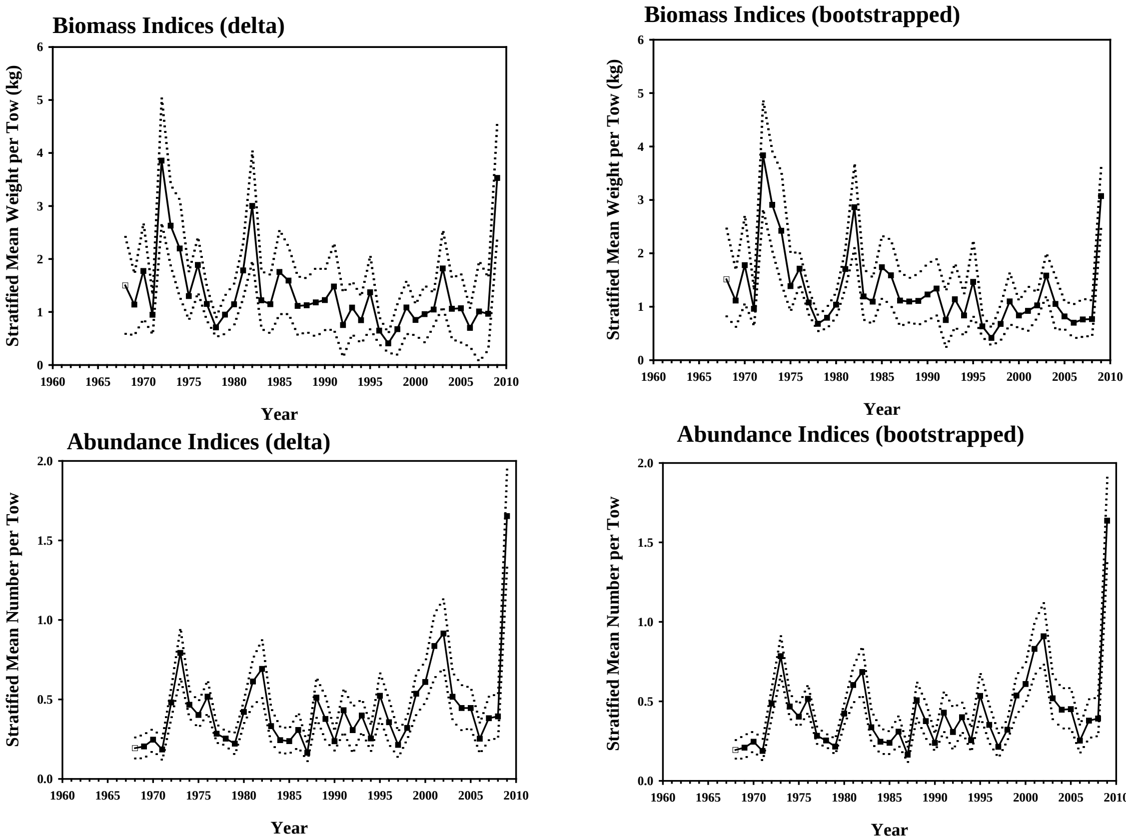


Figure A61. Delta distribution (parametric) and bootstrapped (arithmetic) biomass and abundance indices from the NEFSC spring bottom trawl survey for management regions combined from 1963-2009. Data prior to 1971 have been revised following an audit of historical data. The 95% confidence limits are shown by the dashed line.

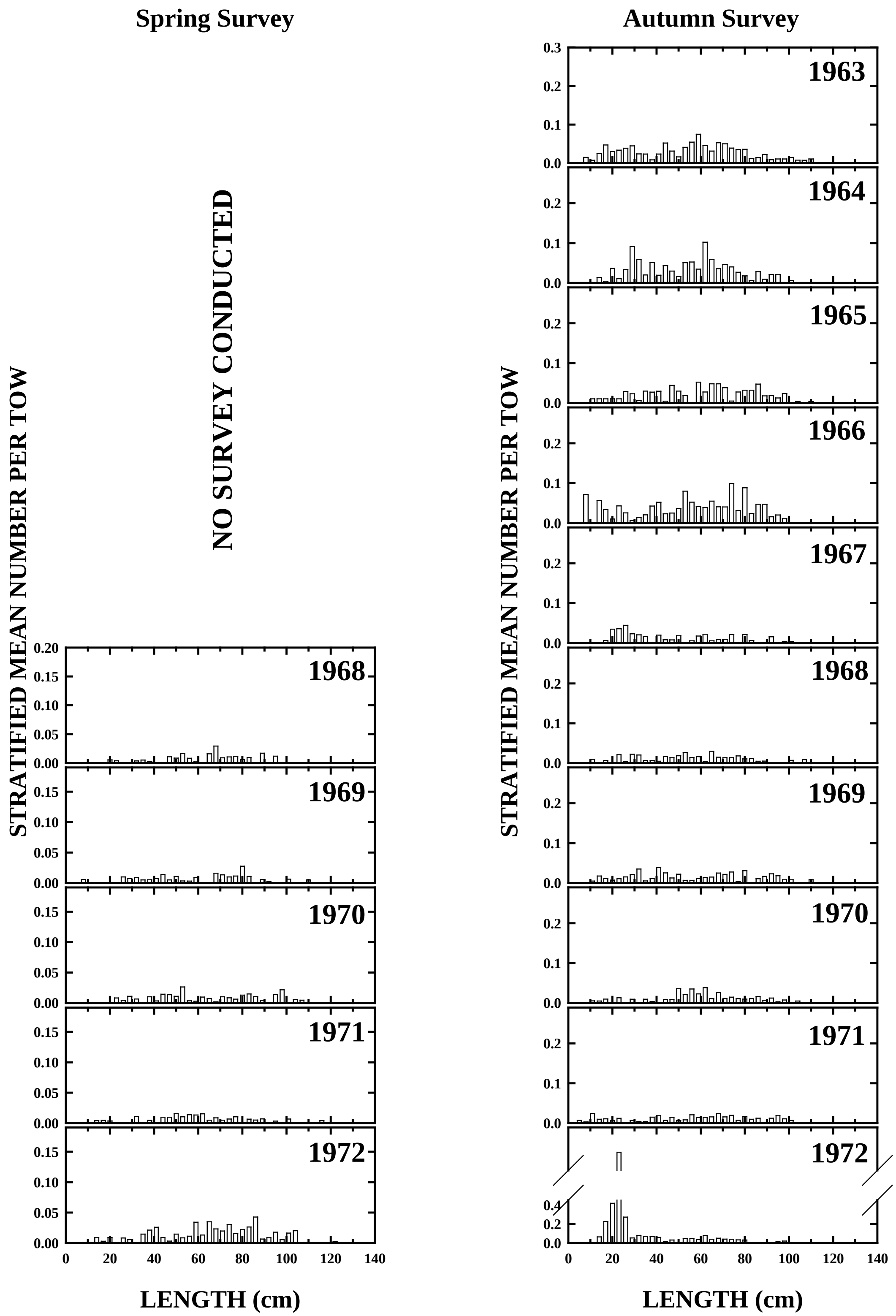


Figure A62. Goosefish length composition from the NEFSC spring and autumn bottom trawl surveys in both management regions combined, 1963-2009.

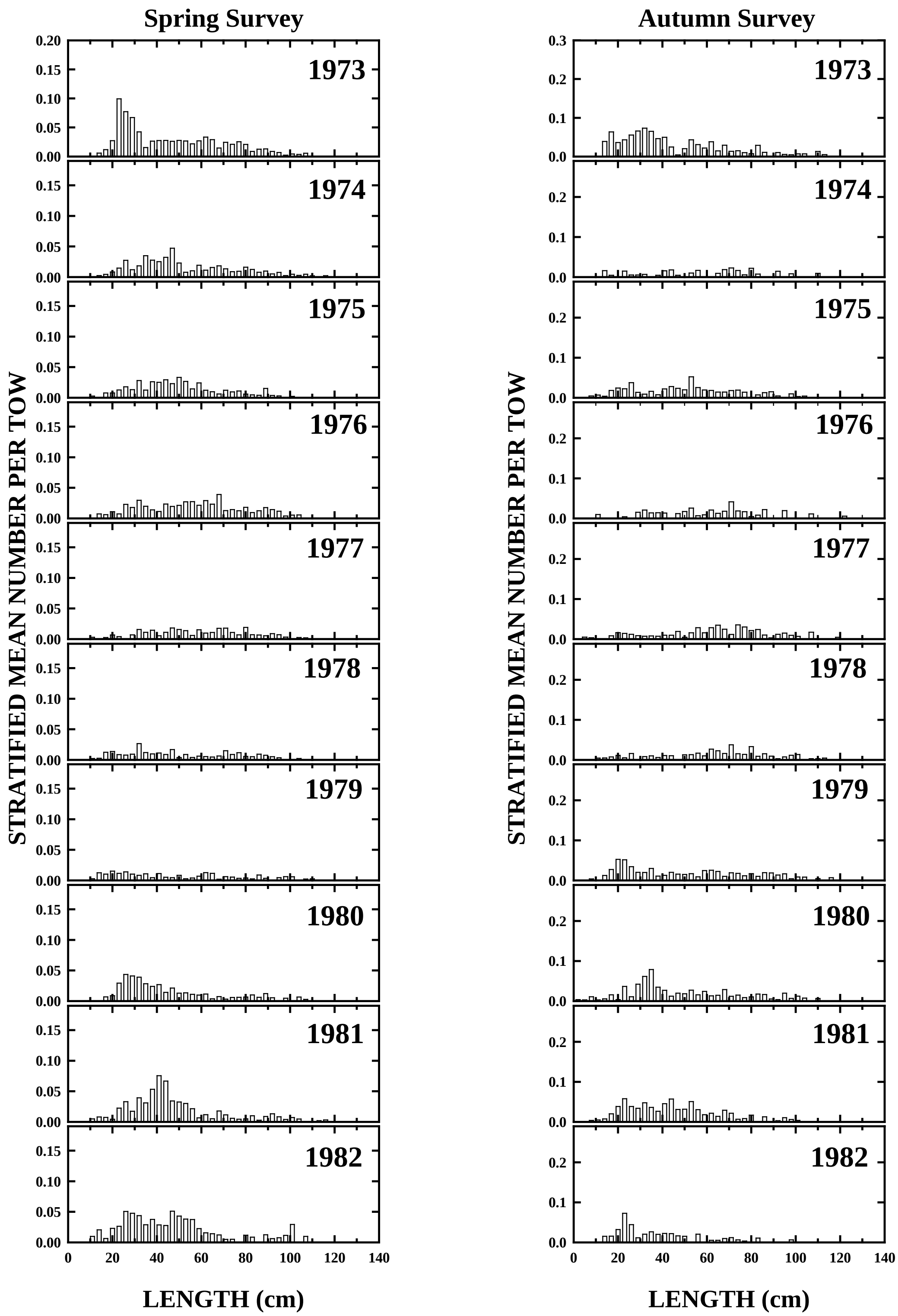


Figure A62, continued

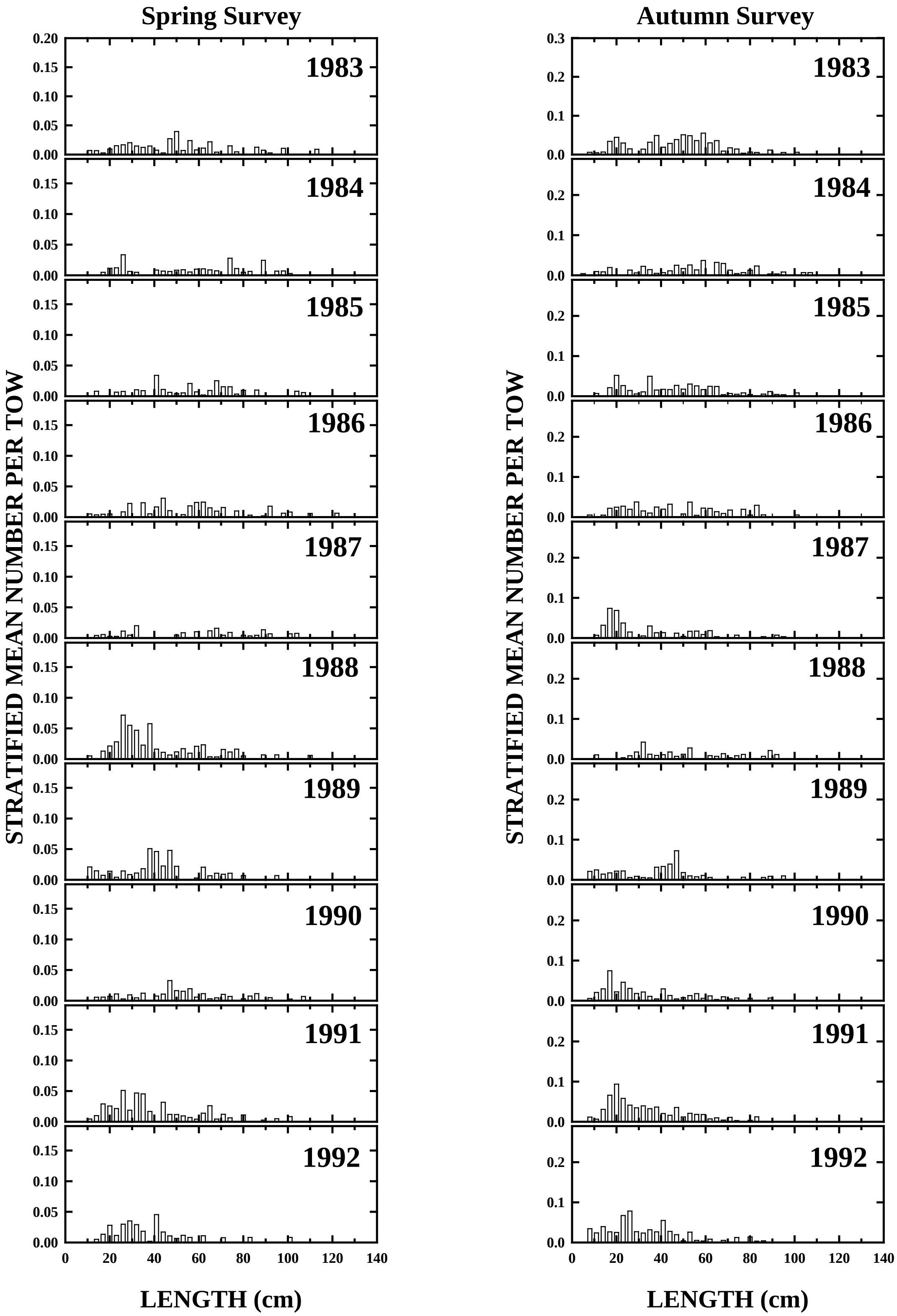
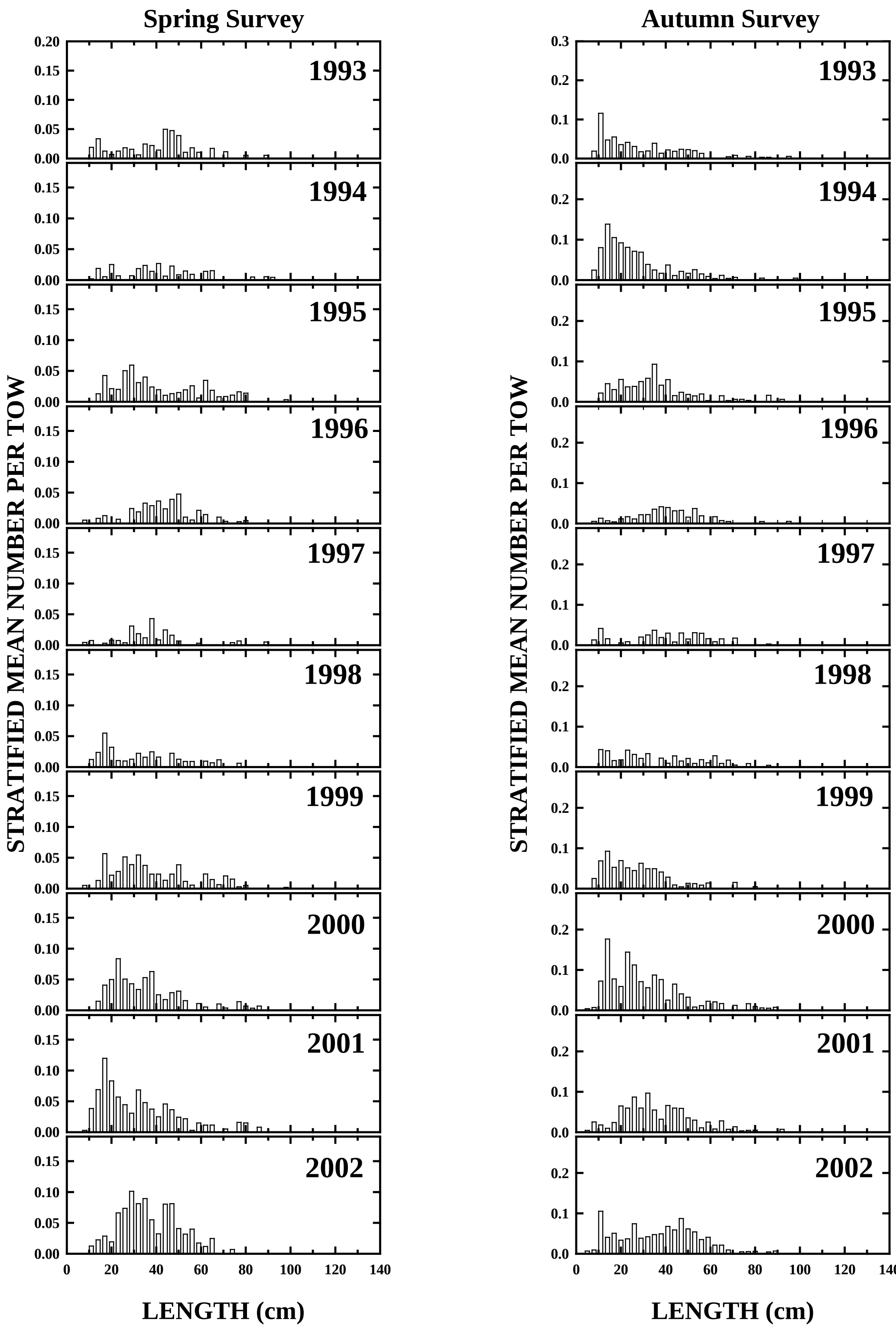


Figure A62, continued



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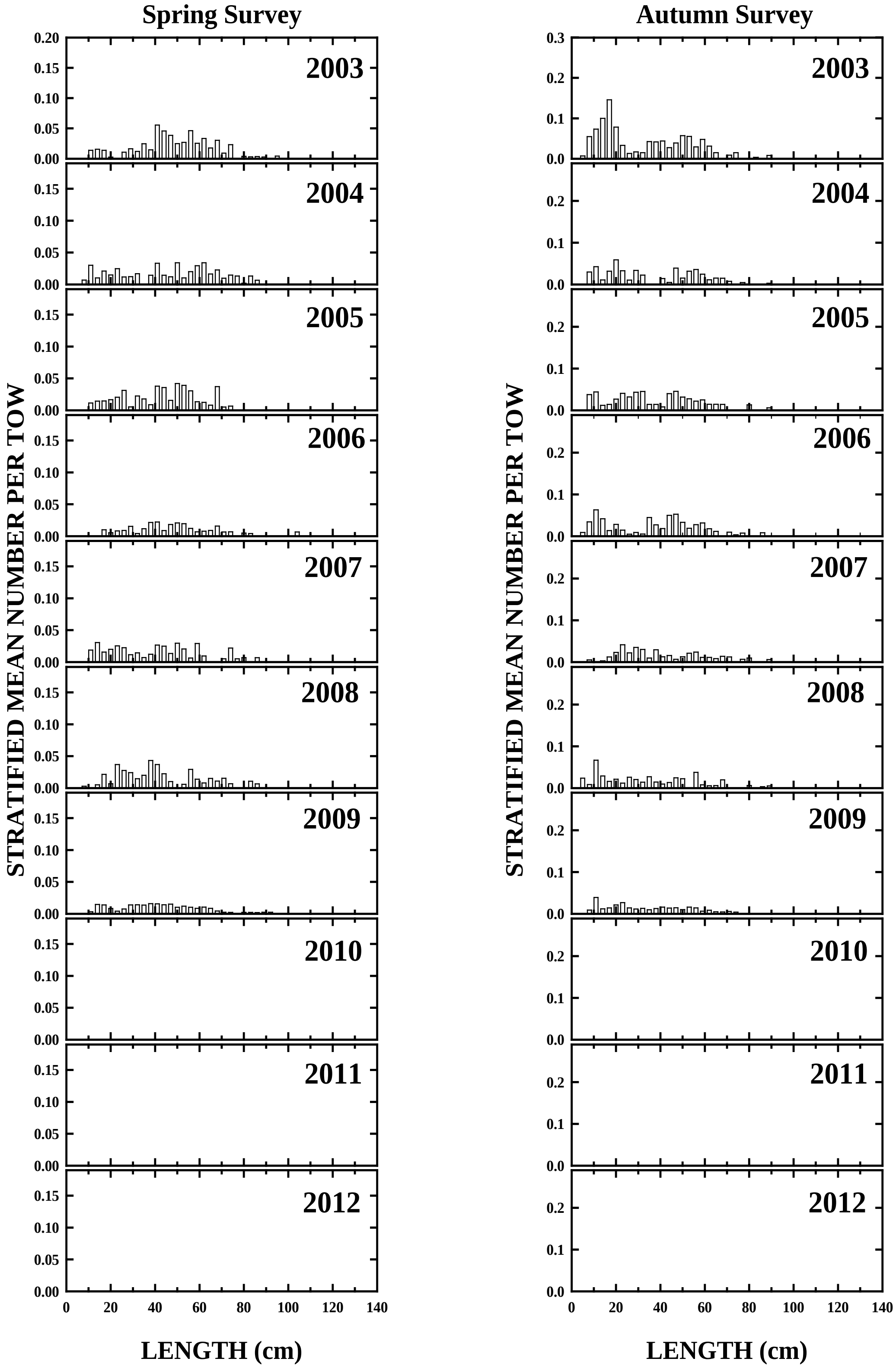
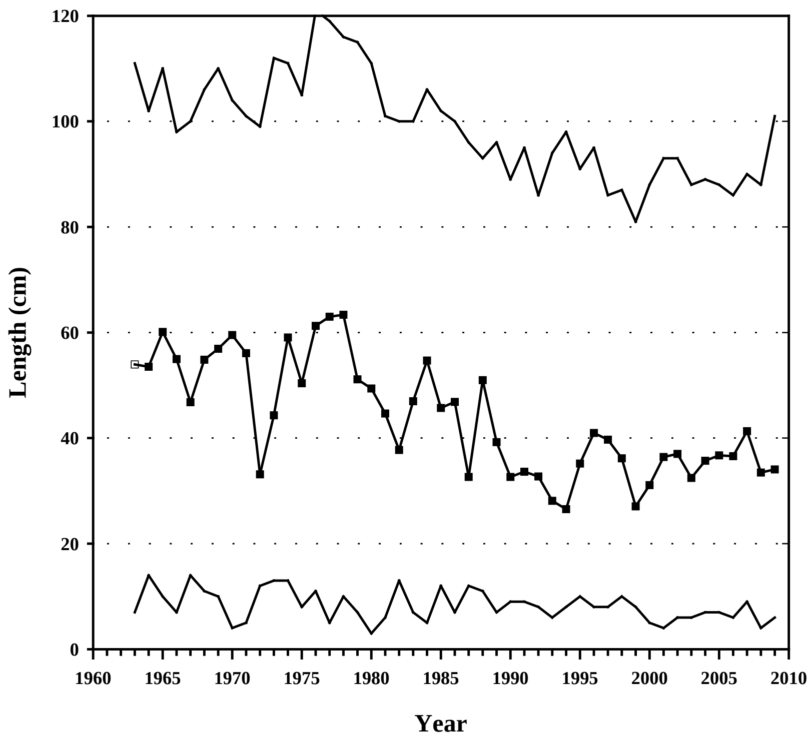


Figure A62, continued

A.



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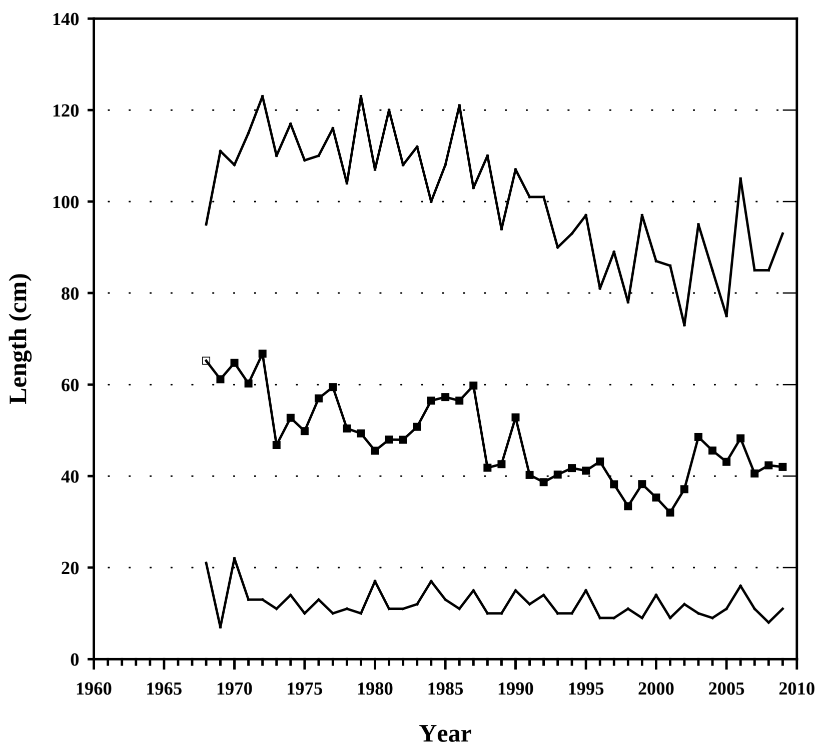


Figure A63. Minimum, median, and, maximum lengths for the northern and southern management regions combined from (A) NEFSC autumn surveys and (B) NEFSC spring surveys.

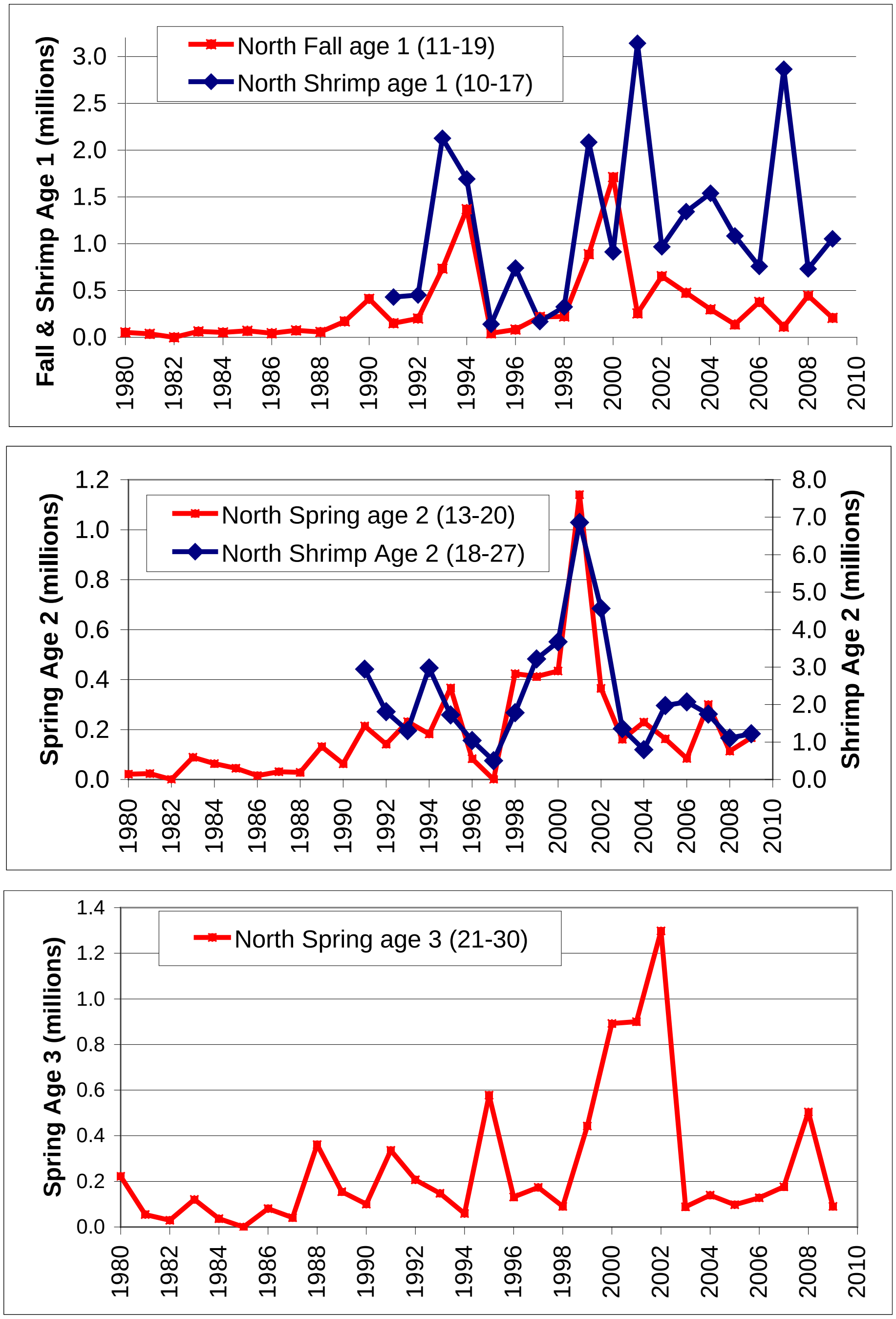


Figure A64. Northern management area monkfish recruitment indices at age. Centimeter intervals used to estimate recruitment ages are given in parenthesis.

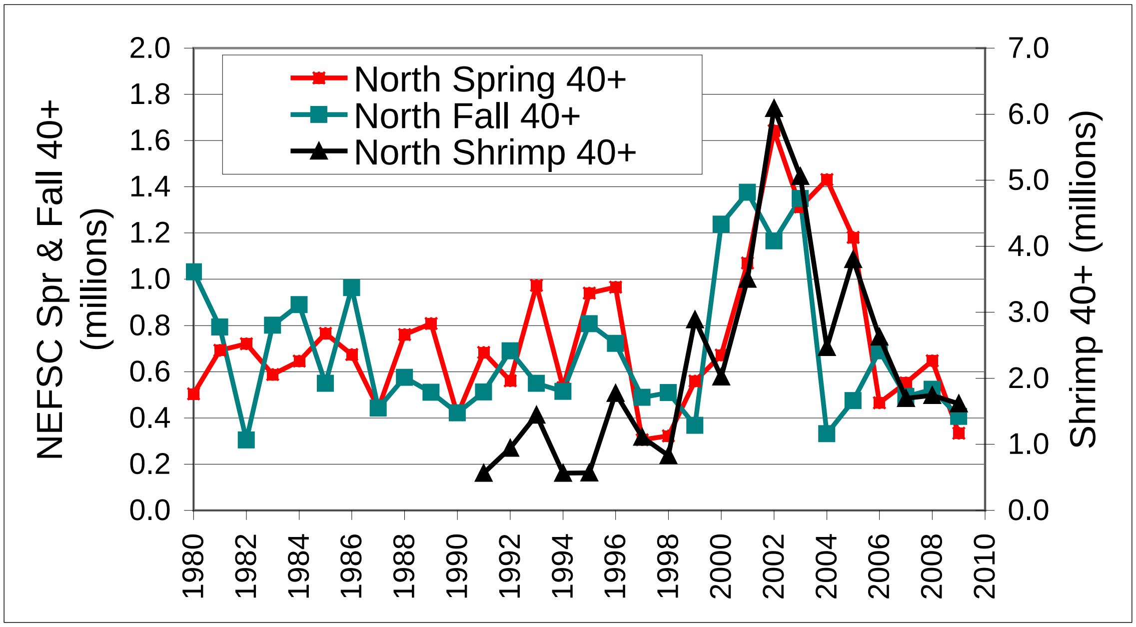
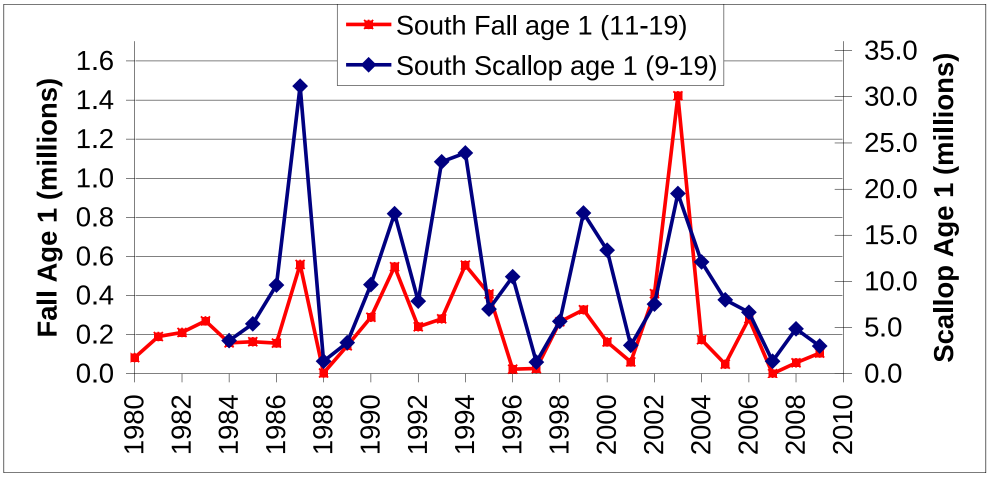
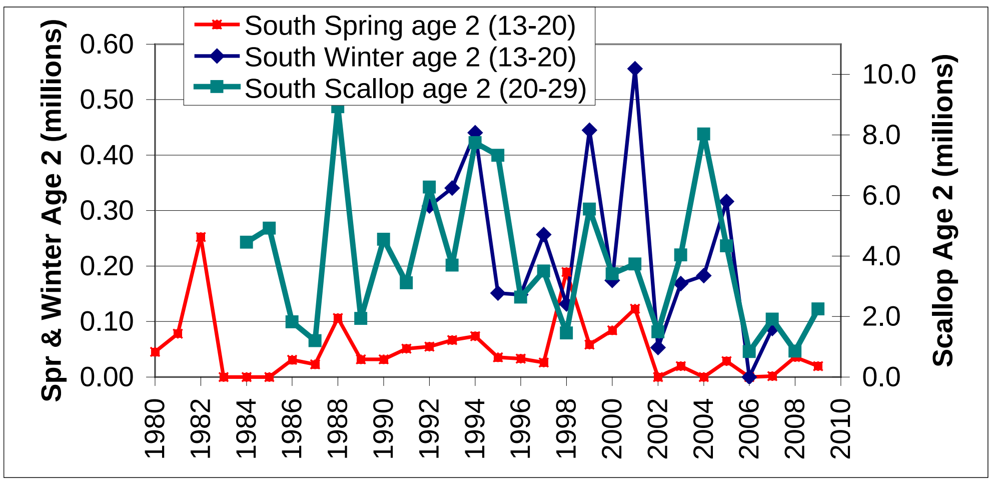


Figure A65. Adult 40+ cm abundance indices for the northern management area.





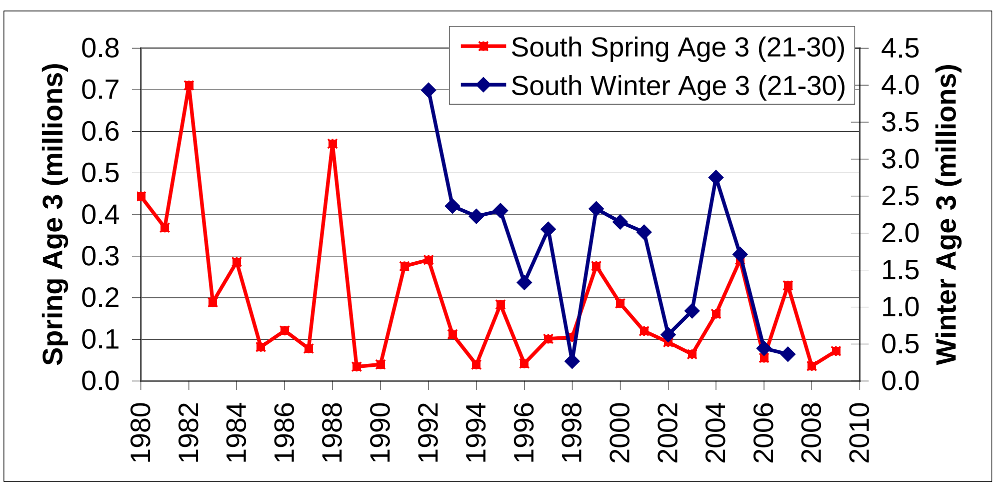


Figure A66. Southern management area monkfish recruitment indices at age. Centimeter interval used to estimate recruitment ages are given in parenthesis.

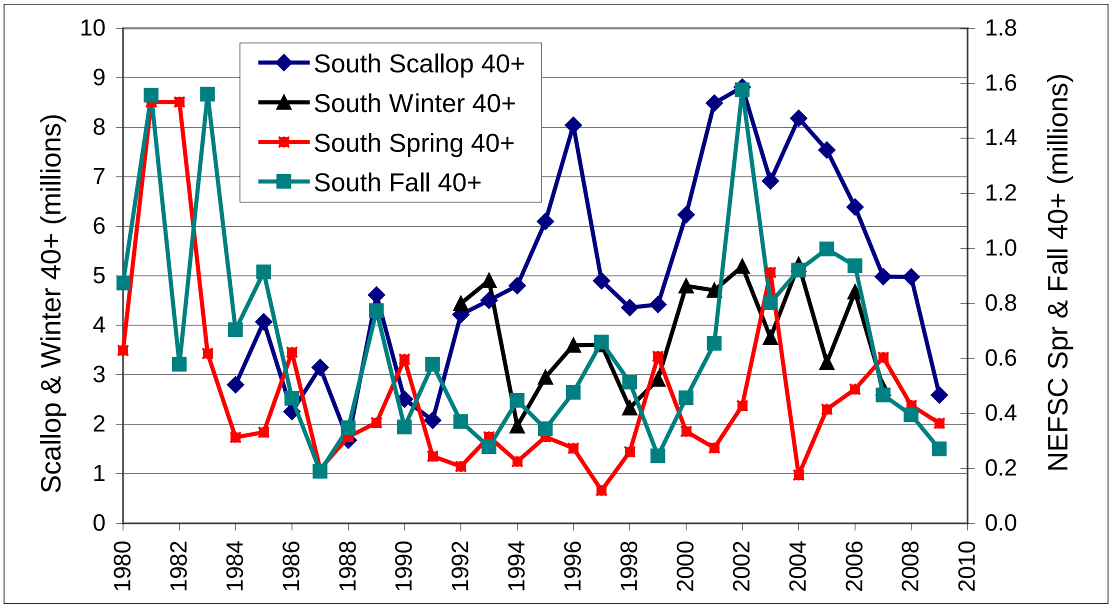


Figure A67. Adult 40+ cm abundance indices for the southern management area.

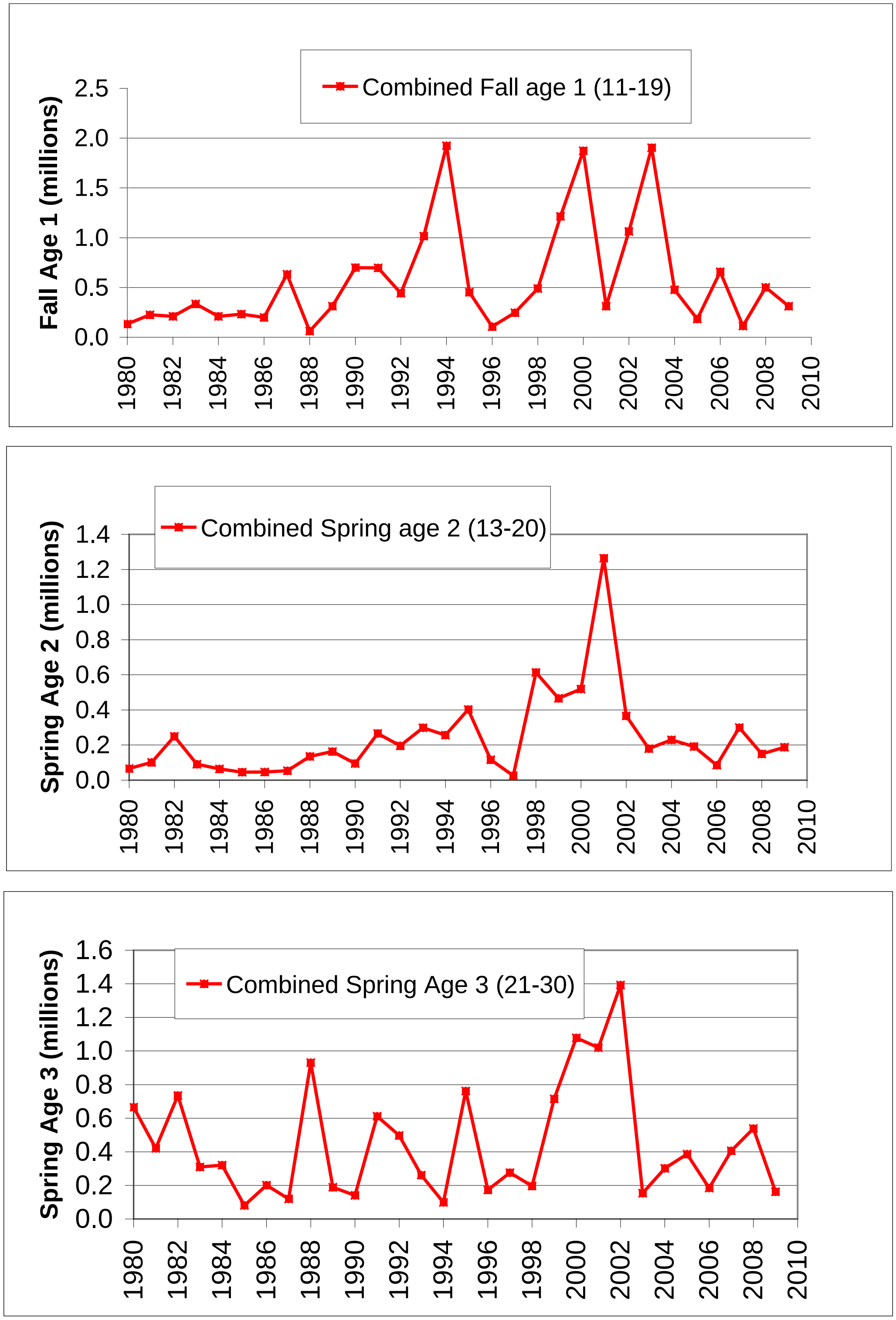


Figure A68. Combined management areas monkfish recruitment indices at age for the NEFSC surveys. Centimeter intervals used to estimate recruitment ages are given in parentheses.

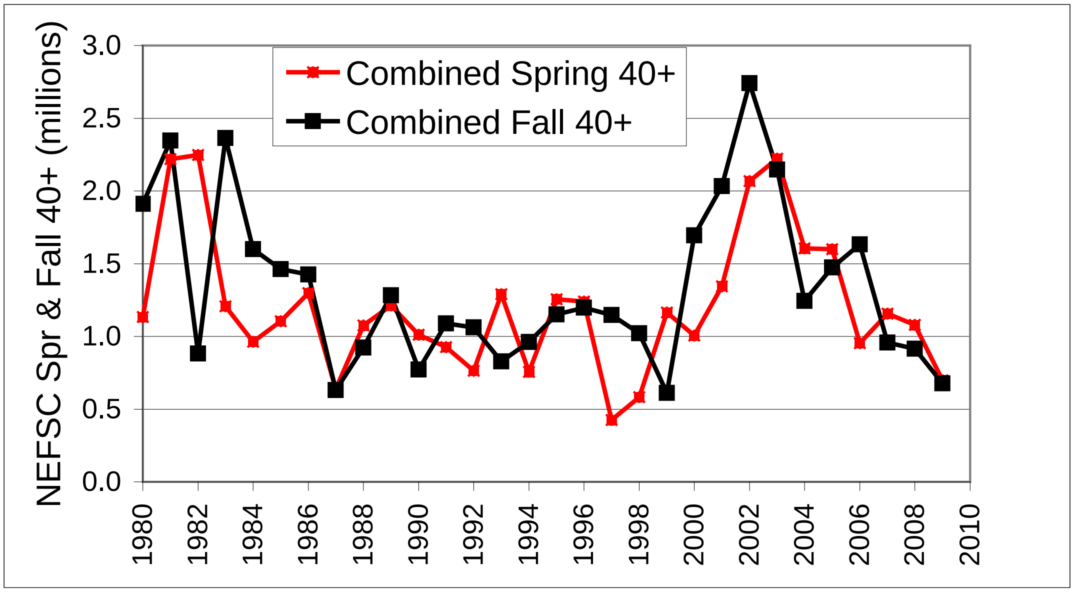


Figure A69. Adult 40+ cm abundance indices for the combined management areas for the NEFSC bottom trawl surveys

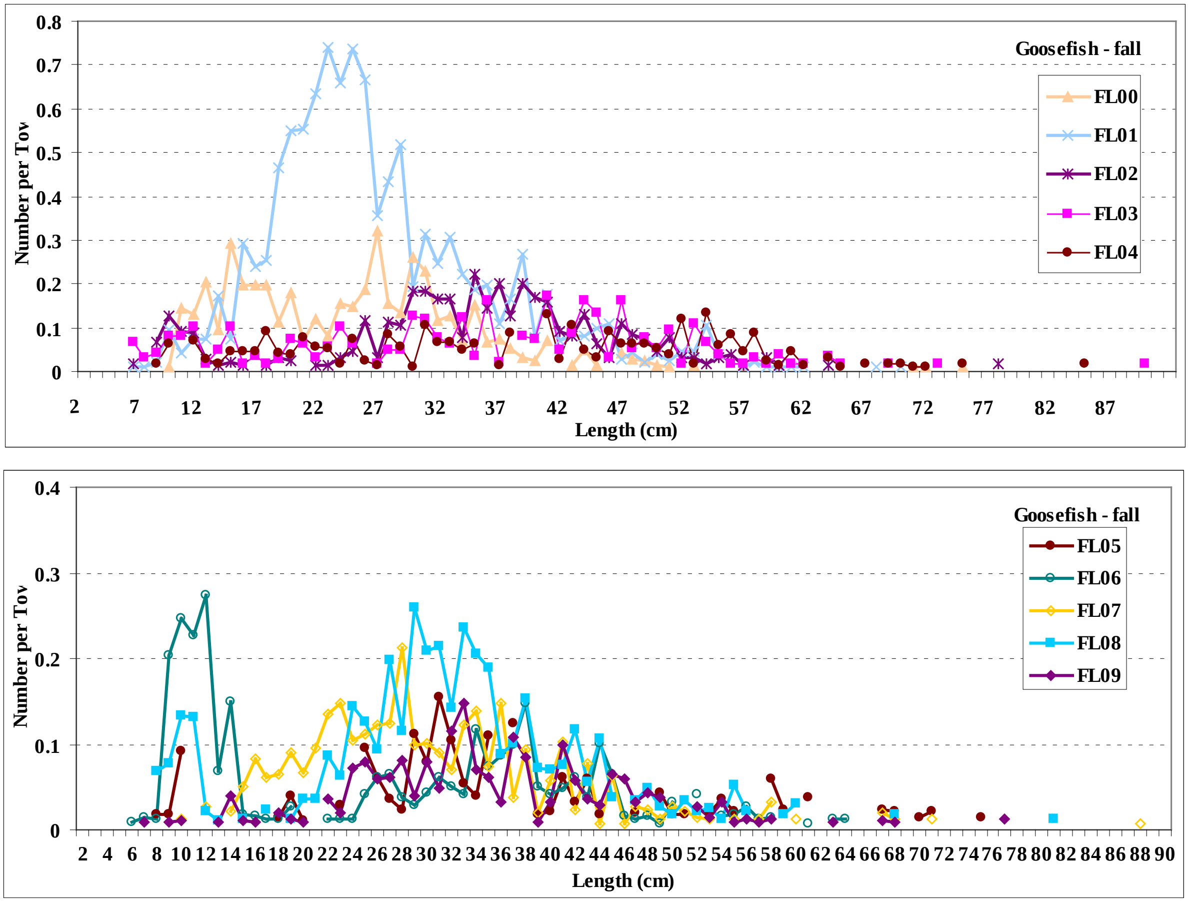


Figure A70. Length frequency distributions from the fall ME/NH bottom trawl survey from 2000 to 2009.

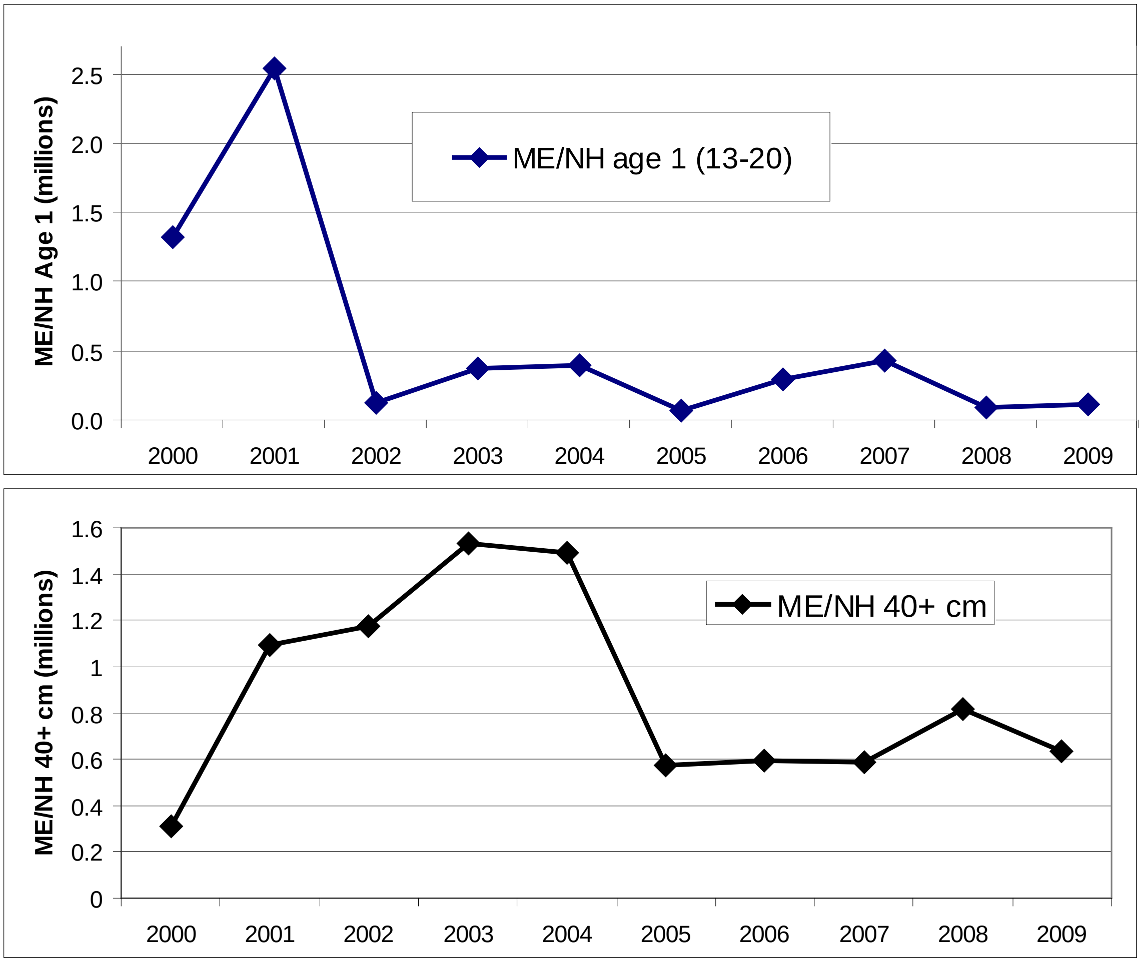
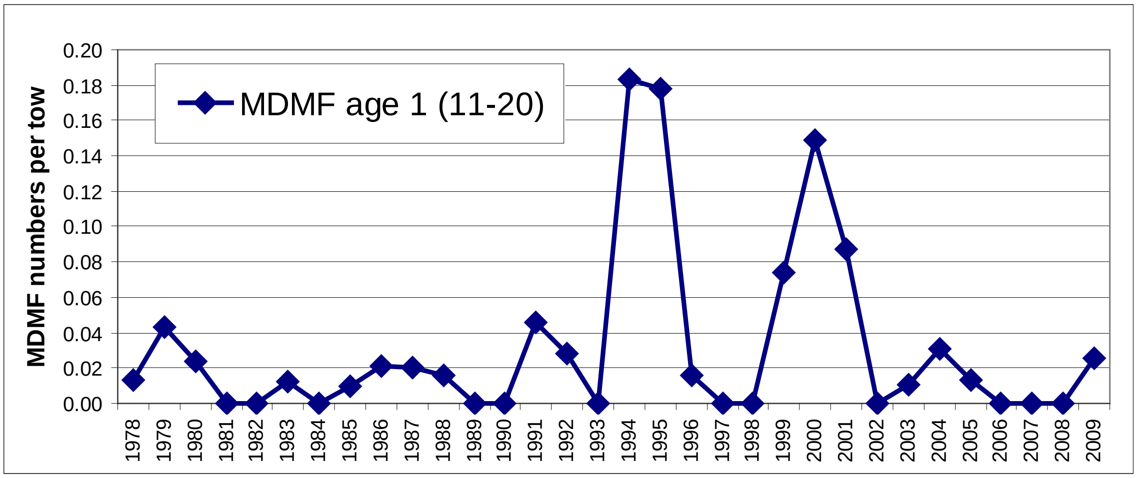


Figure A71. Age 1 (13 to 20cm) and 40+ cm indices from the fall ME/NH bottom trawl survey from 2000 to 2009.



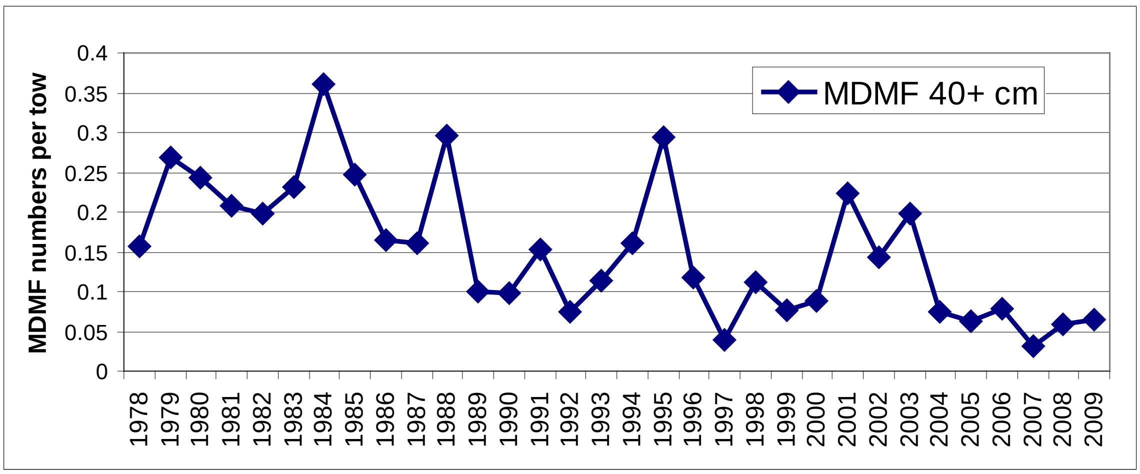
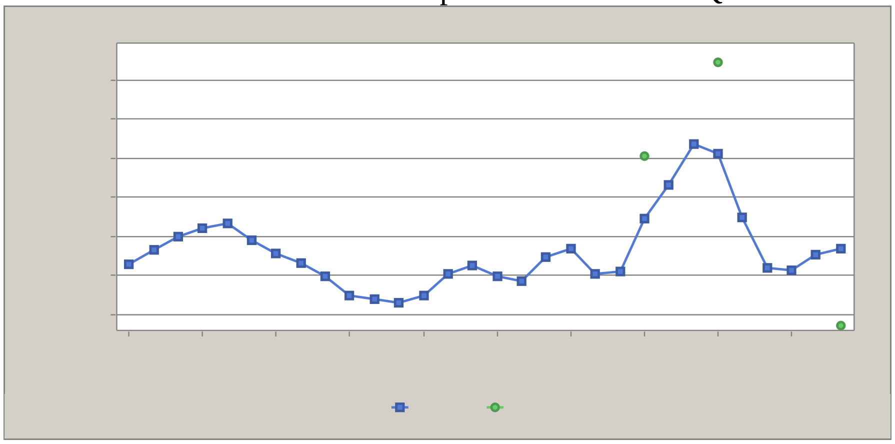
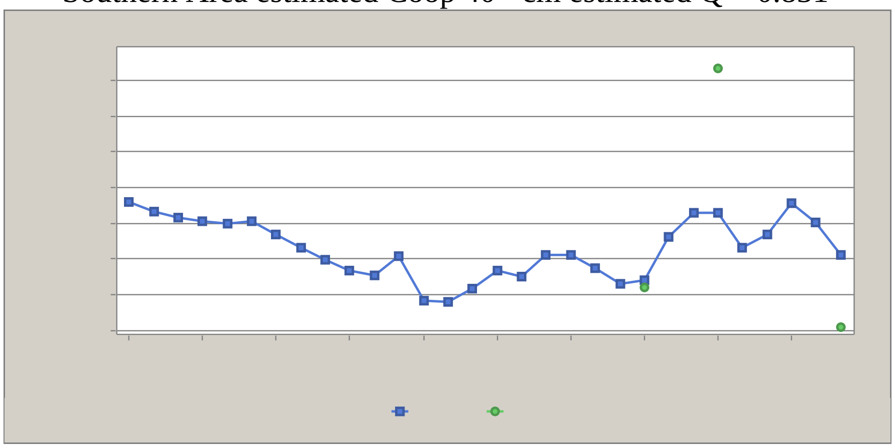


Figure A72. Age 1 (11 to 20cm) and 40+ cm indices from the fall MDMF bottom trawl survey from 1978 to 2009. Many of the years in the age 1 index did not catch any monkfish and relatively low numbers of 40+ cm monkfish are caught per tow.

Northern Area estimated Coop 40+ cm estimated Q = 1.176



Southern Area estimated Coop 40+ cm estimated Q = 0.831



Combined Area estimated Coop 40+ cm estimated Q = 0.679

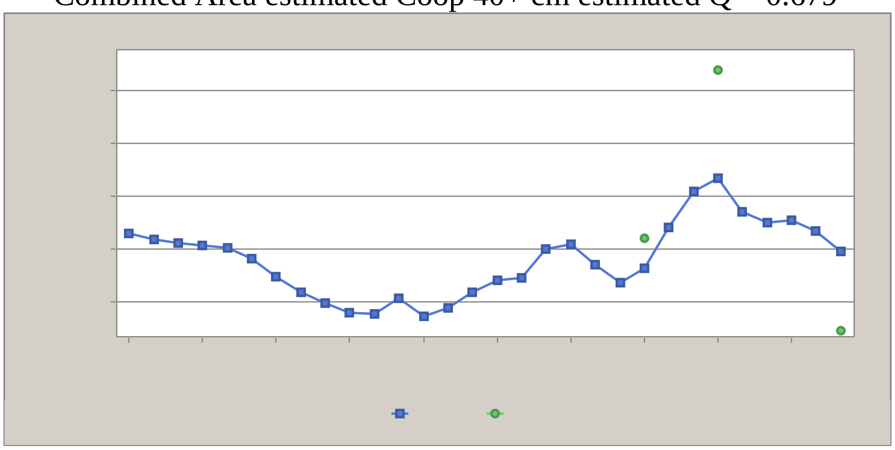


Figure A73. Estimated q’s and fits for the north, south, and combined management area diagnostic runs which incorporated the absolute cooperative 40+ numbers.

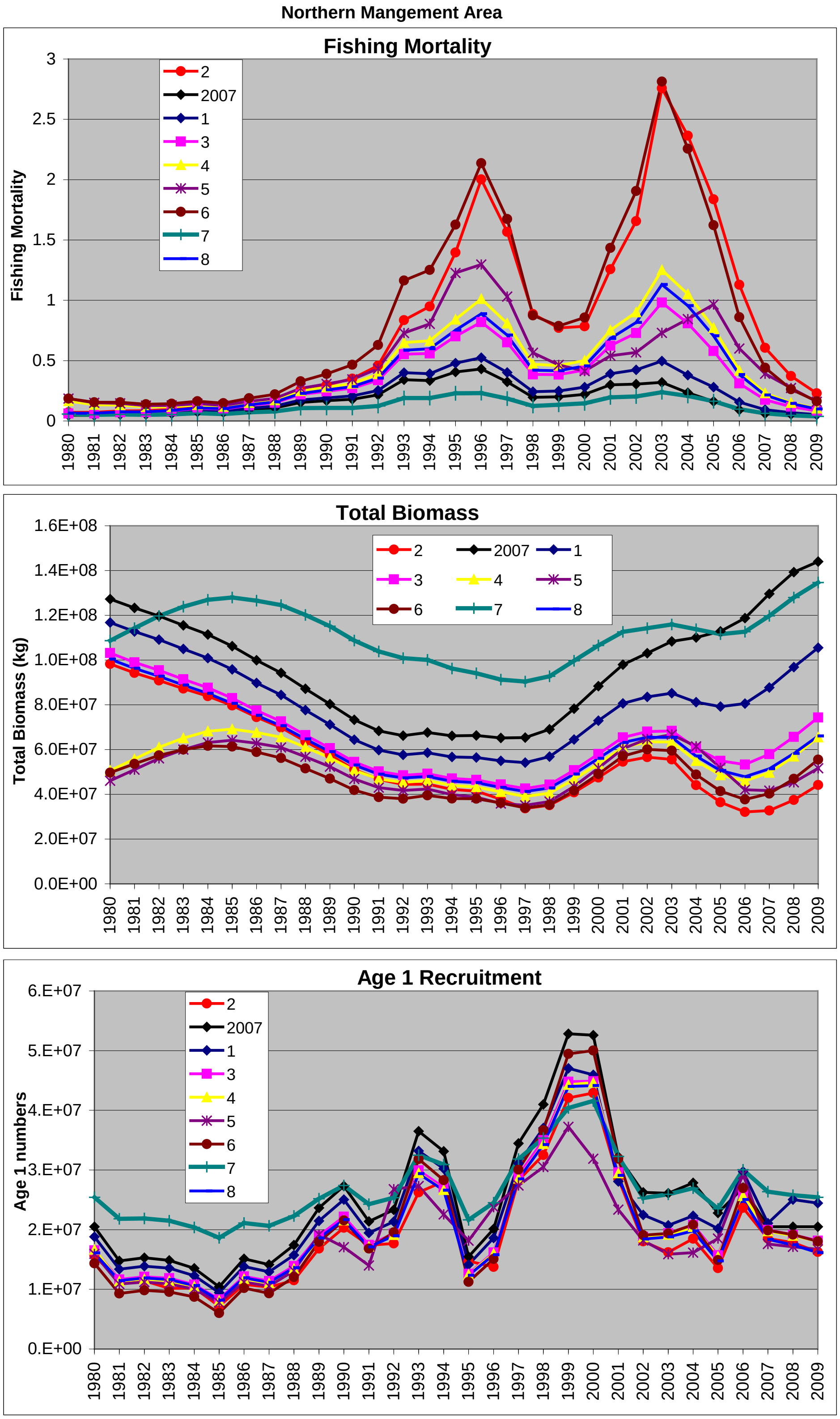


Figure A74. Northern management area monkfish SCALE sensitivity runs (table A3).

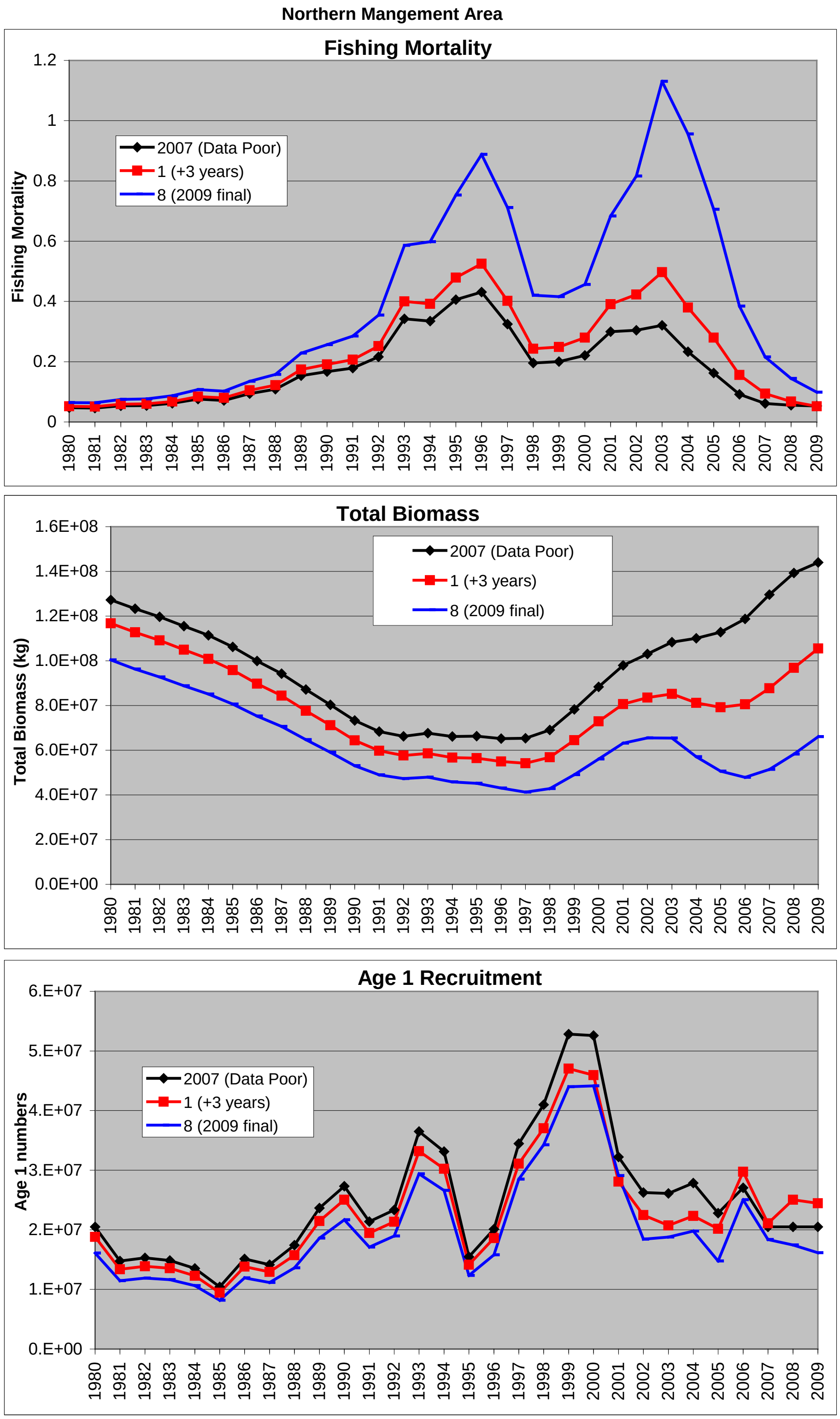


Figure A75. Comparison of northern management area final runs from the 2007 and this assessment. Run 1 (2007 run with updated 2007-2009 data) is also shown.

Northern Mangement Area

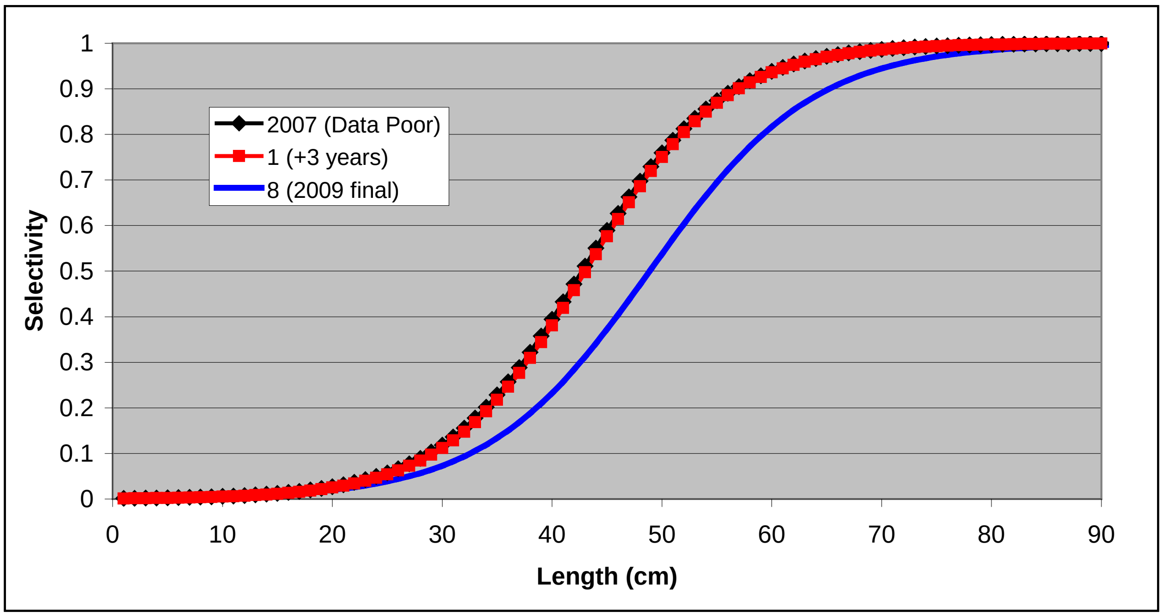


Figure A76. Comparison of northern management area estimated selectivity for the final runs from the 2007 and this assessment. Run 1 (2007 run with updated 2007-2009 data) is also shown.

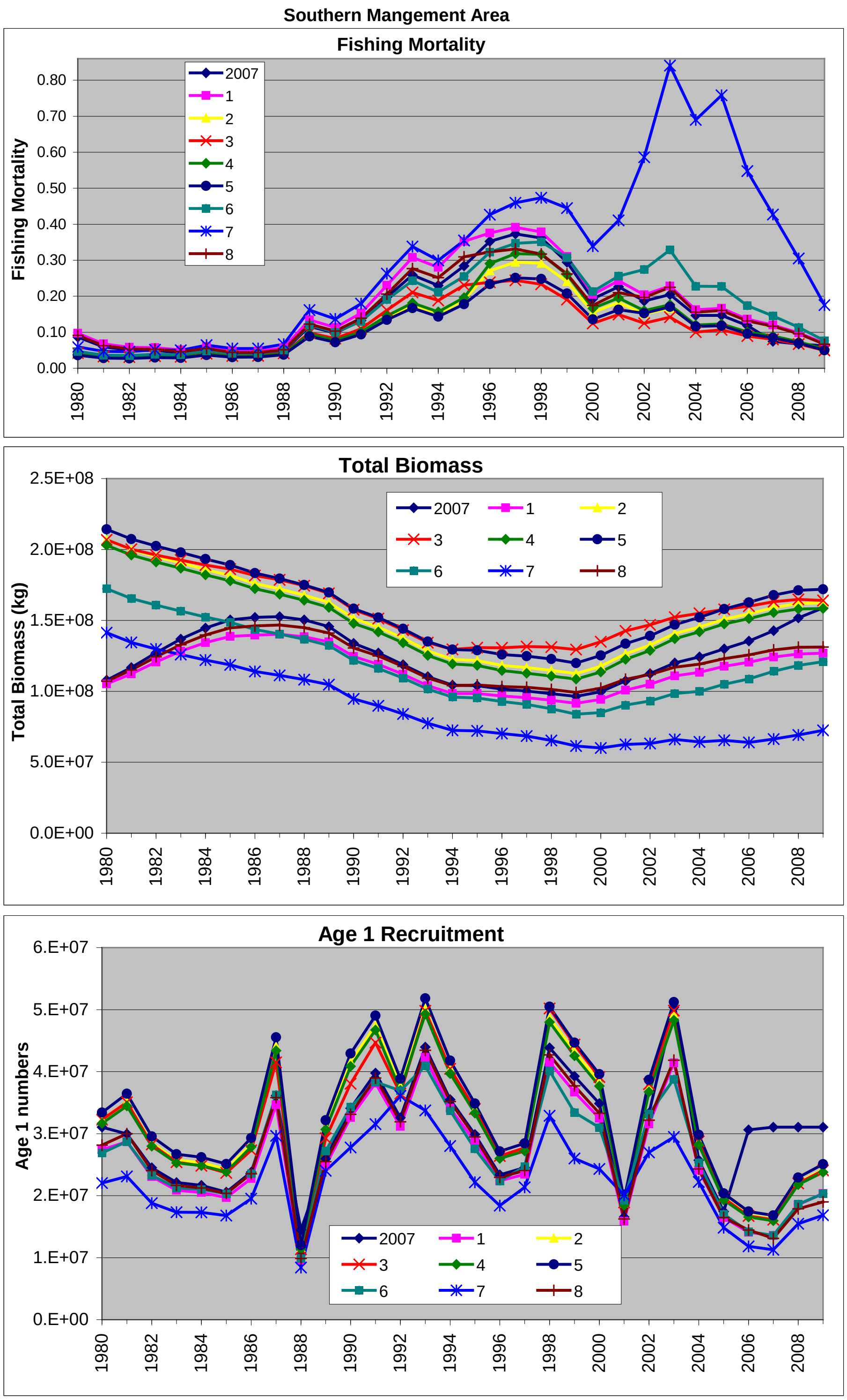


Figure A77. Southern management area monkfish SCALE sensitivity runs.

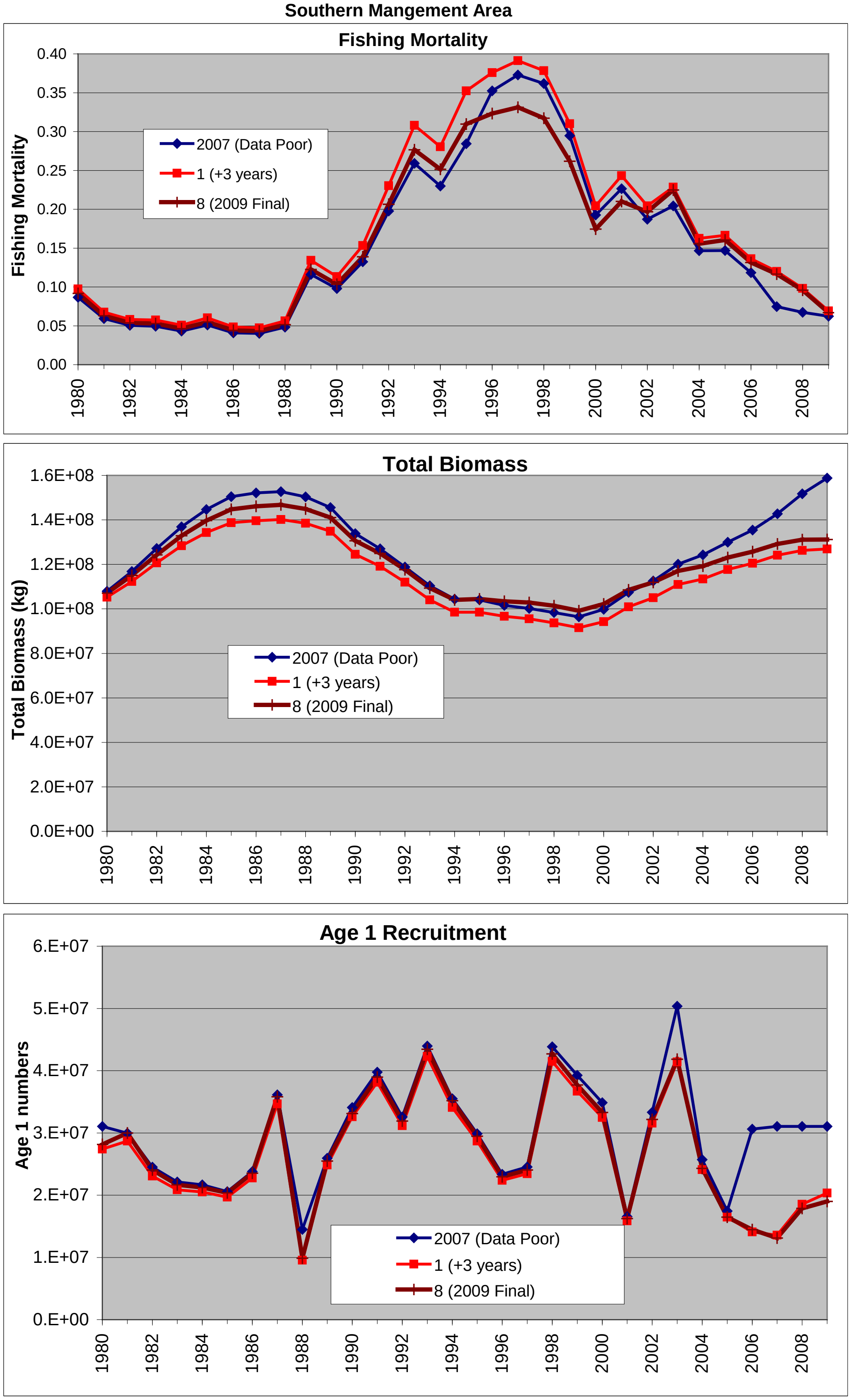


Figure A78. Comparison of southern management area final runs from the 2007 and this assessment. Run 1 (2007 run with updated 2007-2009 data) is also shown.

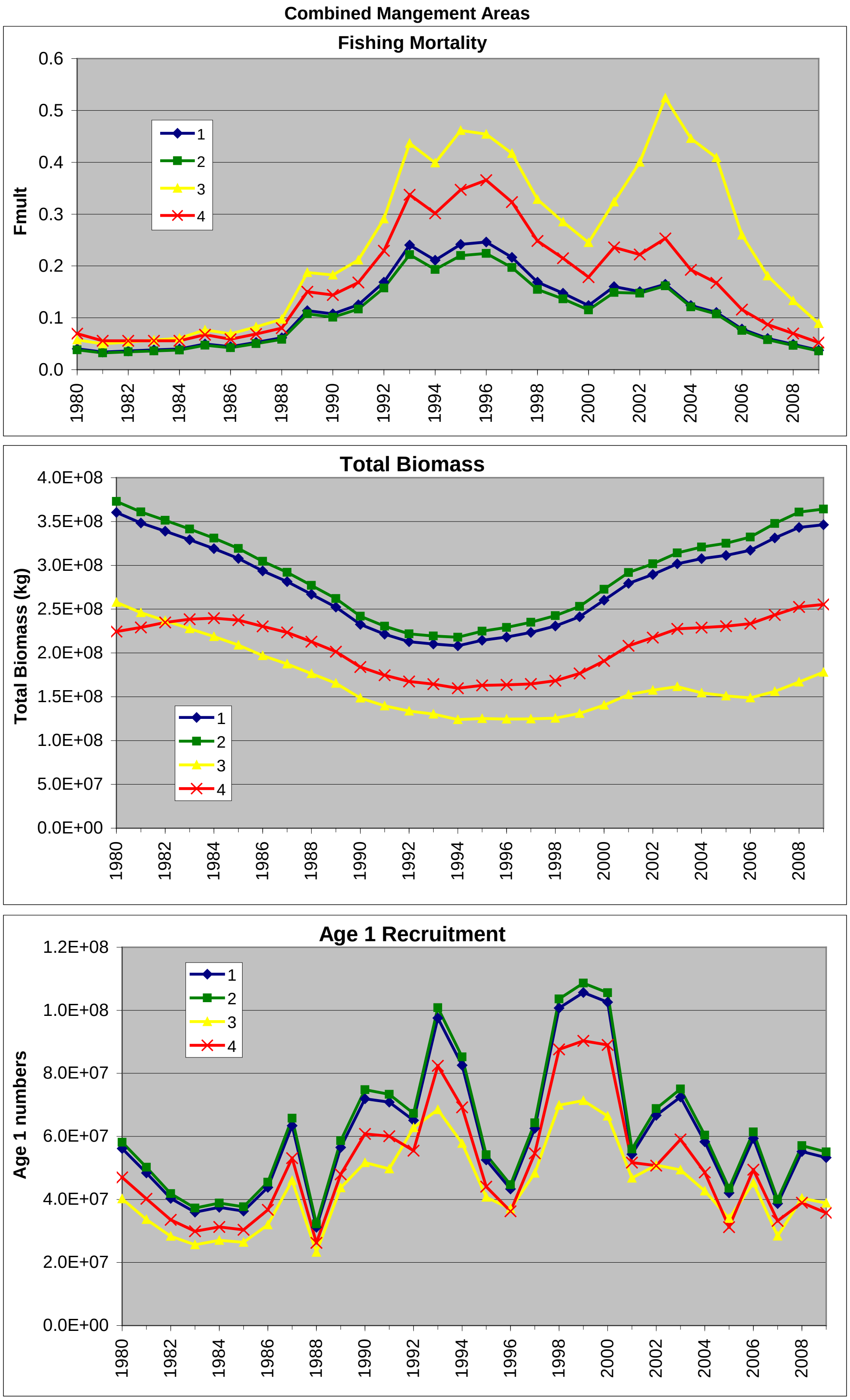
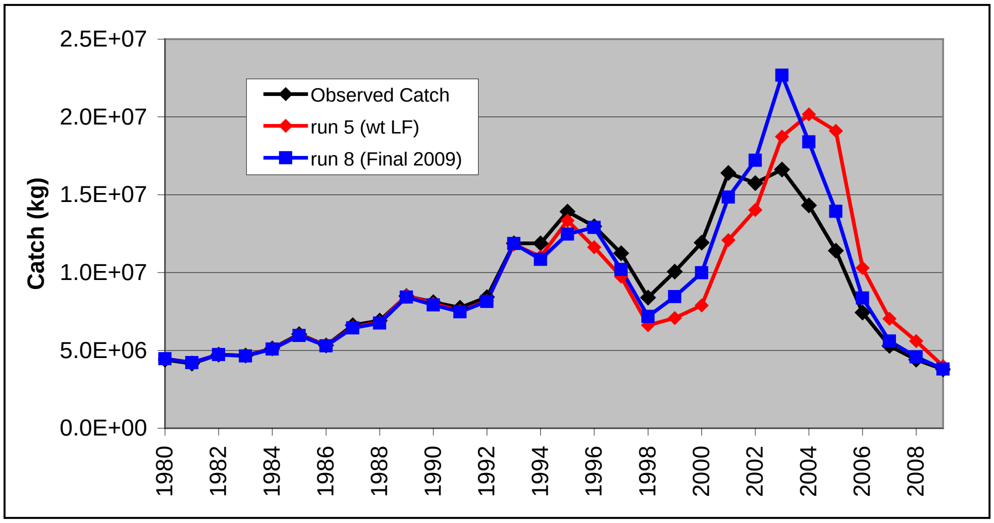


Figure A79. Combined management area monkfish SCALE sensitivity runs.

Northern Mangement Area



Southern Mangement Area

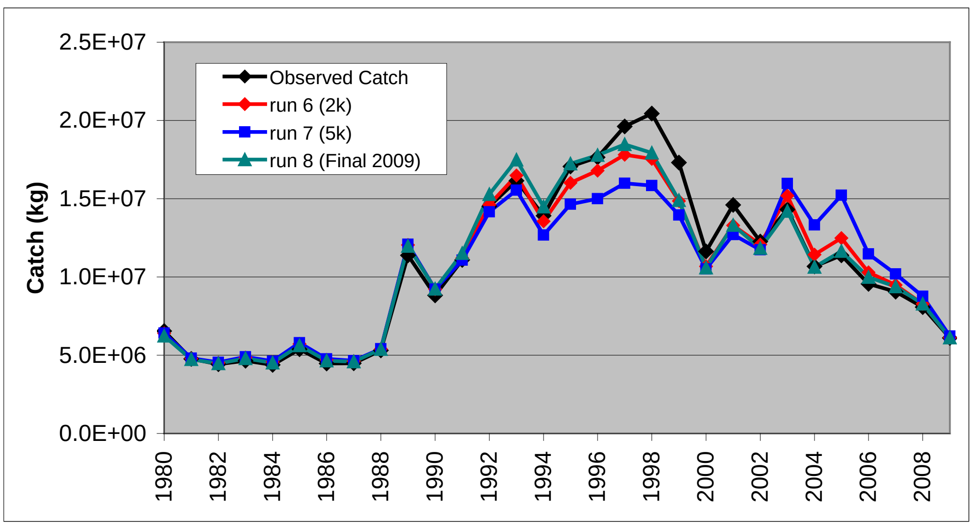


Figure A80. Comparison of northern and southern fits to the catch between the final and sensitivity runs which increased the weighting on fitting the length frequency data.

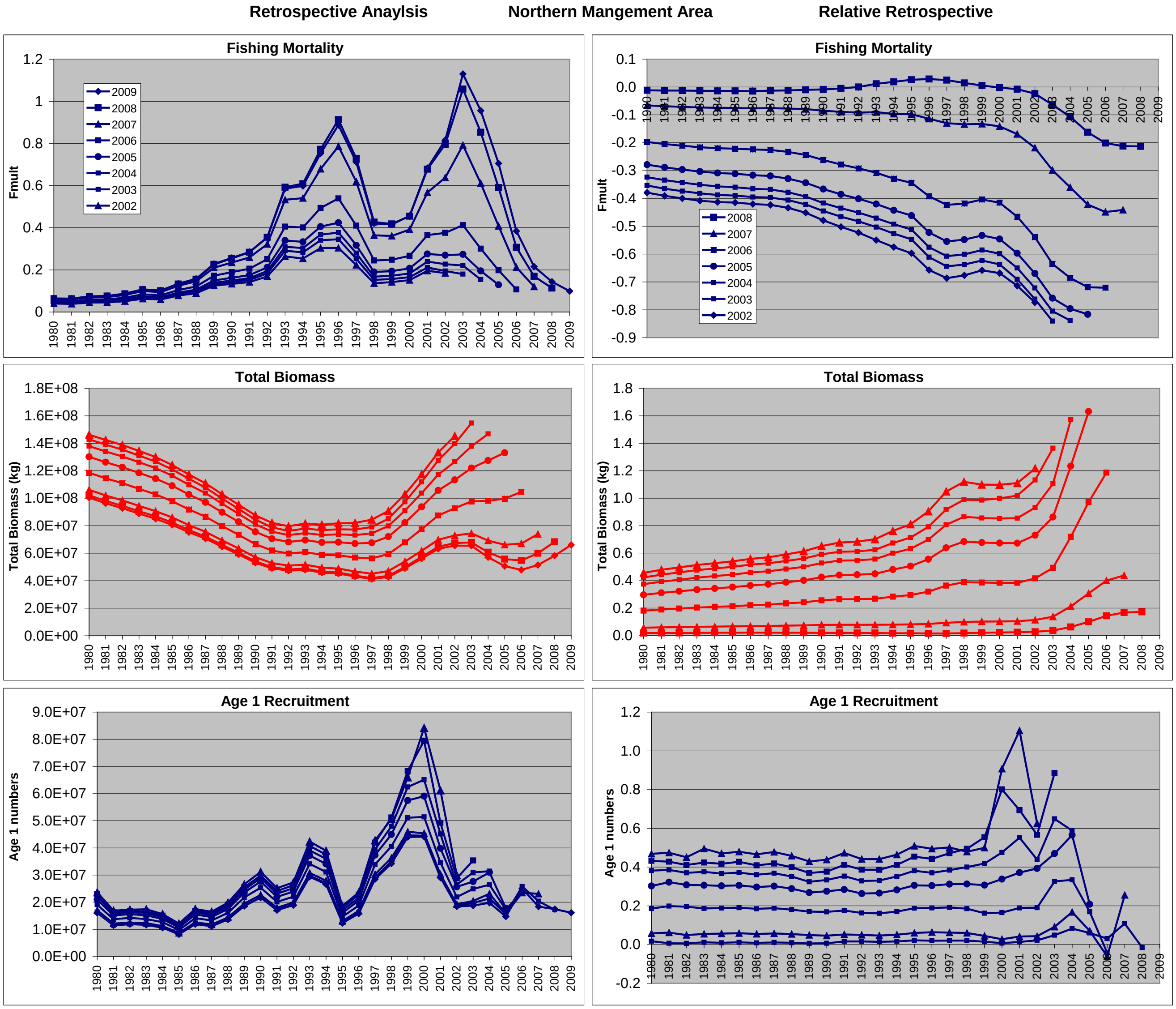


Figure A81. Northern management area retrospective plot for F, total biomass and age 1 recruitment (left). Retrospective relative trends to the terminal year run are on the right.

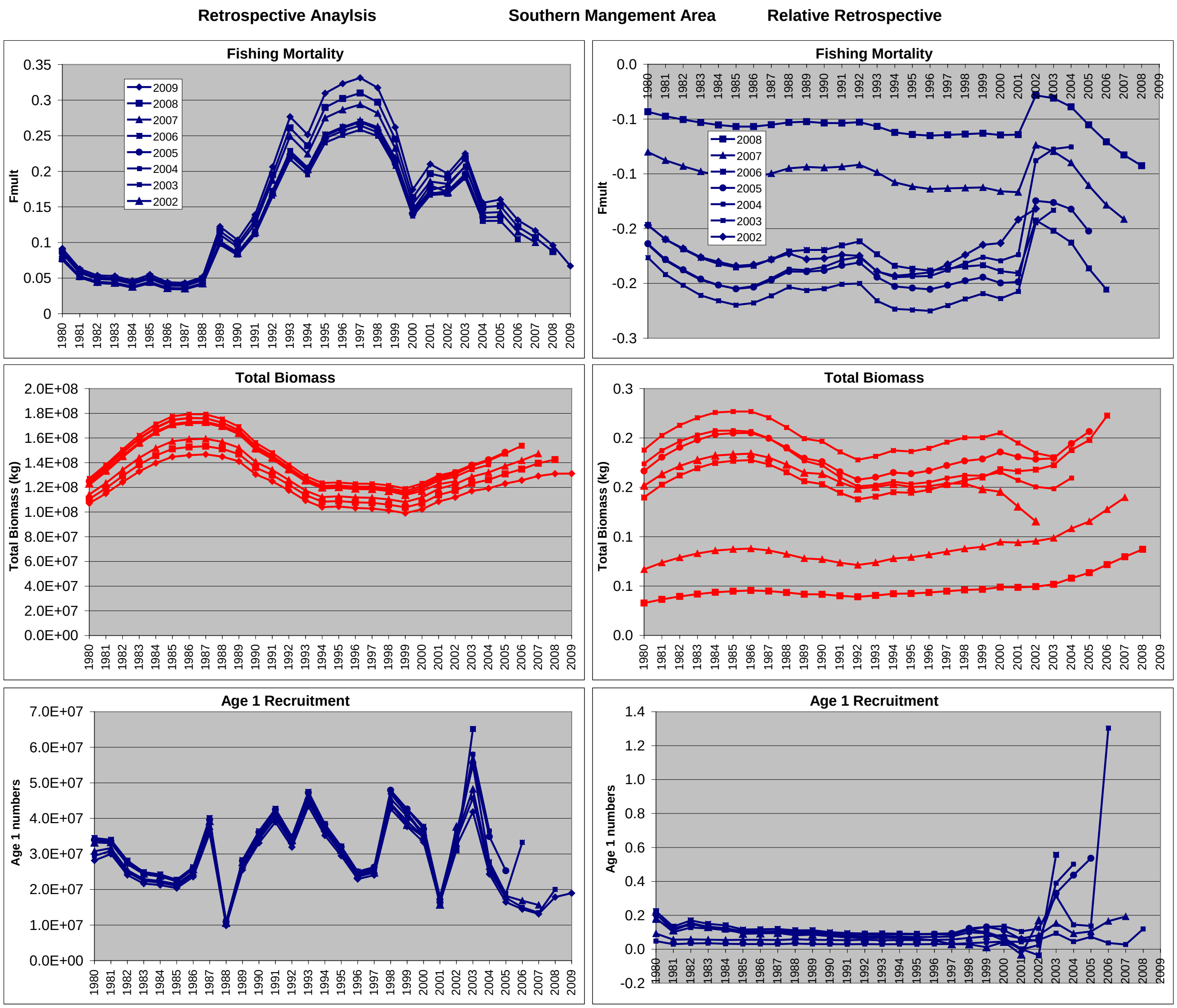


Figure A82. Southern management area retrospective plot for F, total biomass and age 1 recruitment (left). Retrospective relative trends to the terminal year run are on the right.

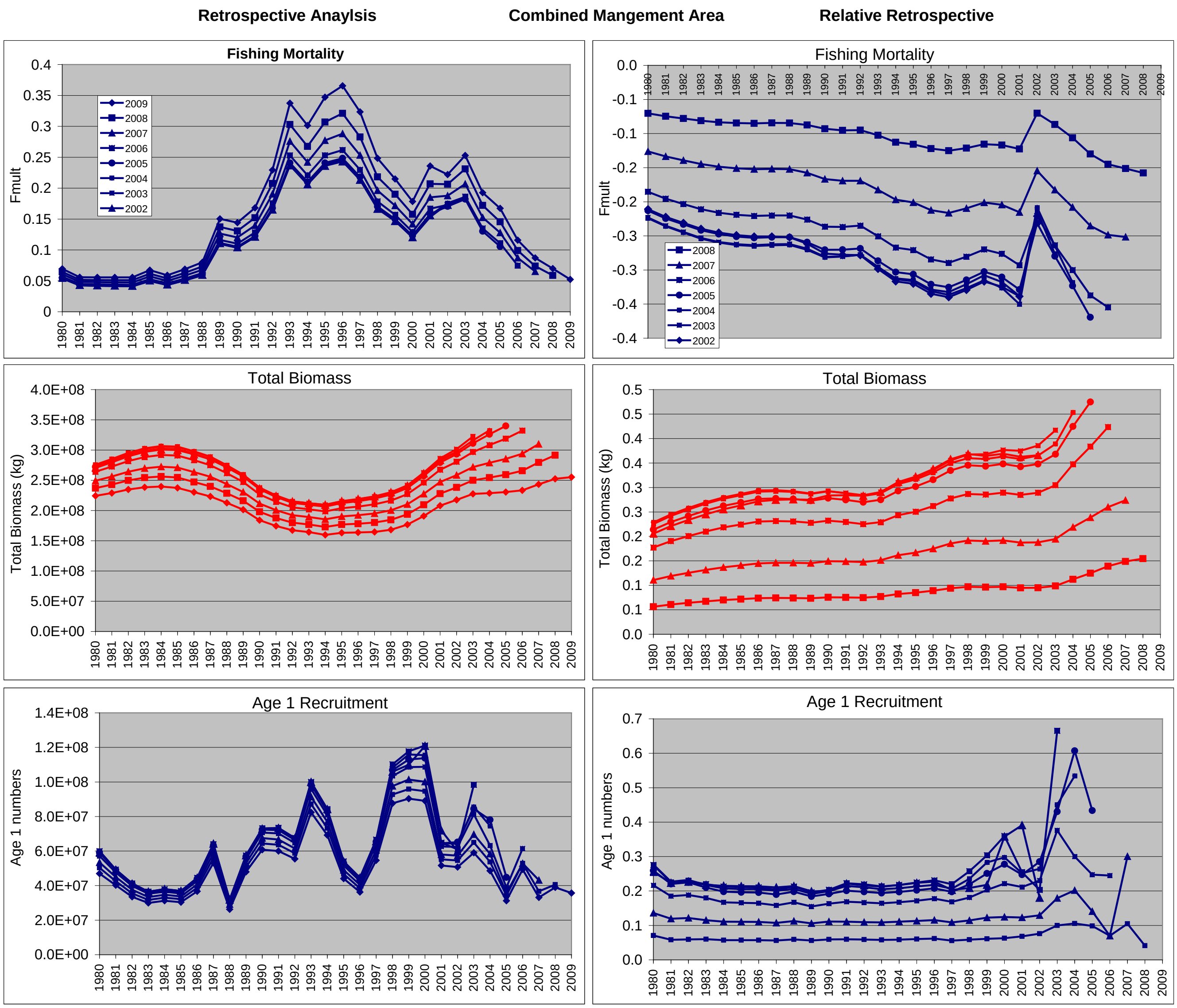


Figure A83. Combined management area retrospective plot for F, total biomass and age 1 recruitment (left). Retrospective relative trends to the terminal year run are on the right.

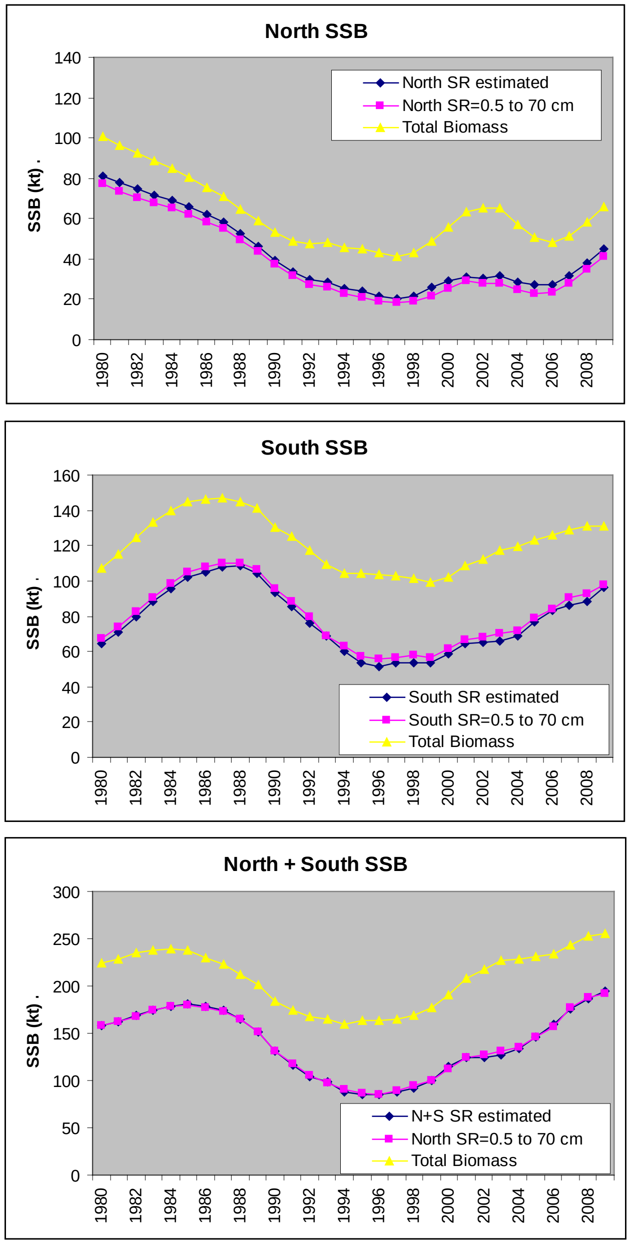


Figure A84. Trends in spawning biomass estimated from SCALE output of numbers at length and applying relationships for maturity at length, weight at length and fraction female at length. Fraction female was estimated from observed ratios at length in survey data (blue diamonds) and assuming 50% female up to 70 cm and 100% female $\geq$ 70 cm (pink squares).

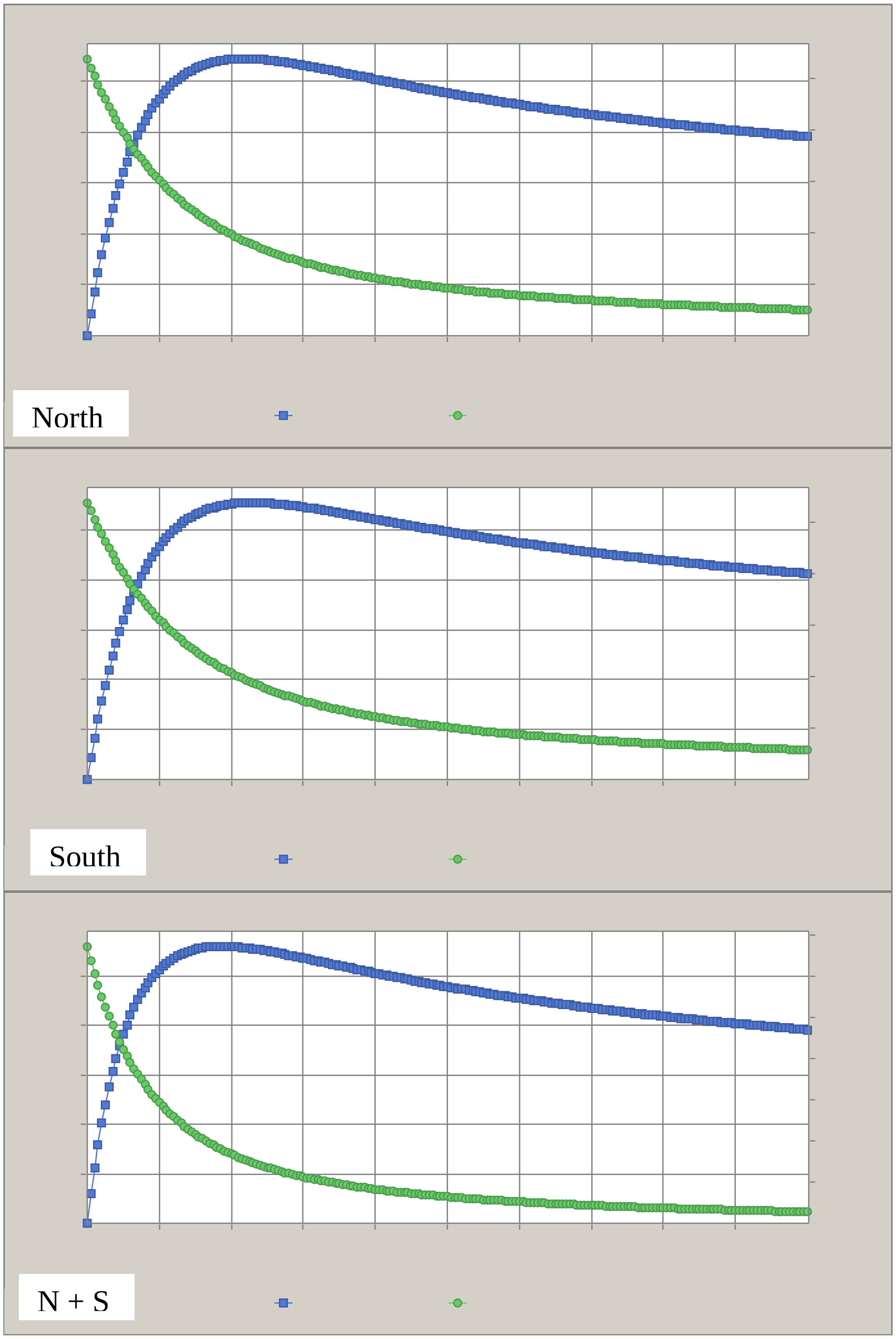


Figure A85. Yield per recruit and spawning stock biomass per recruit curves using selectivity from 2010 SCALE model.

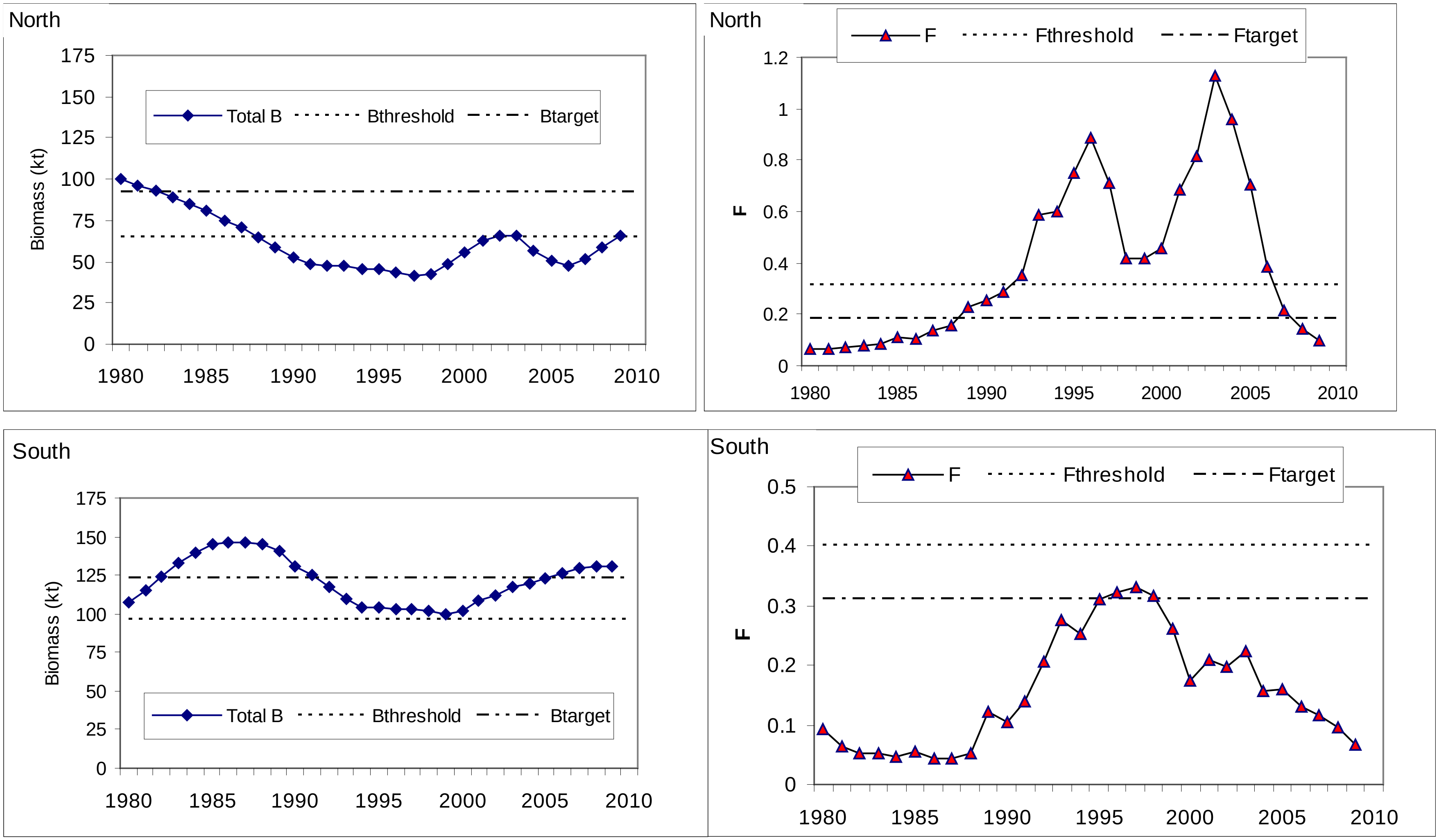


Figure A86. Trends in total biomass and fishing mortality rate (F), from the assessment model (SCALE), relative to the existing (2007) biological reference points for monkfish northern and southern management areas.

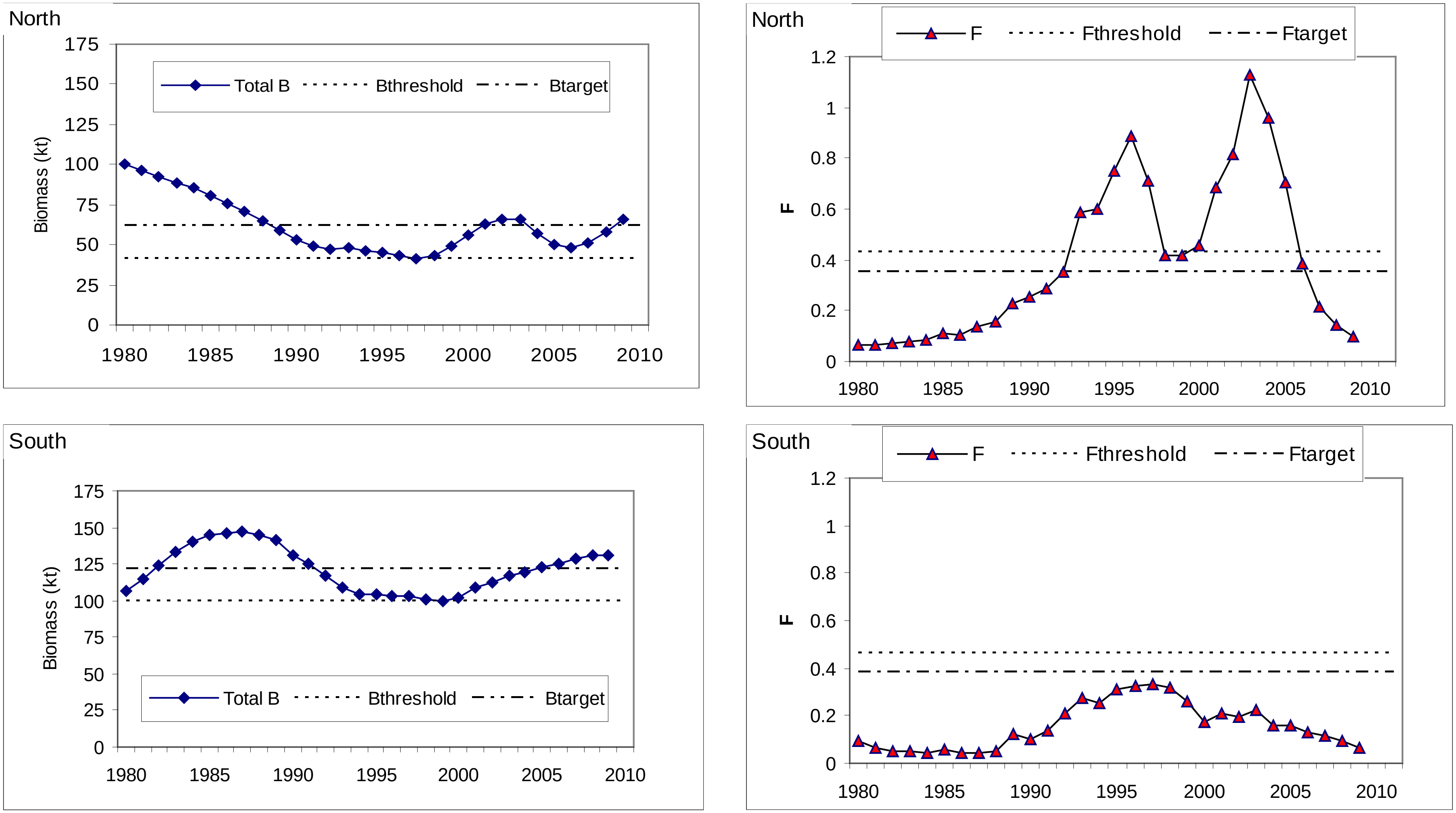
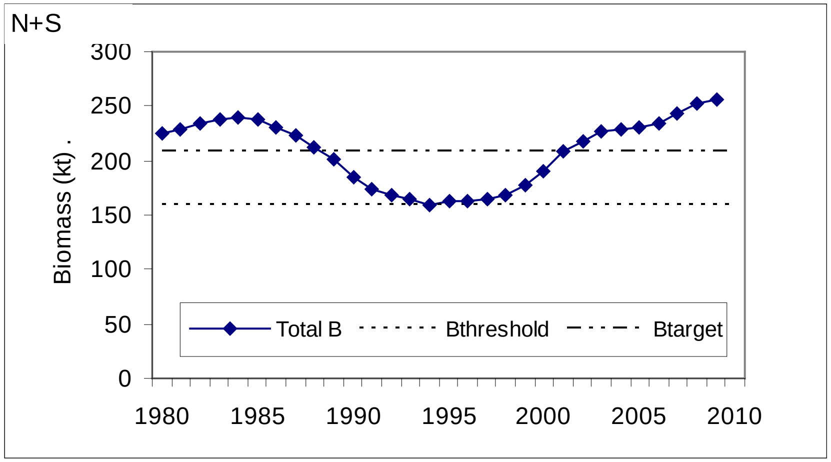


Figure A87. Trends in total biomass and fishing mortality rate (F) from the assessment model (SCALE) relative to updated biological reference points using existing definitions (Bloss, Fmax) for monkfish for northern and southern areas.



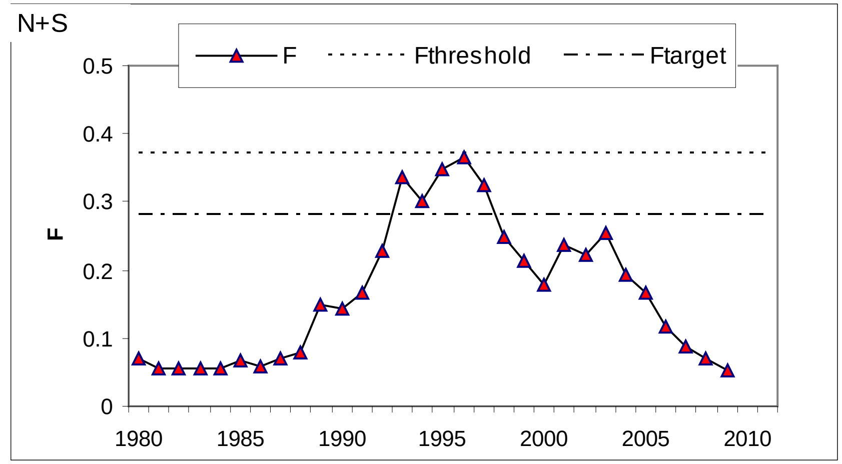


Figure A88. Trends in total biomass and fishing mortality rate (F) from the assessment model (SCALE) relative to updated biological reference points using existing definitions (Bloss, Fmax) for monkfish for combined areas.

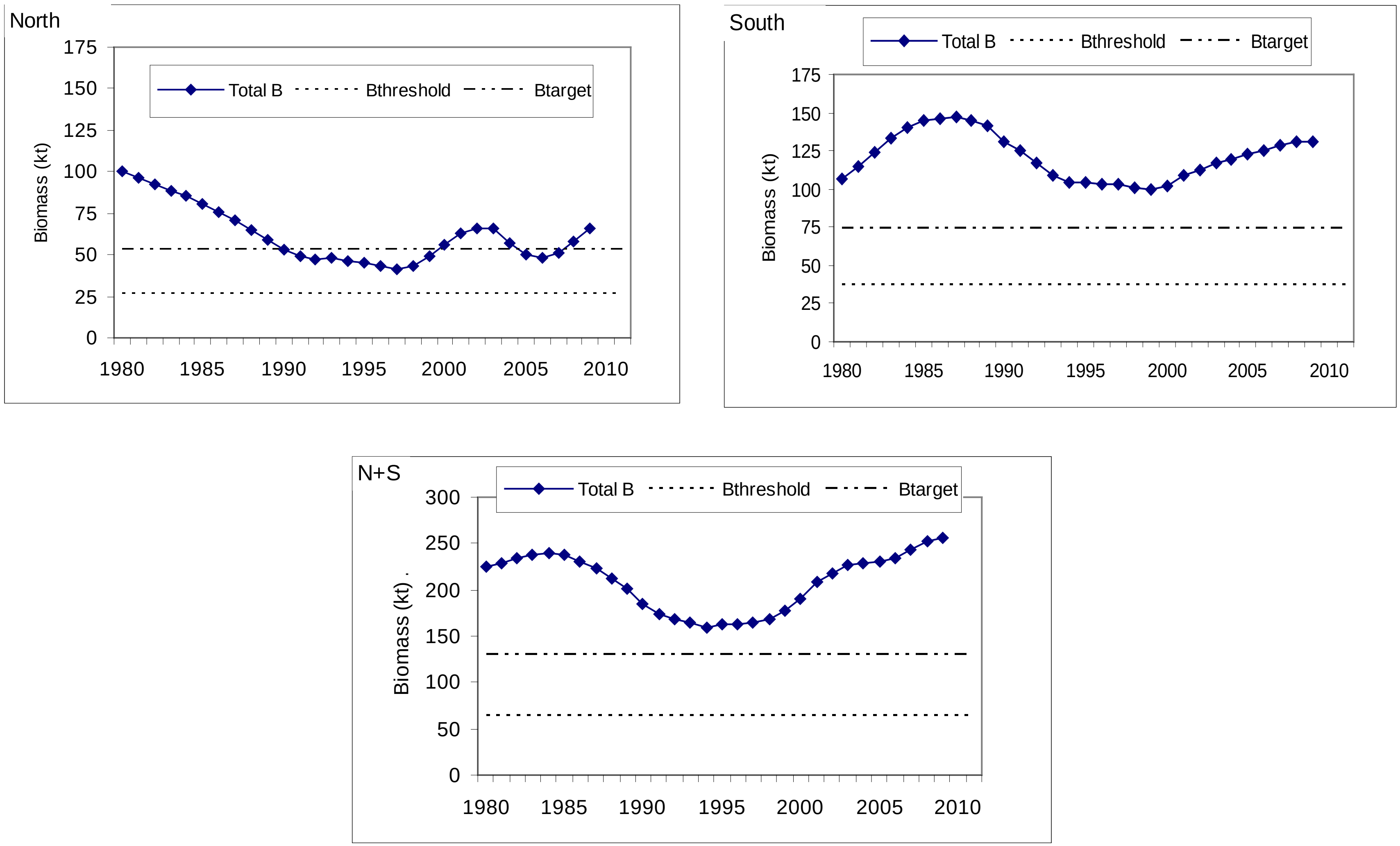


Figure A89. Trends in total biomass from the assessment model (SCALE), relative to the Bmax biological reference points for monkfish for northern, southern and combined management areas.

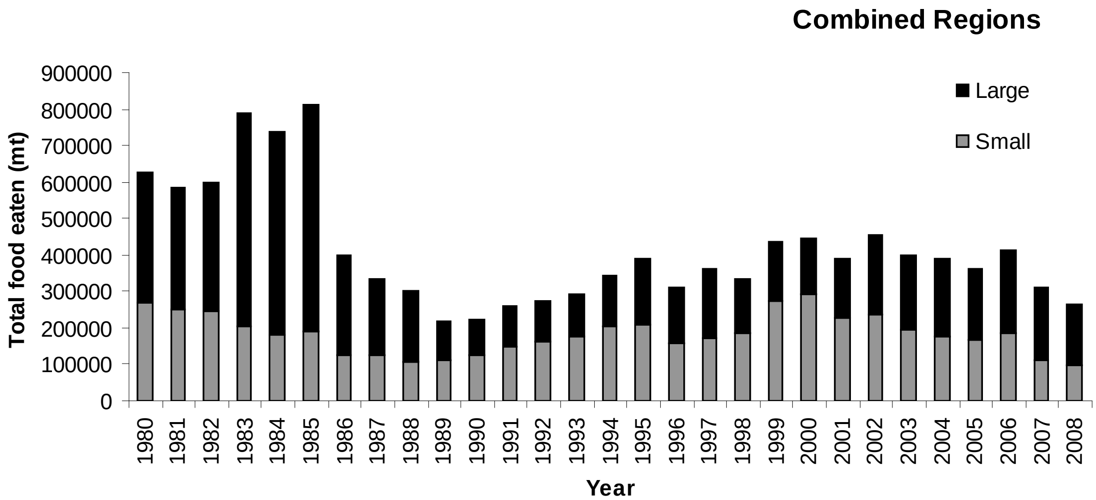


Figure A90. Total amount of food consumed by goosefish.

Initial Analyses of Depletion Experiments for Monkfish

April 12, 2010

Southern Demersal Working Group

SARC 50

Paul Rago

The Catchability Coefficient
A Fundamental Property in Fisheries Science

- Catchability is a scalar that translates indices of relative abundance to absolute abundance.

- The catchability coefficient q was first defined in 1918 by Baranov who called it the "elemental intensity of fishing" which is the fractional reduction in average density per application of a unit of effort.

- Catchability is a parameter in every fisheries model that combines indices of abundance and estimates of total removals. If the model estimates absolute biomass or numbers, then there is a q buried in the equation sets.

- Index = Catchability x Absolute Abundance

- Model-based estimates of catchability can be a source of instability in dynamic models.

Simple Depletion Models
Leslie and Davis 1939, DeLury 1947

Primary assumptions include

1) All extant individuals have the same probability of being caught in a sample,
2) Expected catch in a sample is proportional to sampling effort,
3) Units of sampling effort are independent and additive,
4) Catch depends on the cumulative catch of preceding samples, and
5) All removals are known.

Assumptions are violated in subtle but important ways

- Variations with size of animal
- Changes in availability to gear
- Changes in behavior of animals
- Loss of animals as a result of sampling

The Basic Depletion Model

Catch = P(Capture|Encounter) x P(Encounter) x Population

$$(1) \qquad E(C) = e\left(\frac{a}{A}\right)N$$

Where

- e = gear efficiency
- a= area swept by unit of gear
- A= Total area occupied by population
- N = total population size
- q = e (a/A)

Note that density D = N/A so that

C = e a D

Deriving the Recursive Model

- Consider a population of size N_o in an area of size A such that the initial density is $D_o = N_o/A$.

Let $C_j = q\ N_{j-1}$ and $N_{j+1} = N_j - C_j$

- Then $C_1 = q\ N_0$ and $N_1 = N_0 - C_1$
- Then $C_2 = q\ N_1$ and $N_2 = N_1 - C_2$
- Then $C_3 = q\ N_2$ and $N_3 = N_2 - C_3$
- Lather, rinse, repeat to get

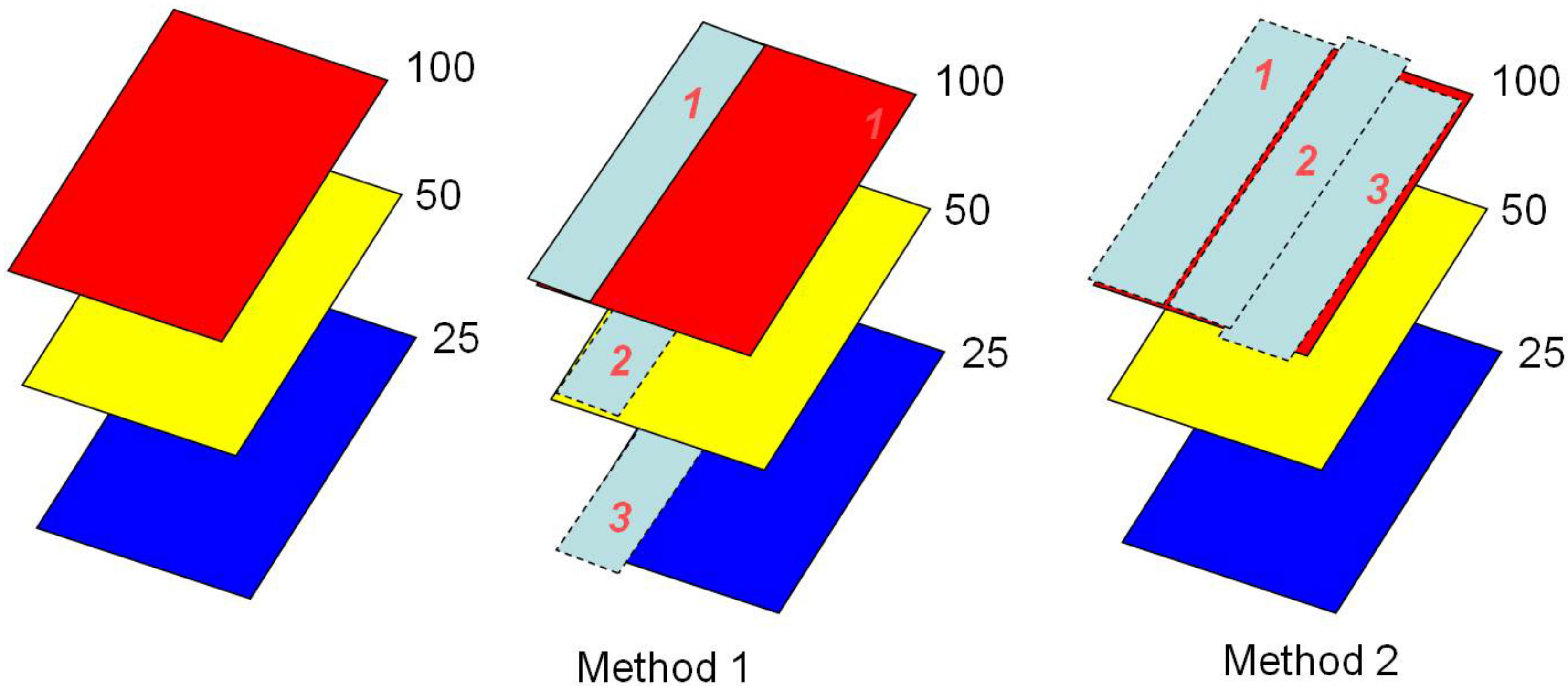
$$E(C_i) = q(N_0 - T_{i-1}) \quad (2)$$

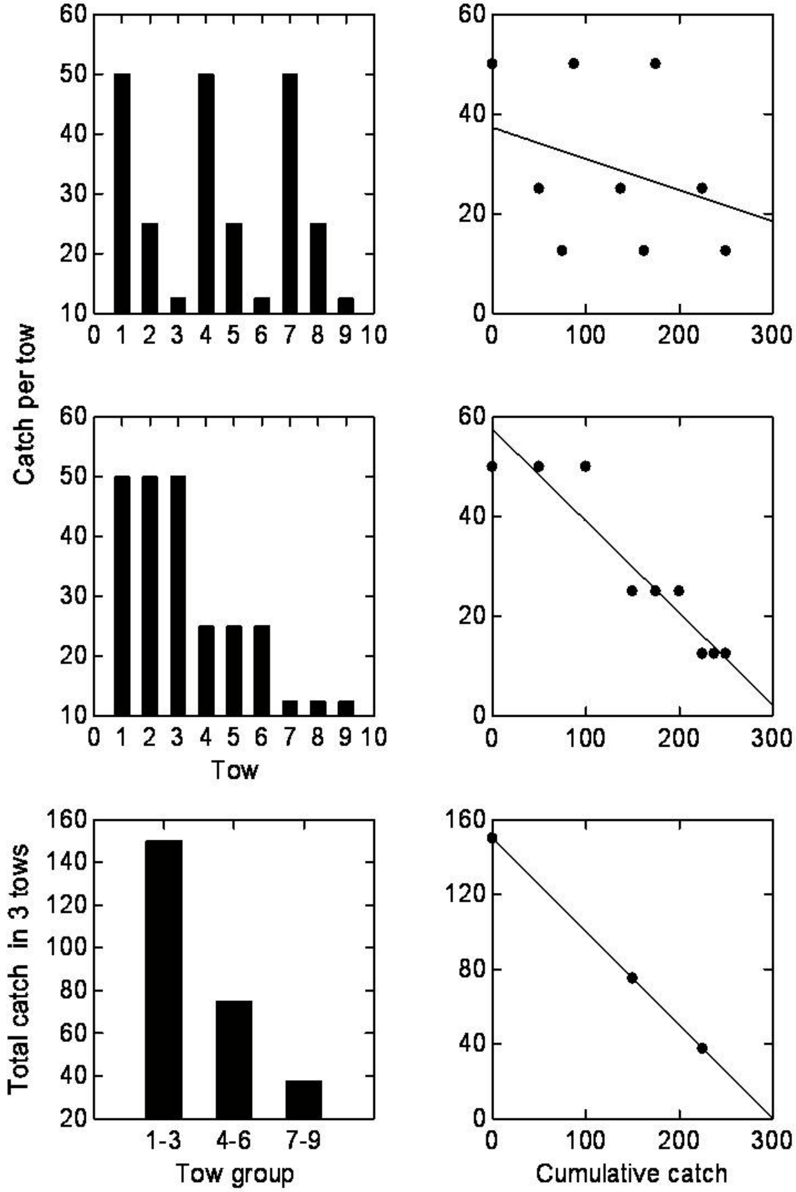
where $T_{i-1} = \sum_{j=1}^{i-1} C_j$,

for $i = \text{tow number}$.

Why Space Matters

- Consider a population that exists over some area A and that the population N is sessile. Assume that the sampling device has a 50% efficiency and that it can sample 1/3 of the area per unit effort.





Toy Example: Why spatial pattern of depletion tows matters.

True Population = 300
True Efficiency=0.5

MLE(1) N=595, Efficiency=0.06

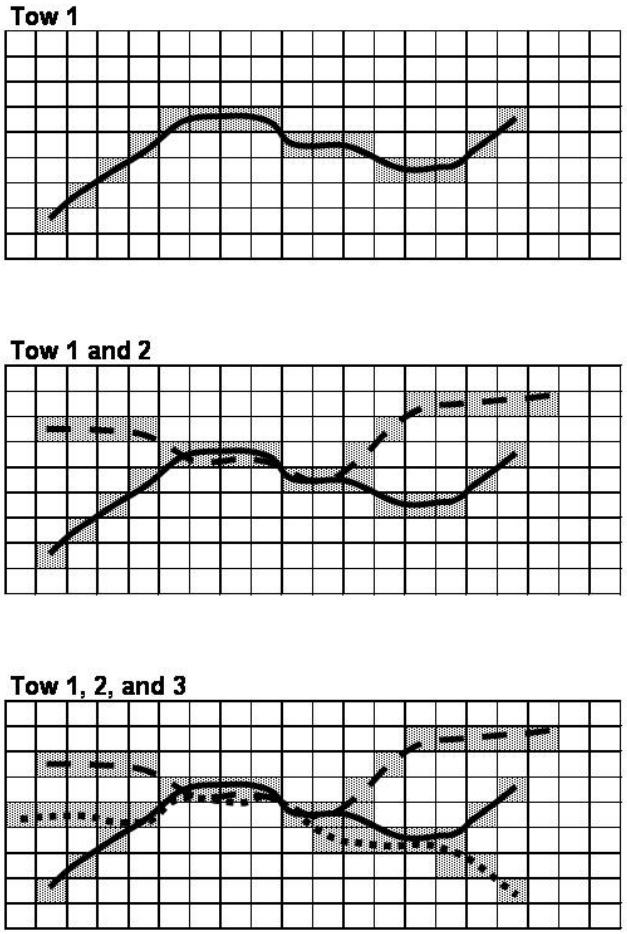
If the catch patterns are incorrectly assumed to be the result of random variability, then MLE estimates are biased.

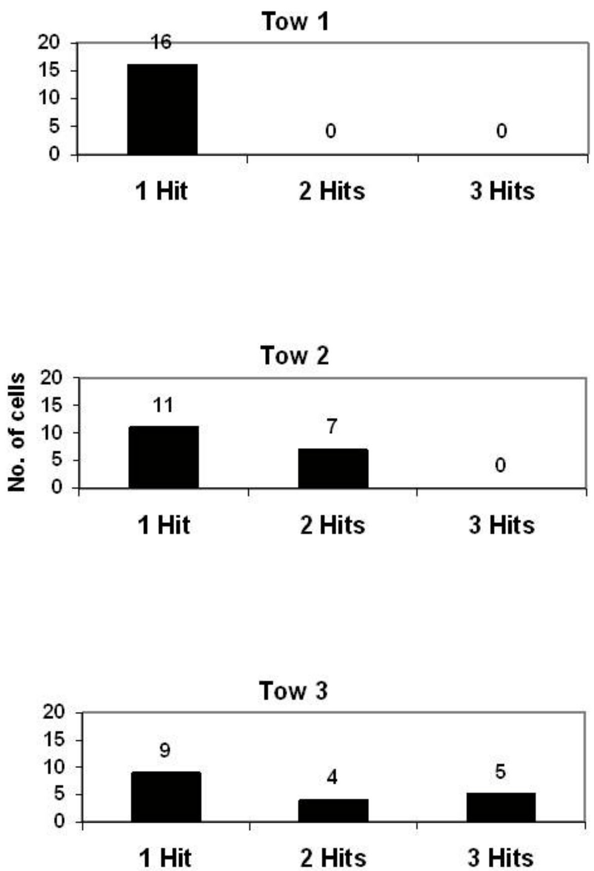
MLE(2) N=312 Efficiency=0.18

Pooling of samples can work *IF* you know how to aggregate the tows.

MLE(3) N=300 Efficiency=0.50

Consider a spatial pattern where the precision of sampling cannot be controlled but it is possible to "know" where the gear is, after the sample is taken. Clearly, the expected catch is a function of the amount of overlap between successive tows.





To solve the problem, it is necessary to recast the depletion problem in terms of density per unit area, AND to consider a sample as a string of quadrats or patches.

N_0	$D_0 = N_0/A$
$N_1 = N_0 - C_1$ $= N_0 - e\,(a/A)N_0$ $= N_0\,(1 - e\,(a/A))$	$D_1 = N_1/A$ $= (N_0/A)\,(1\text{-}e\,(a/A))$
$N_2 = N_1 - C_2$ $= N_0(1\text{-}e(a/A)) - e\,(a/A)N_0\,(1\text{-}e(a/A))$ $= N_0\,(1\text{-}e(a/A))\,(1\text{-}e(a/A))$ $= N_0\,(1\text{-}e(a/A))^2$	$D_2 = N_2/A$ $= (N_0/A)\,(1\text{-}e\,(a/A))^2$ $= D_0\,(1\text{-}e\,(a/A))^2$
$N_3 = N_2 - C_3$ $= N_0\,(1\text{-}e(a/A))^2 - e\,(a/A)N_0\,(1\text{-}e\,(a/A))^2$ $= N_0\,(1\text{-}e(a/A))^2\,(1\text{-}e(a/A))$ $= N_0\,(1\text{-}e(a/A))^3$	$D_3 = N_3/A$ $= (N_0/A)\,(1\text{-}e\,(a/A))^3$ $= D_0\,(1\text{-}e\,(a/A))^3$

The expected catch as a function of patch density.

- Via the miracle of recursive pluggation

(3) $$E(C_j) = e\,a\,D_o\left(1 - e\left(\frac{a}{A}\right)\right)^{j-1}$$

- Now we need to extend this concept to a tow where a tow consists of a set of contiguous patches linked together. Record the number of times that a tow "hits" a particular patch. The first tow will consist of a set of quadrats with one hit each. The second tow, if it exactly overlaps the first, will consist of a set of quadrats with two hits each. Otherwise it will have a mix of 1 and 2 hit cells. The third tow can have some mix of 1, 2 or 3 hits. Etc. With some algebra you get

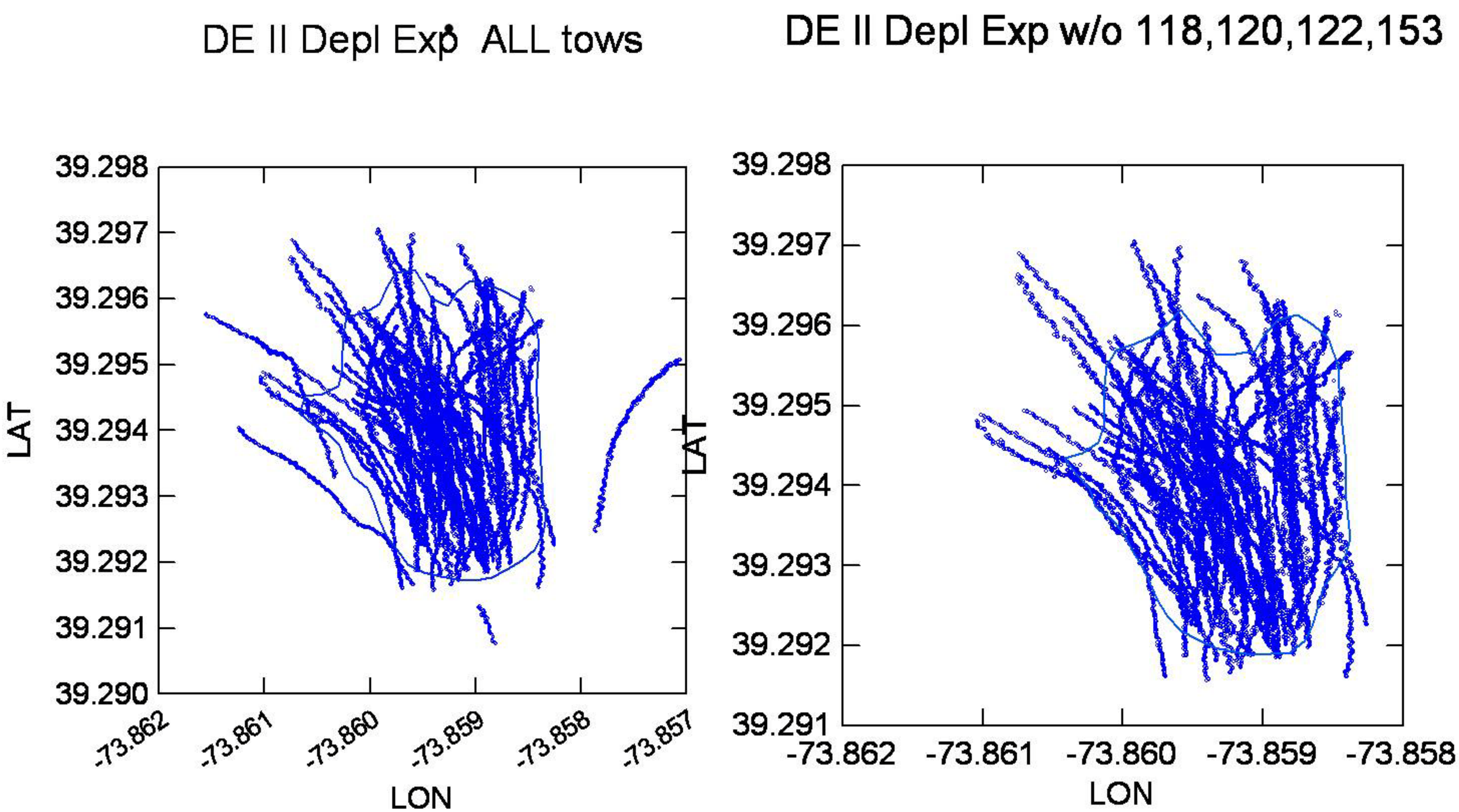
(4) $$E(C_i) = e\,a_i\,D_o \sum_{j=1}^{i} f_{i,j}\,(1 - e\gamma)^{j-1}$$

OK, where did the gamma come from and what is $f_{i,j}$?

(4) $$E(C_i) = e\,a_i\,D_o \sum_{j=1}^{i} f_{i,j} (1 - e\gamma)^{j-1}$$

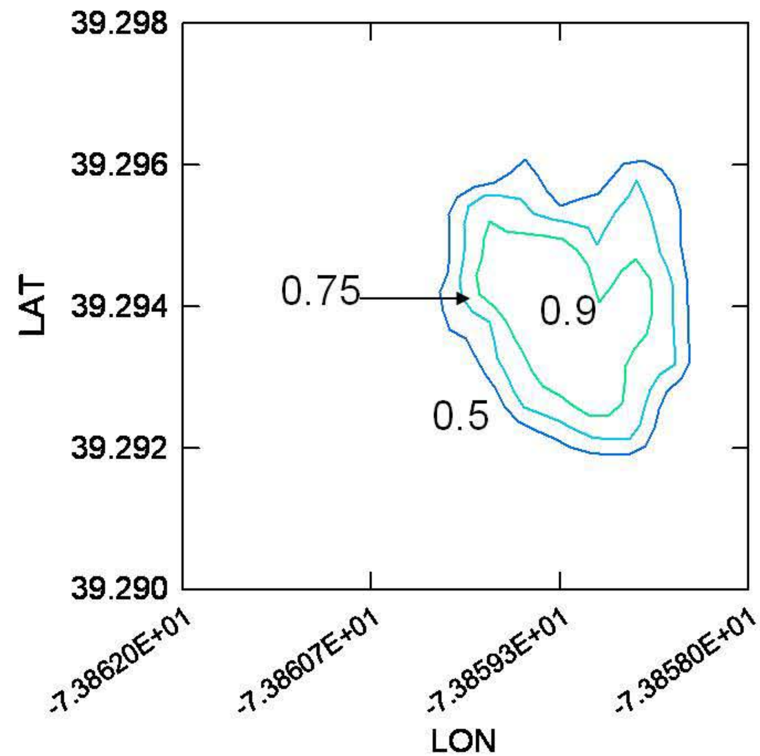
- $f_{i,j}$ is the fraction of a tow of swept area a_i that is hit j times
- Gamma is ratio of the sampling device width over the width of the patch. If the width of sampler is ½ the width of the cell, then gamma =0.5. Thus the patch size can increase in response to increasing uncertainty in the actual position of the sampling gear.
- Gamma can also be used to account for indirect effects of sampling which may occur in a variety of ways. More on this later.

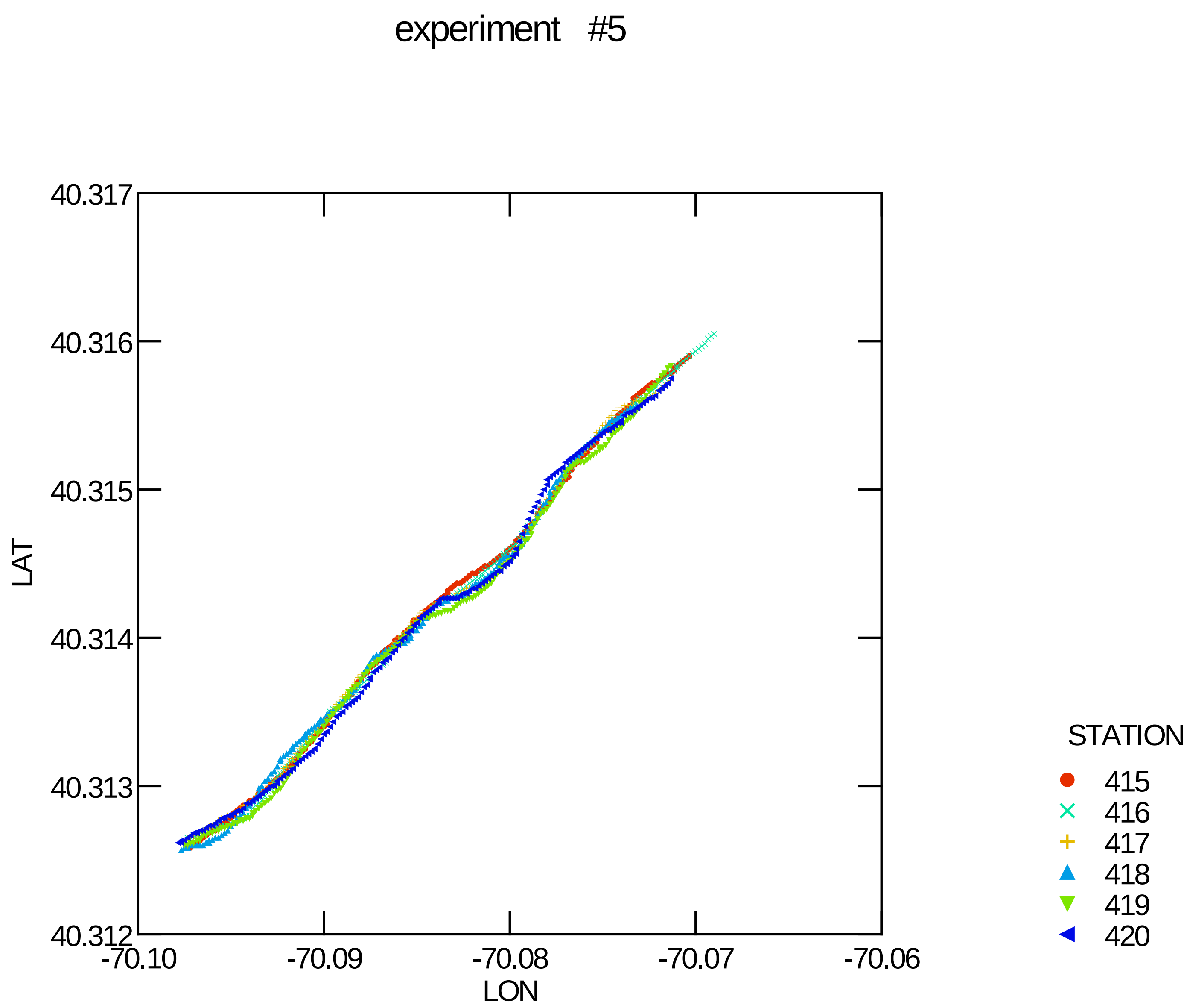
Deriving the expected catch for a set of randomly overlapping tows. A depletion experiment on DE II

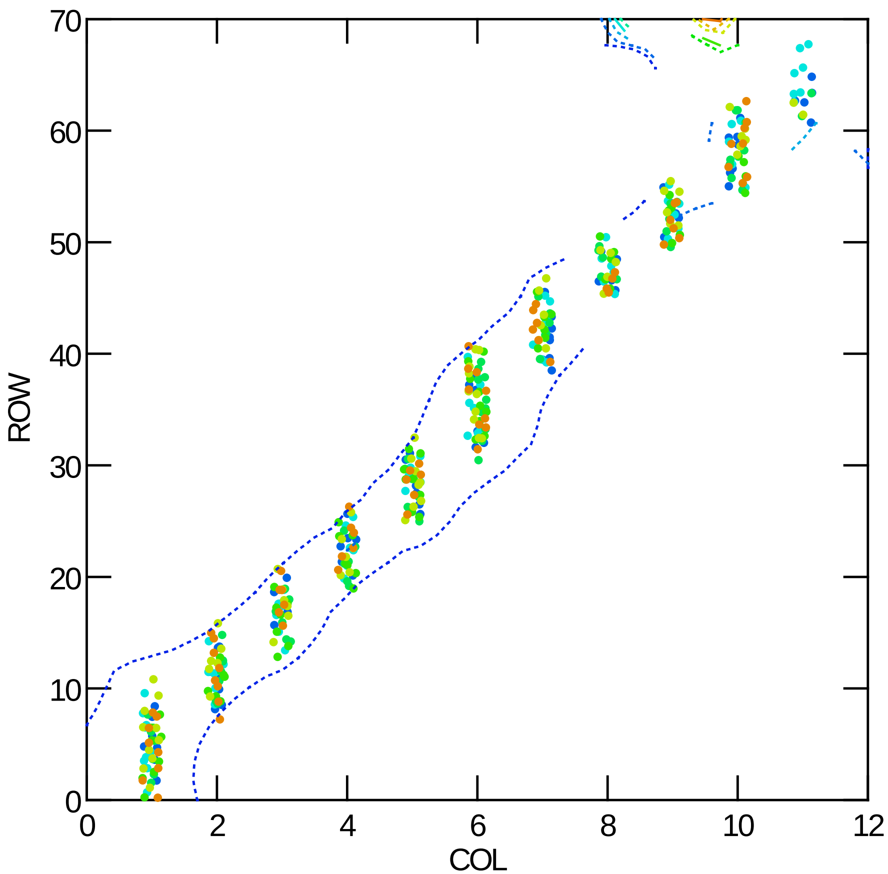


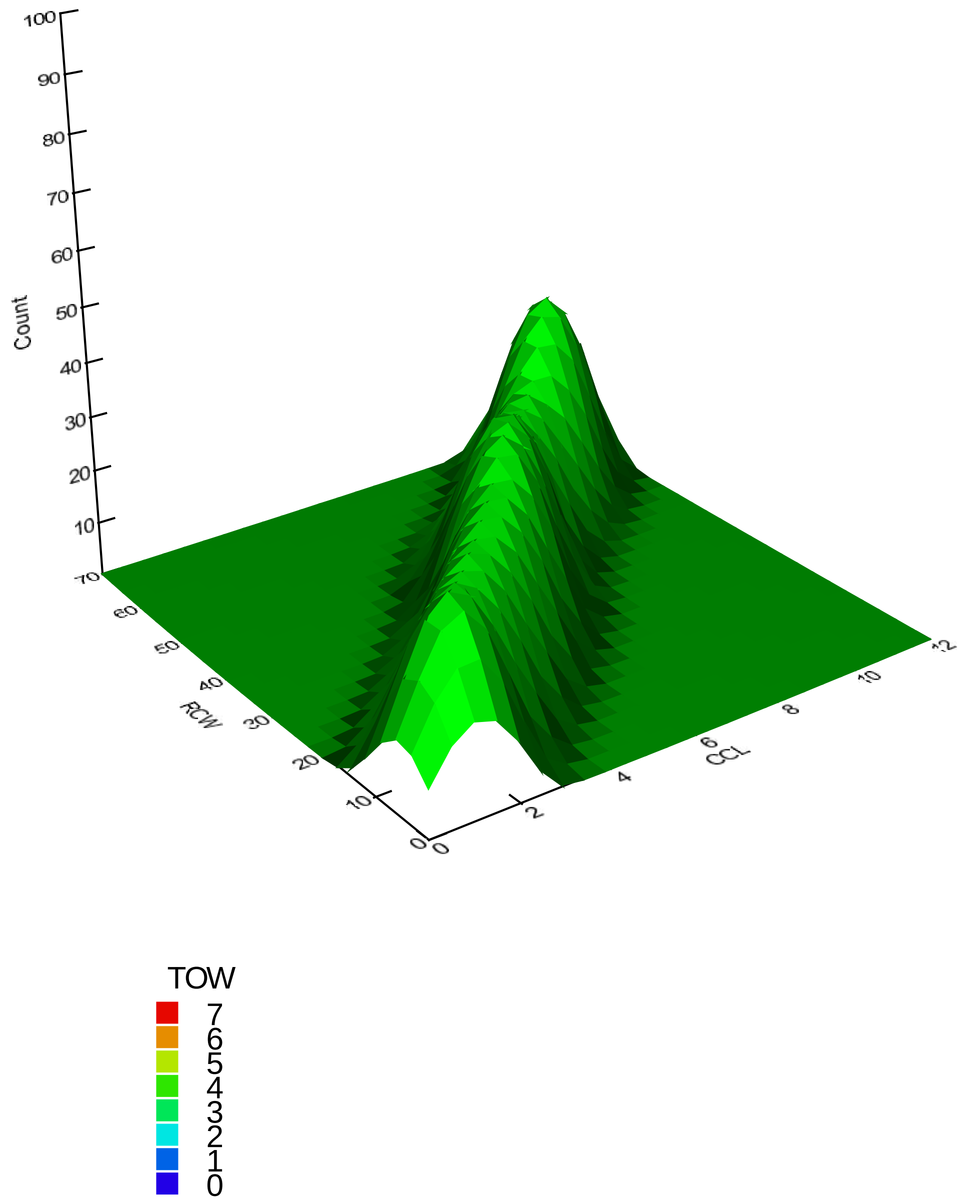
A kernel density can be used to illustrate to concentration of sampling intensity.

- DE II Depl Exp w/o 118,120,122,153

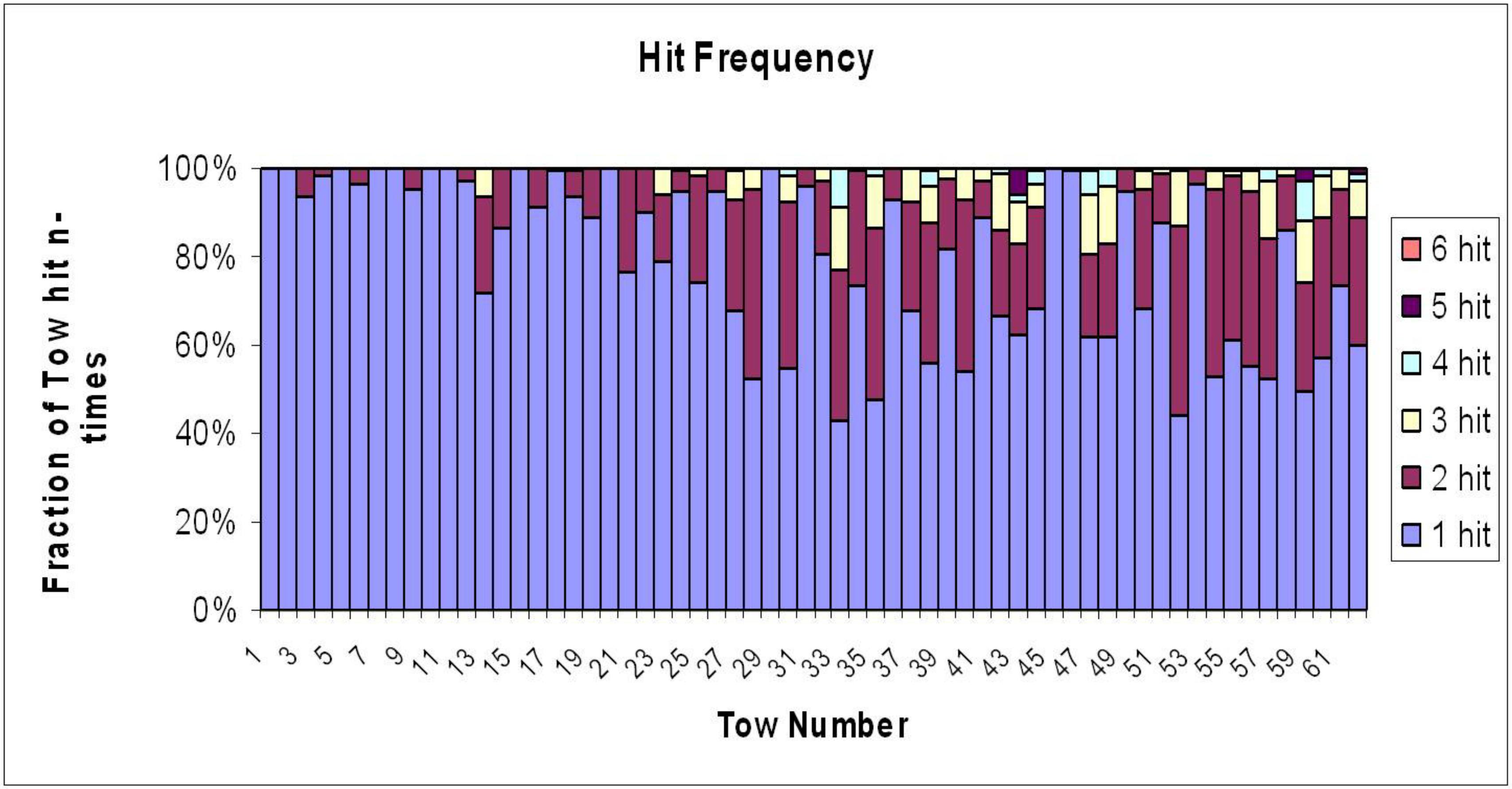


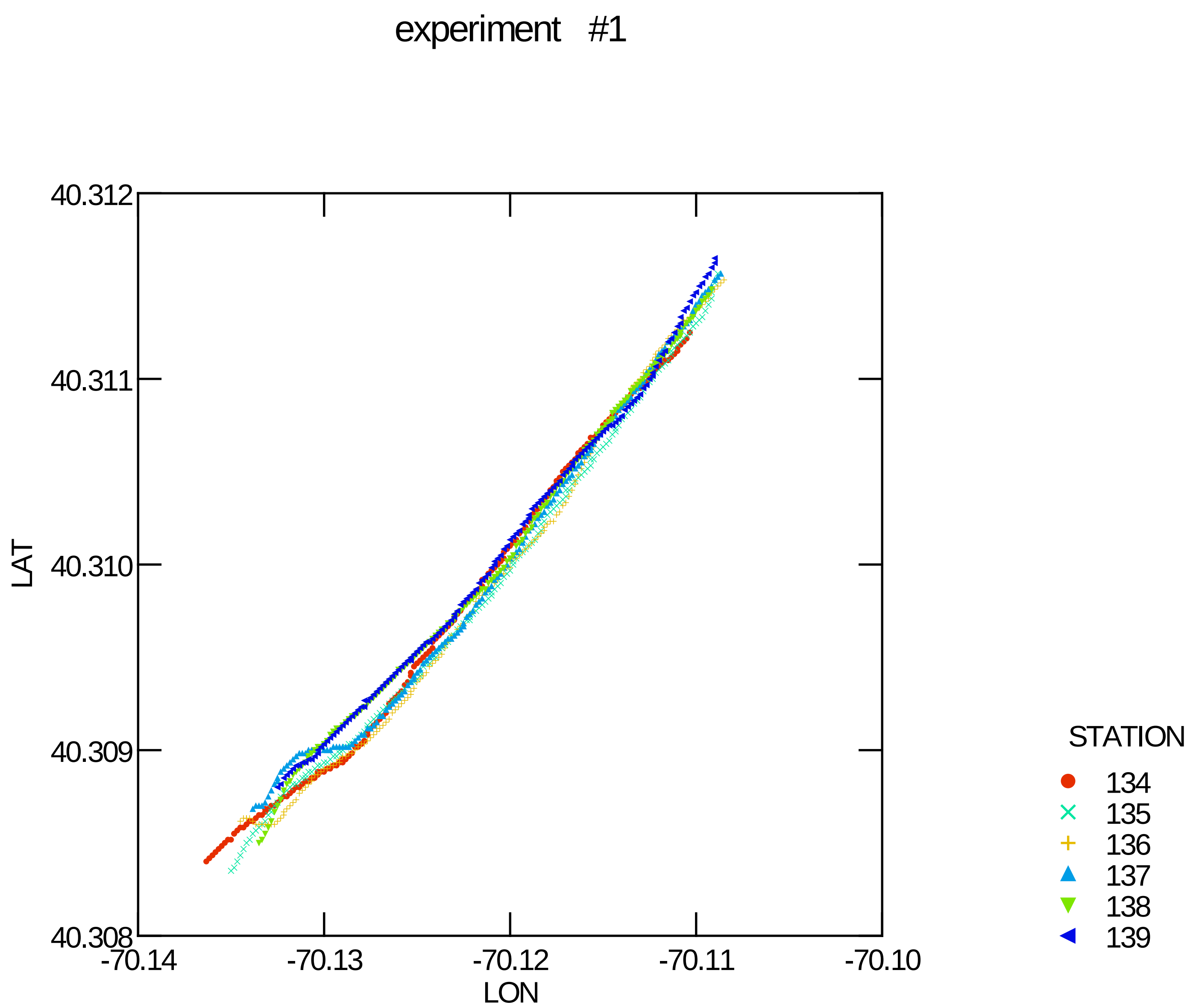

experiment #5
40.317
40.316
40.315
40.314
40.313
40.312
LAT
-70.10
-70.09
-70.08
-70.07
-70.06
LON
STATION
415
416
417
418
419
420

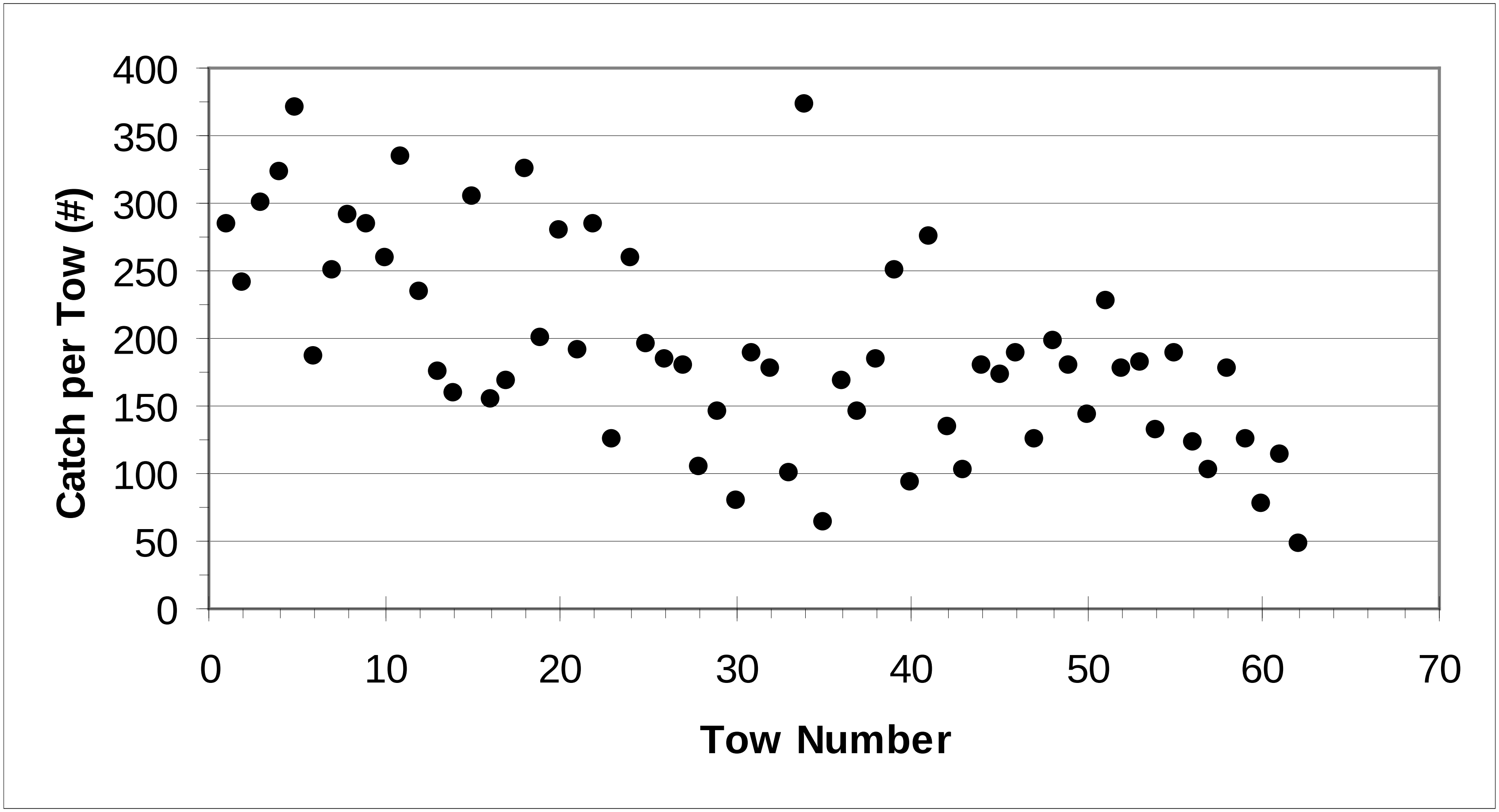

ROW
COL
0
10
20
30
40
50
60
70
0
2
4
6
8
10
12

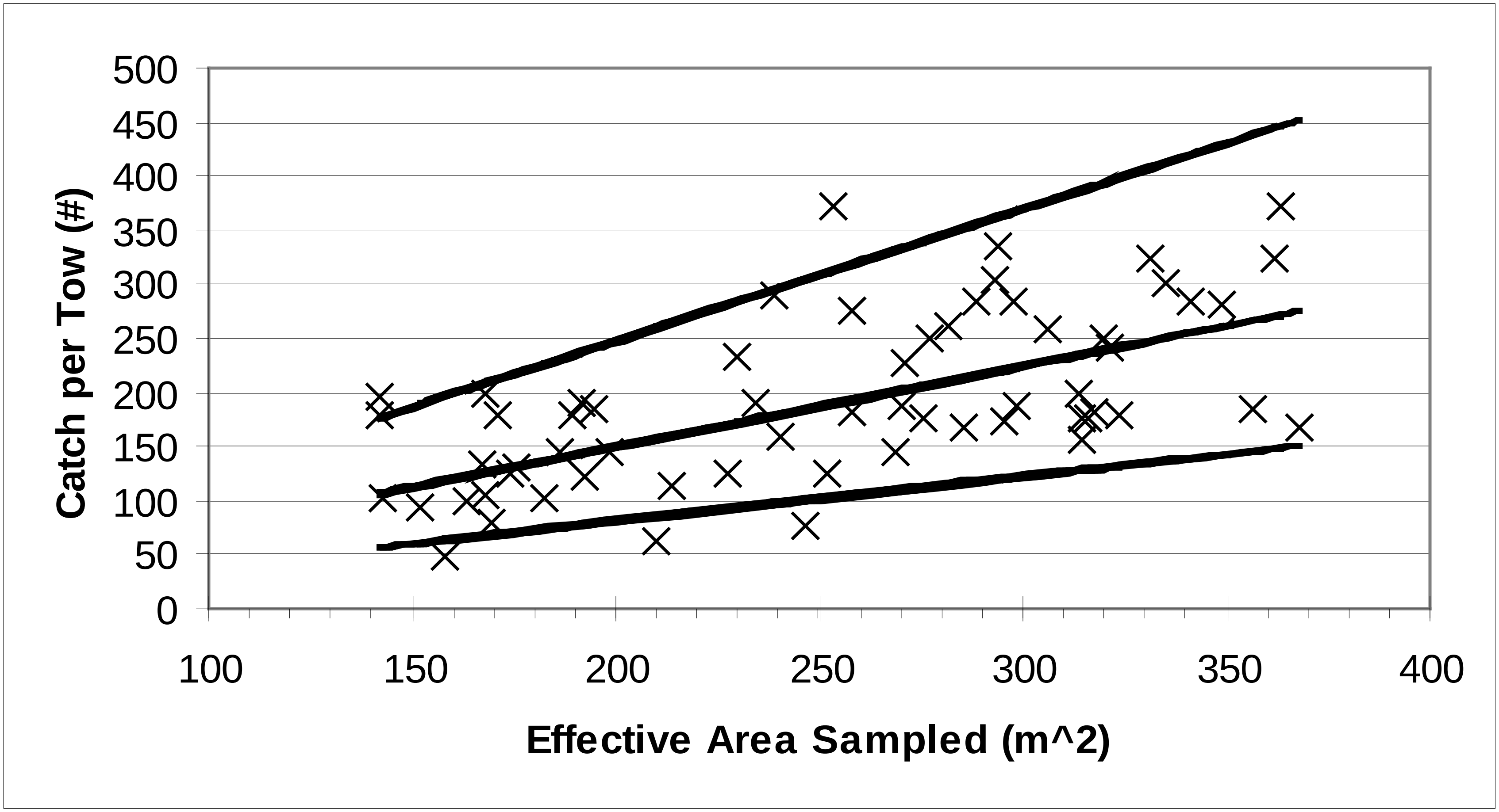

Count
100
90
80
70
60
50
40
30
20
10
0
ROW
CCL
TOW
7
6
5
4
3
2
1
0

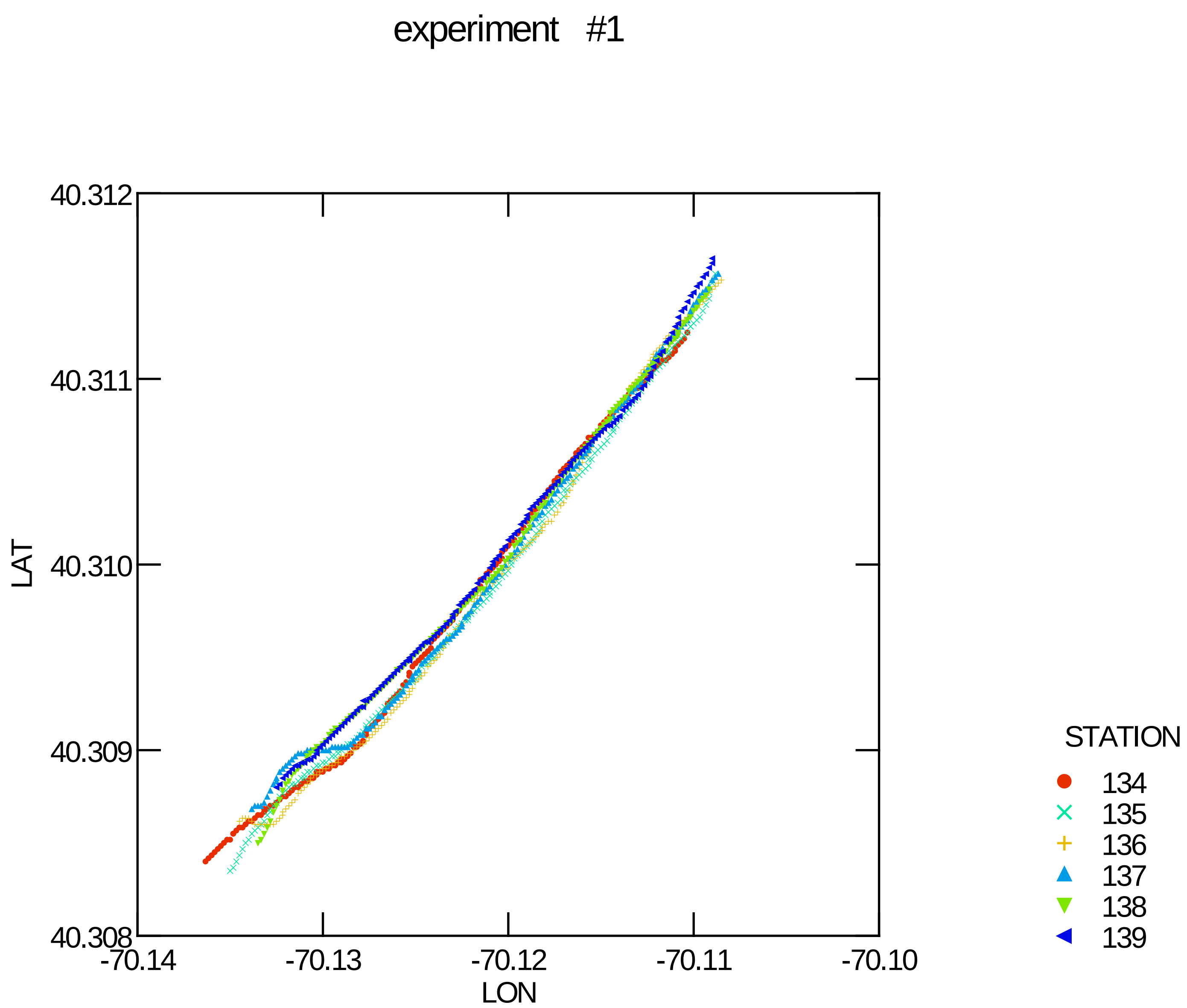
The hit frequency matrix for the Delaware II depletion experiment



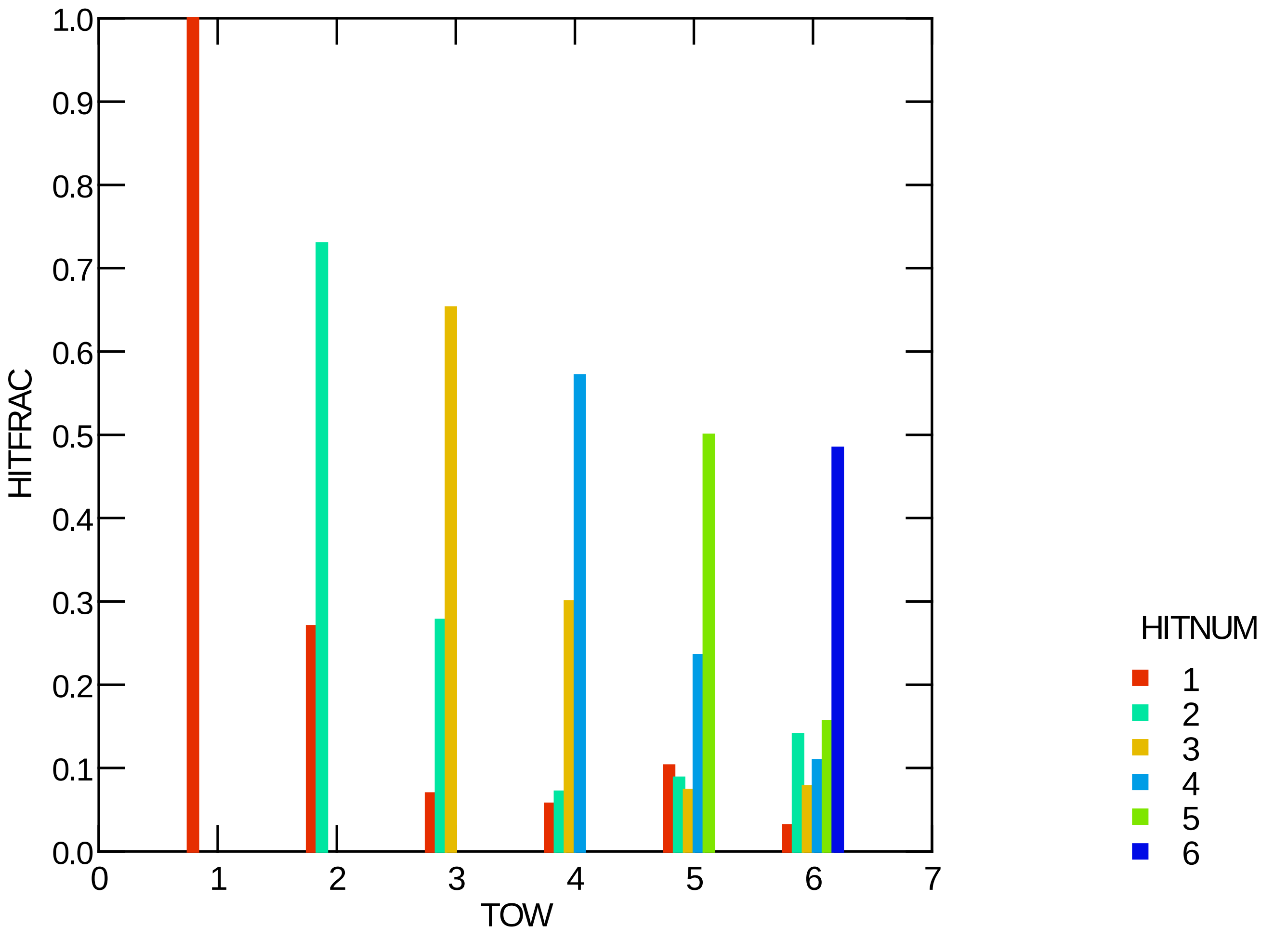

experiment #1
40.312
40.311
40.310
40.309
40.308
LAT
-70.14
-70.13
-70.12
-70.11
-70.10
LON
STATION
134
135
136
137
138
139


Catch per Tow (#)
400
350
300
250
200
150
100
50
0
0
10
20
30
40
50
60
70
Tow Number

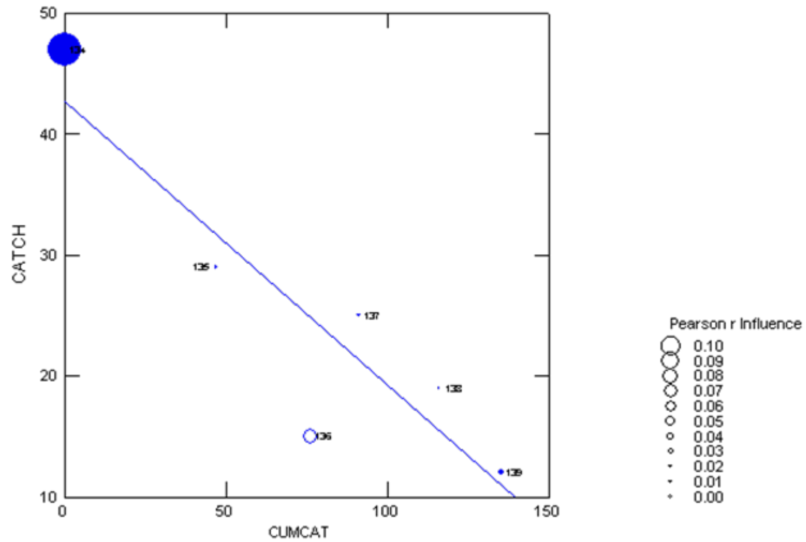

Catch per Tow (#)
500
450
400
350
300
250
200
150
100
50
0
100
150
200
250
300
350
400
Effective Area Sampled (m^2)


experiment #1
40.312
40.311
40.310
40.309
40.308
LAT
-70.14
-70.13
-70.12
-70.11
-70.10
LON
STATION
134
135
136
137
138
139

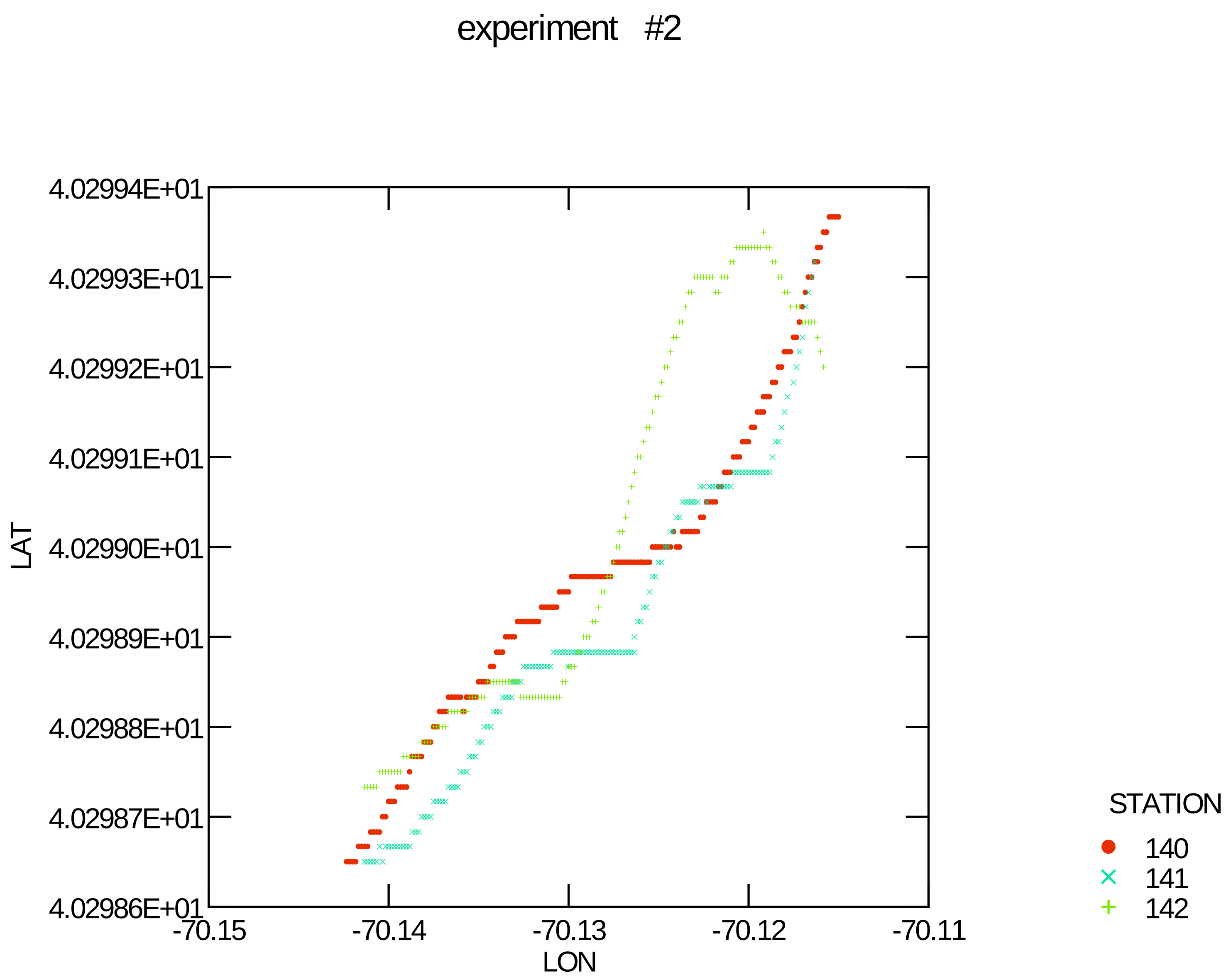
Experiment #1



Experiment #1

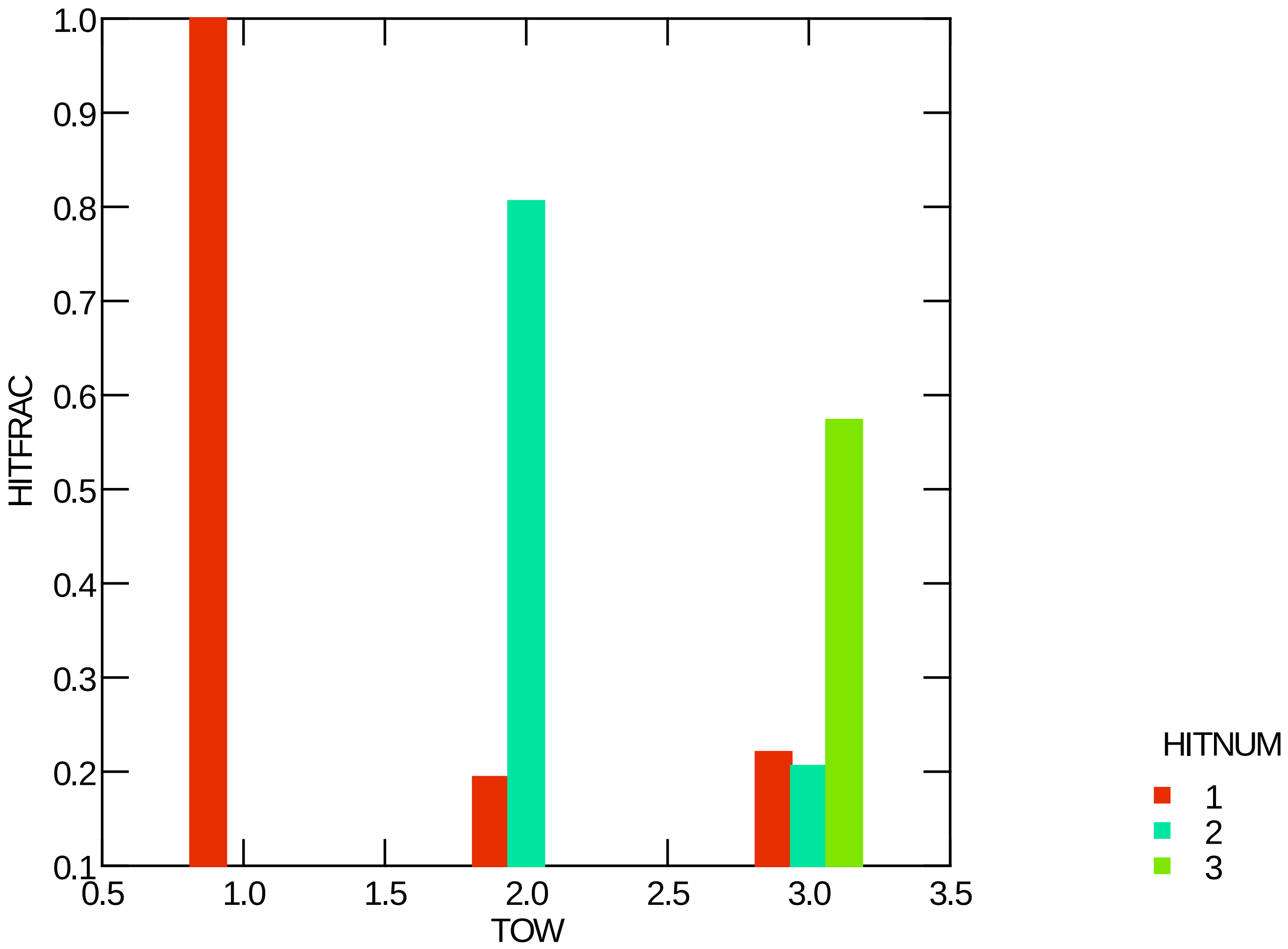


Tow	Area Swept	Efftv Area	C_5%	C_50%	C_pred	OBS	C_95%
CI 1	566598.0	194434.7	29.	41.	41.	47.	56.
CI 2	572557.0	157118.4	23.	34.	33.	29.	46.
CI 3	569490.0	120094.9	17.	26.	25.	15.	36.
CI 4	545629.0	90817.8	12.	20.	19.	25.	29.
CI 5	525474.0	78258.5	10.	17.	16.	19.	25.
CI 6	509265.0	62348.7	8.	14.	13.	12.	21.

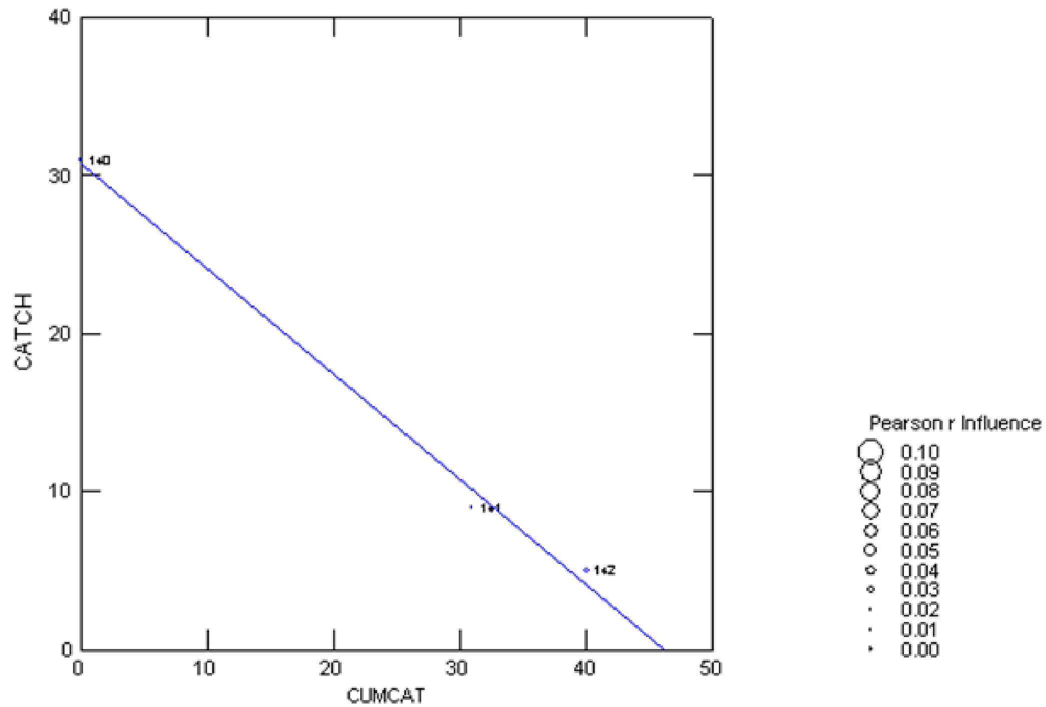


experiment #2
LAT
4.02994E+01
4.02993E+01
4.02992E+01
4.02991E+01
4.02990E+01
4.02989E+01
4.02988E+01
4.02987E+01
4.02986E+01
-70.15
-70.14
-70.13
-70.12
-70.11
LON
STATION
140
141
142

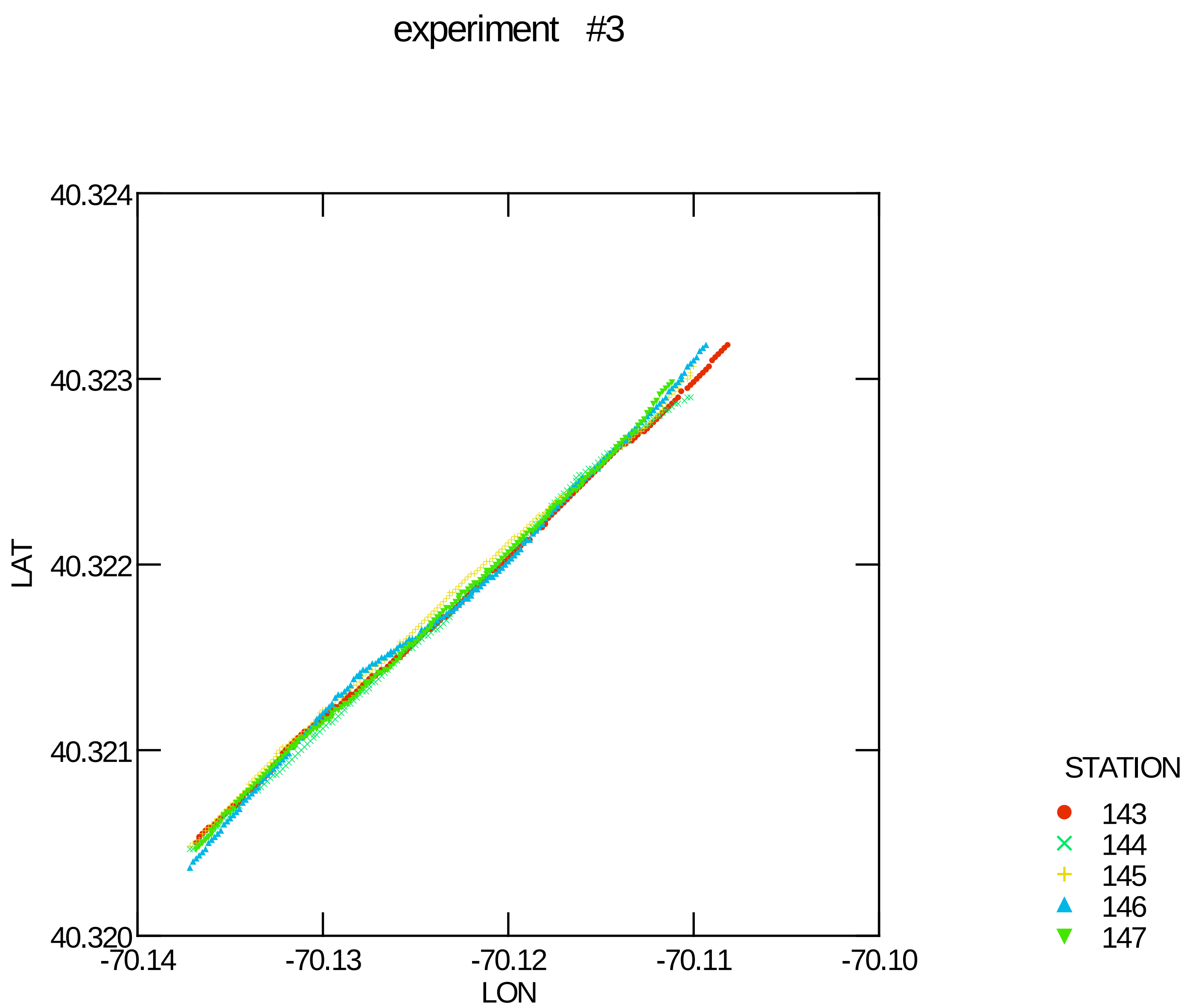
Experiment #2

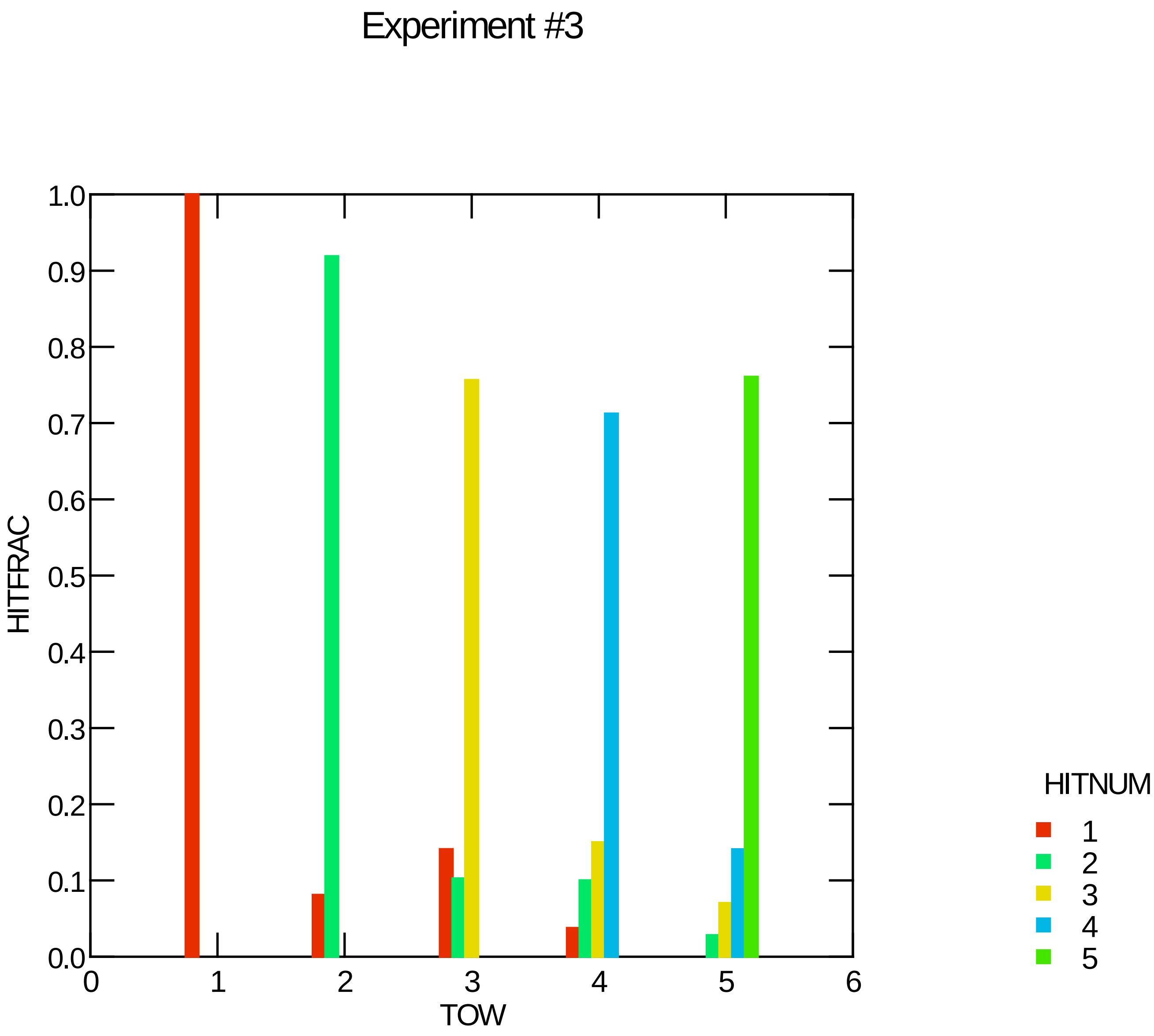


Experiment #2

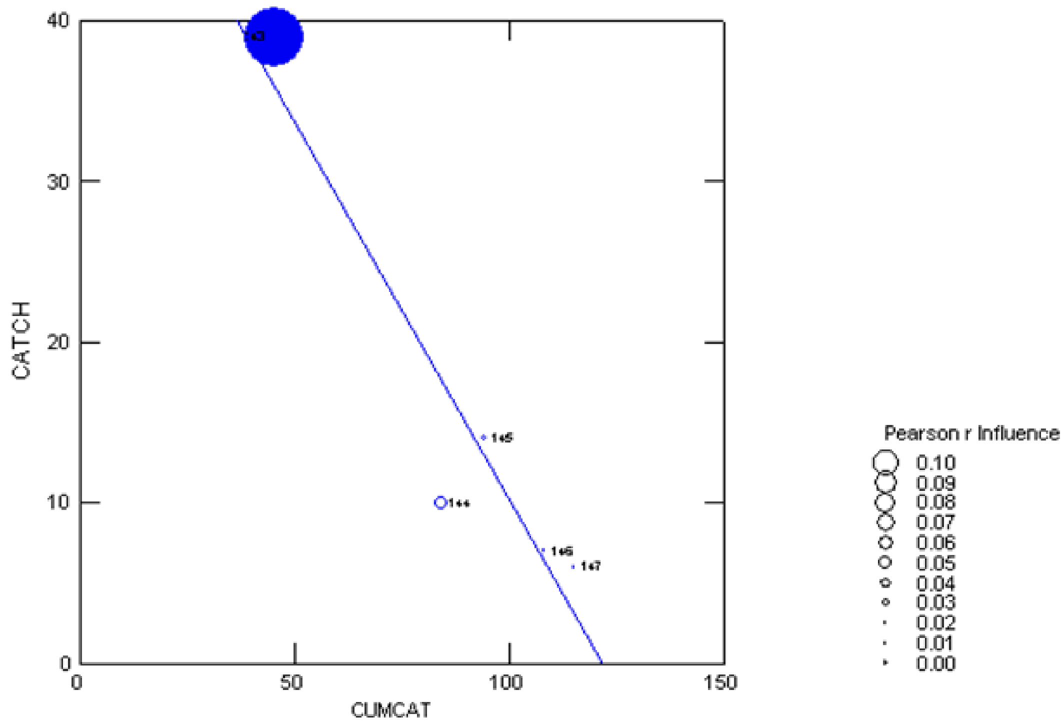


Tow	Area Swept	Efftv Area	C_5%	C_50%	C_pred	OBS	C_95%
CI 1	590158.0	560650.0	20.	28.	28.	31.	38.
CI 2	533897.0	196483.1	6.	10.	10.	9.	16.
CI 3	545551.0	157031.4	4.	9.	8.	5.	14.

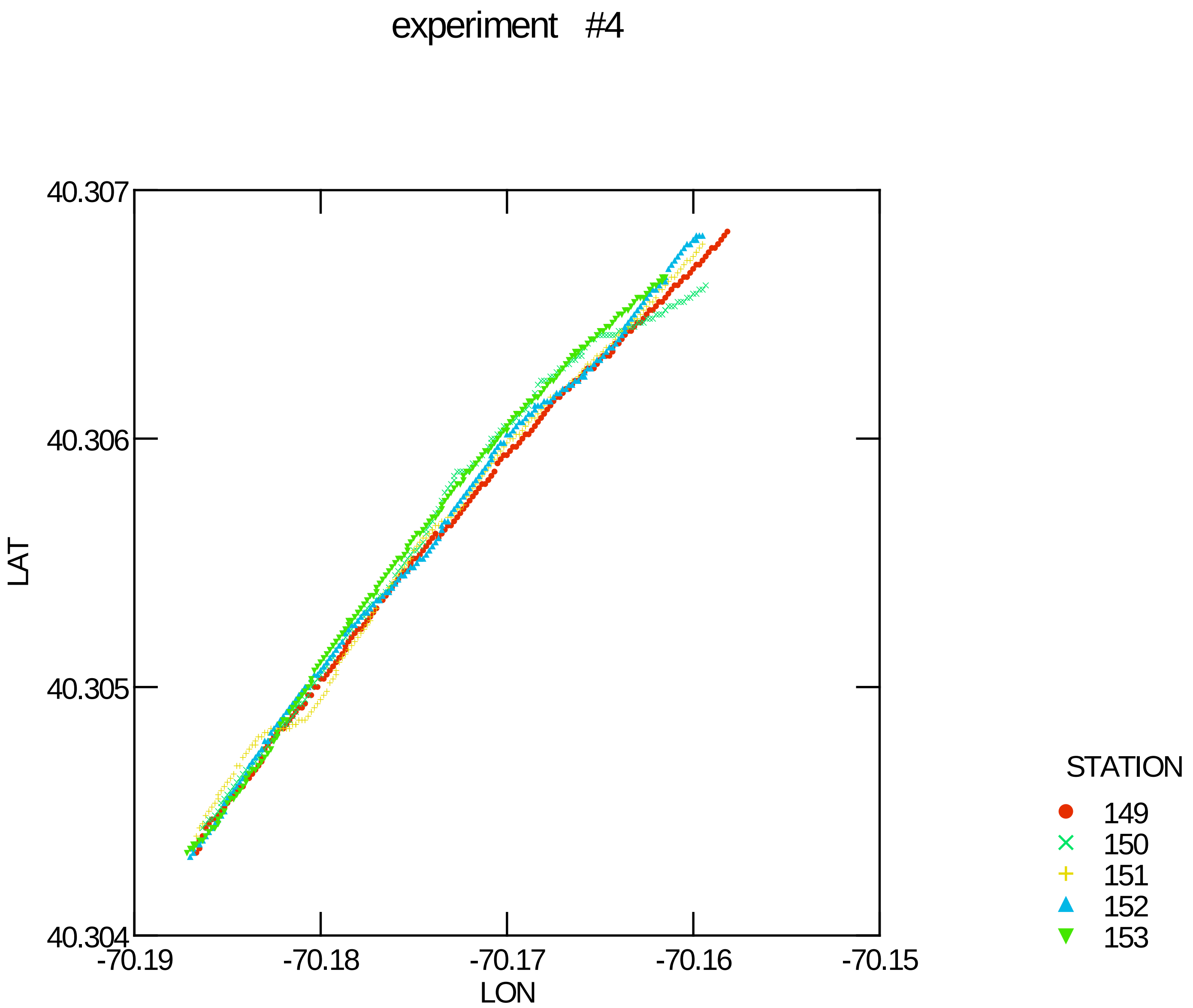

experiment #3
40.324
40.323
40.322
40.321
40.320
LAT
-70.14
-70.13
-70.12
-70.11
-70.10
LON
STATION
143
144
145
146
147


Experiment #3
HITFRAC
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
1
2
3
4
5
6
TOW
HITNUM
1
2
3
4
5

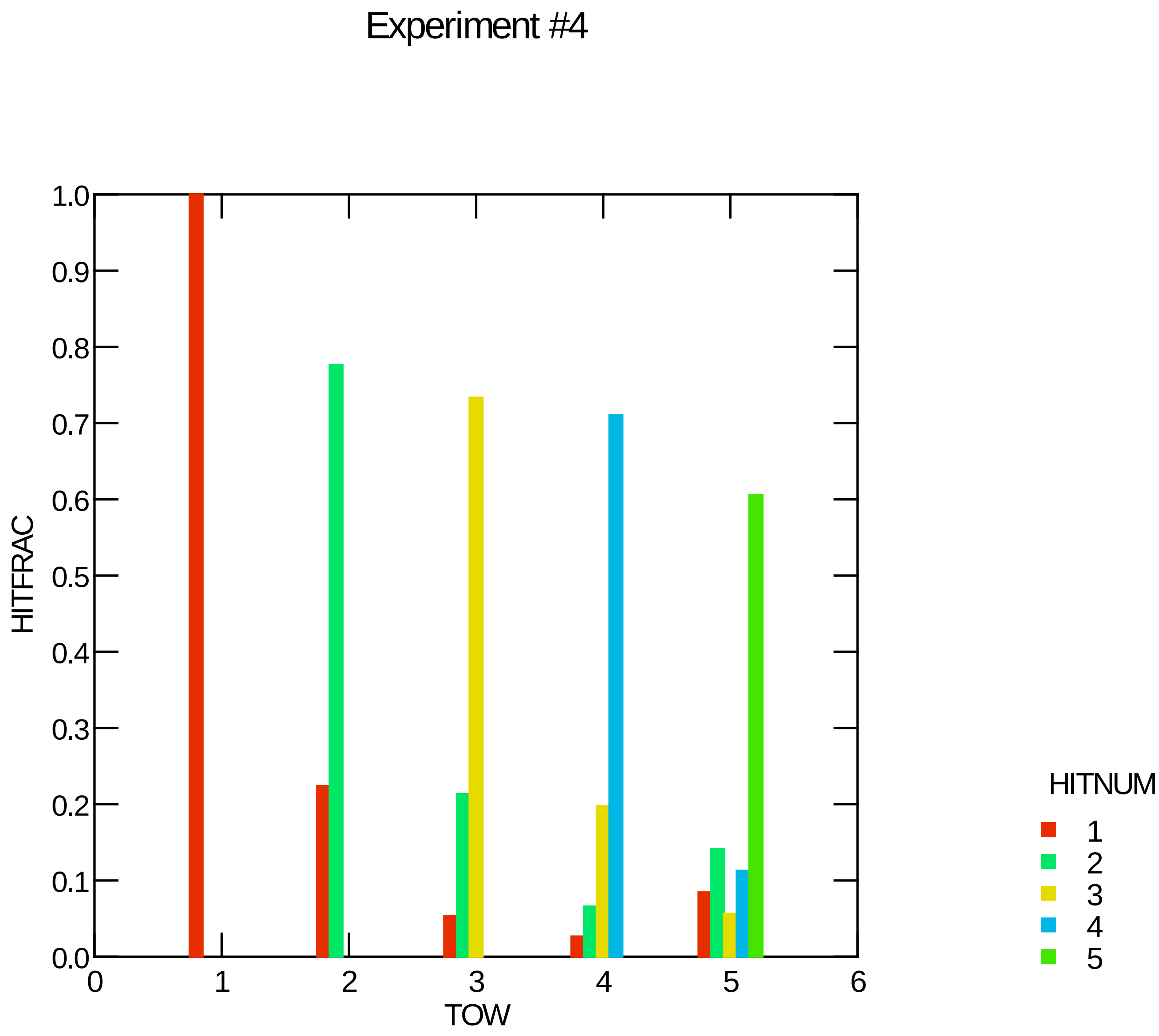
Experiment #3



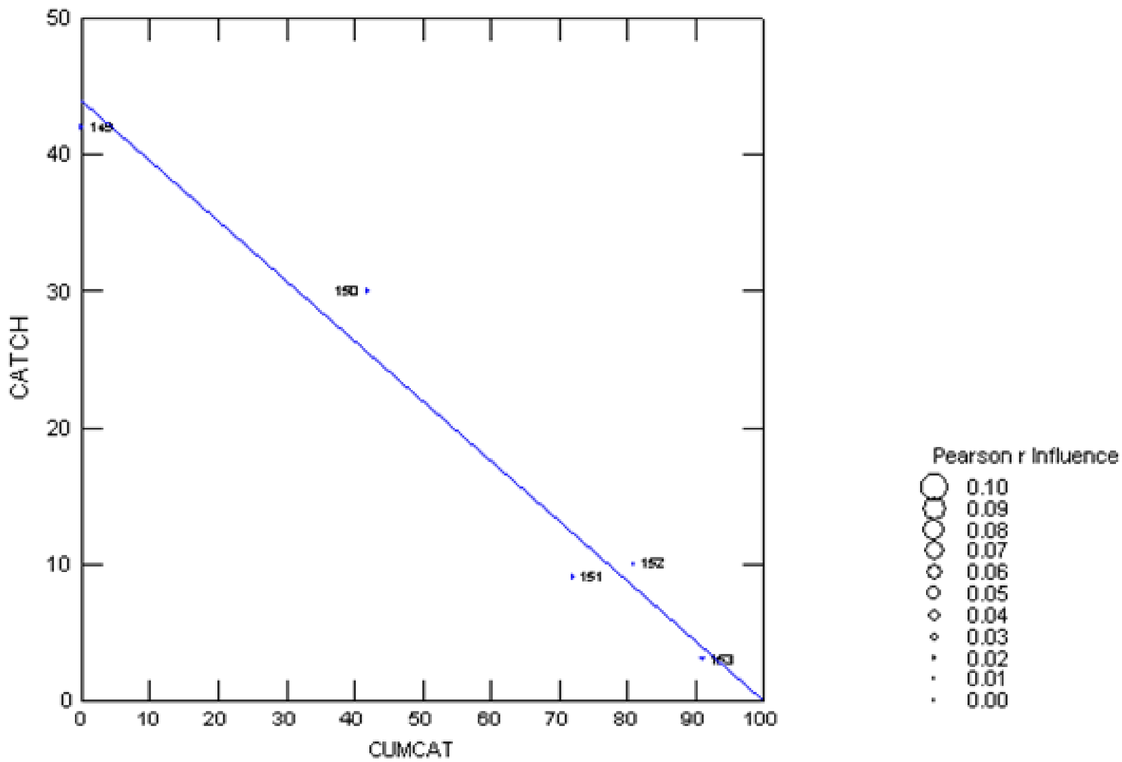
	Tow	Area Swept	Efftv Area	C_5%	C_50%	C_pred	OBS	C_95%
CI	1	634514.0	346094.2	21.	32.	32.	39.	46.
CI	2	590274.0	192848.7	11.	18.	18.	10.	28.
CI	3	597123.0	143012.4	8.	14.	13.	14.	22.
CI	4	612709.0	89918.2	5.	9.	8.	7.	15.
CI	5	562786.0	43035.3	2.	5.	4.	6.	9.



experiment #4
40.307
40.306
40.305
40.304
LAT
-70.19
-70.18
-70.17
-70.16
-70.15
LON
STATION
149
150
151
152
153

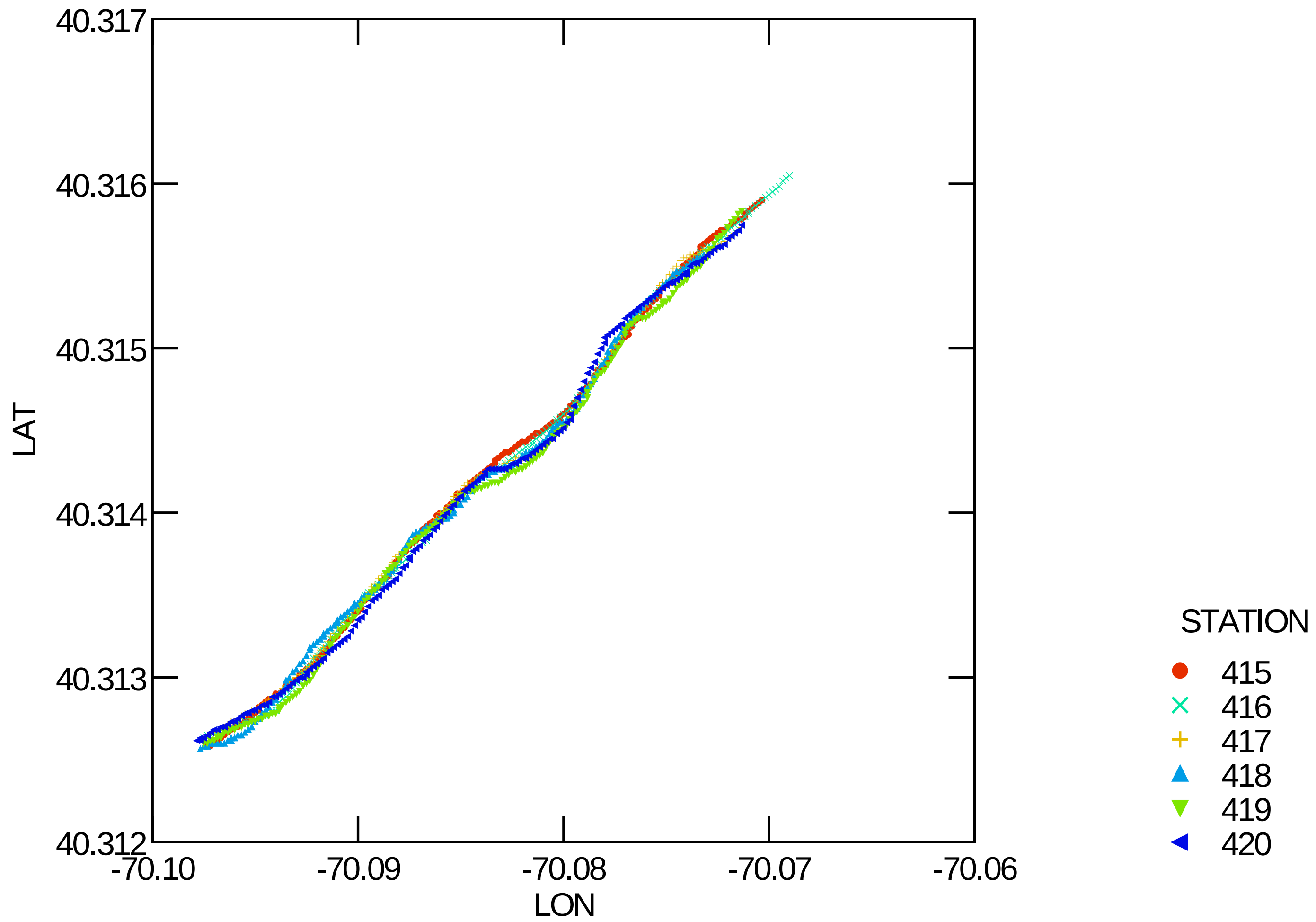

Experiment #4
HITFRAC
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
1
2
3
4
5
6
TOW
HITNUM
1
2
3
4
5

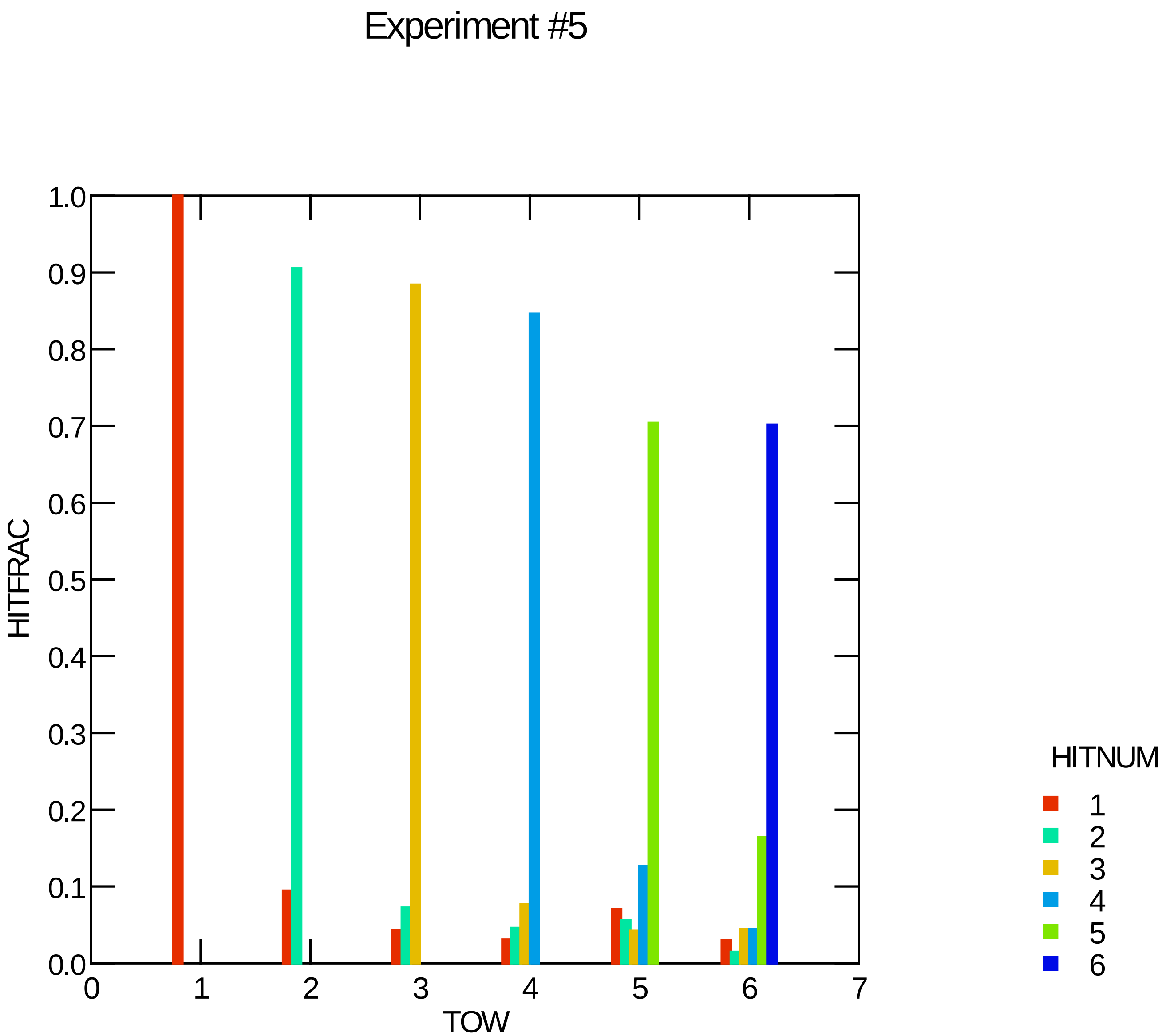
Experiment #4



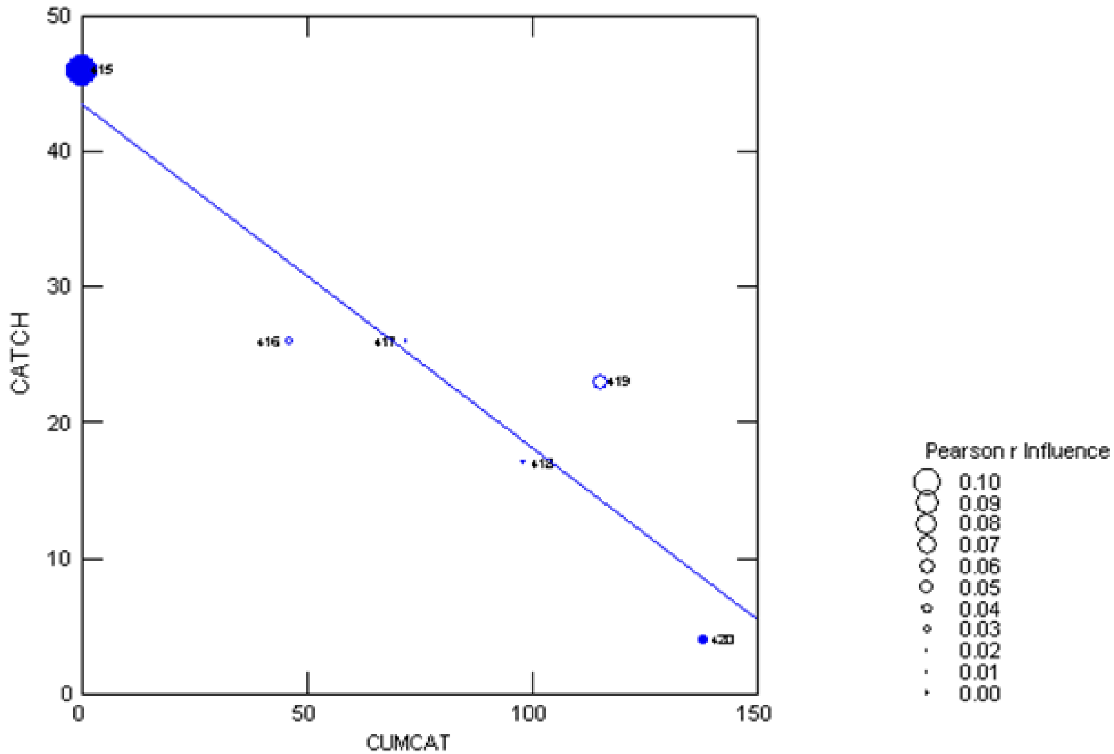
Tow	Area Swept	Efftv Area	C_5%	C_50%	C_pred	OBS	C_95%
CI 1	623017.0	425046.3	34.	44.	43.	42.	56.
CI 2	586683.0	230645.1	17.	24.	24.	30.	33.
CI 3	592784.0	121917.5	8.	13.	12.	9.	20.
CI 4	603661.0	67315.5	4.	8.	7.	10.	12.
CI 5	561273.0	75208.0	4.	9.	8.	3.	14.

experiment #5

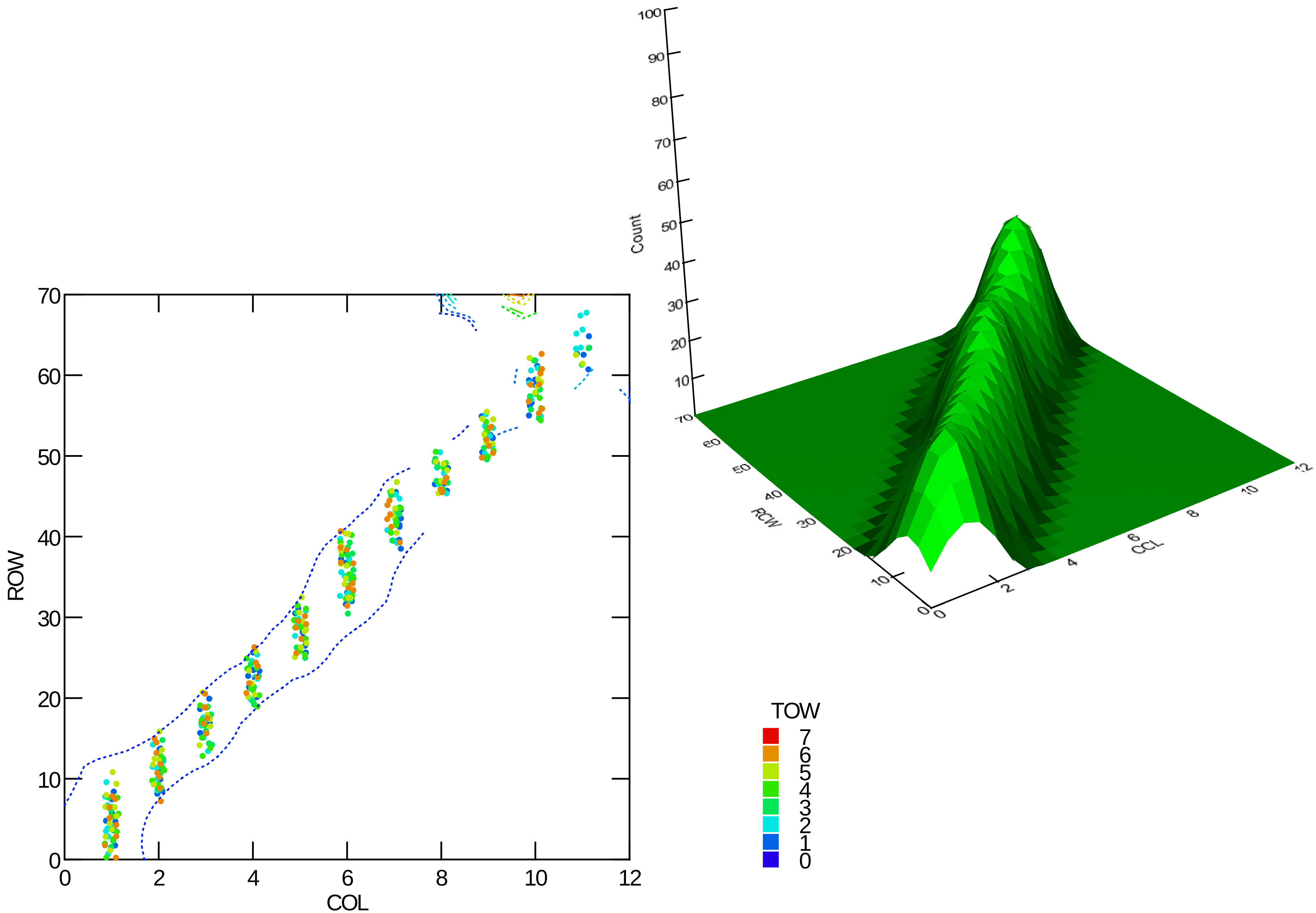



Experiment #5
HITFRAC
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
1
2
3
4
5
6
7
TOW
HITNUM
1
2
3
4
5
6

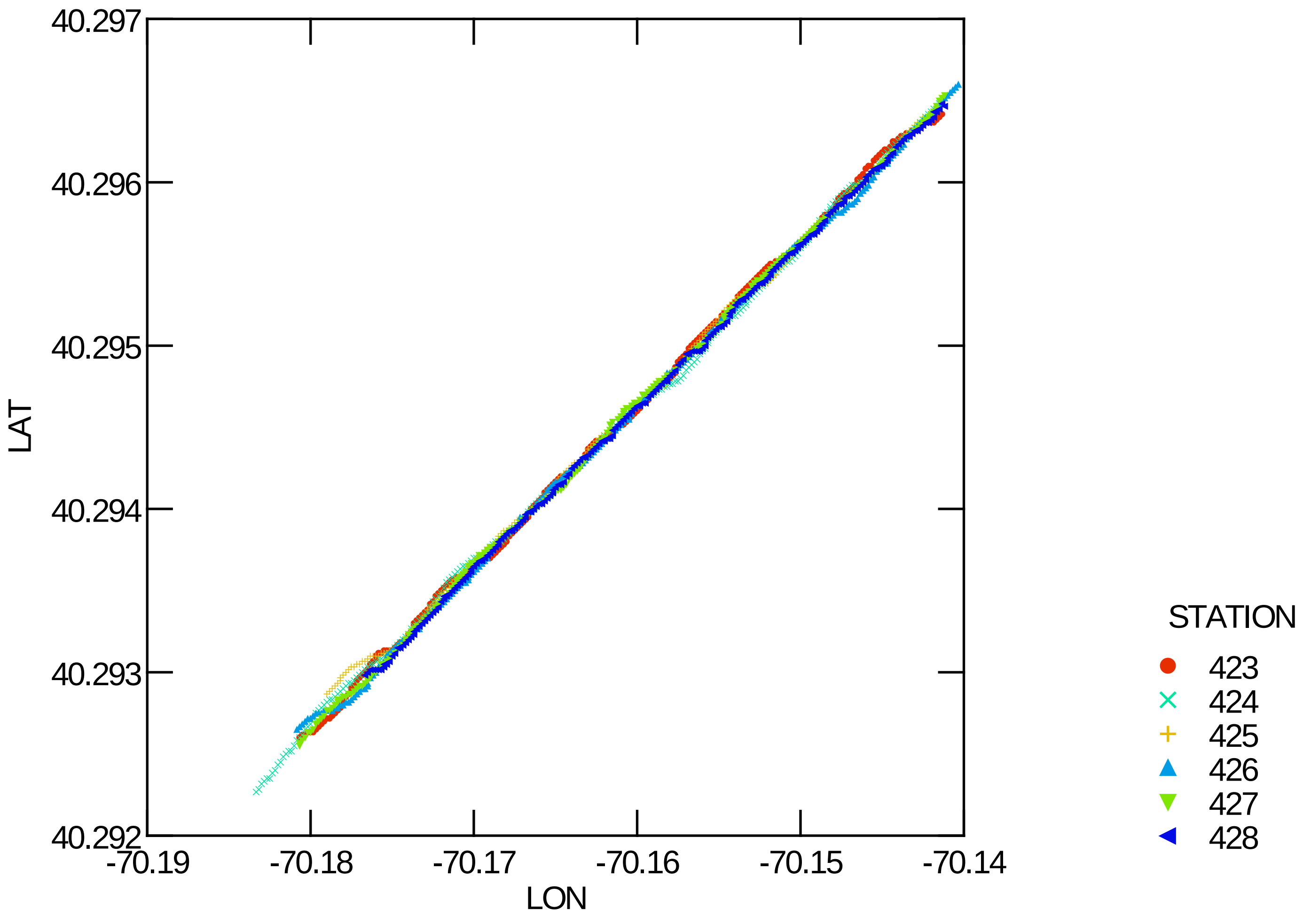
Experiment #5

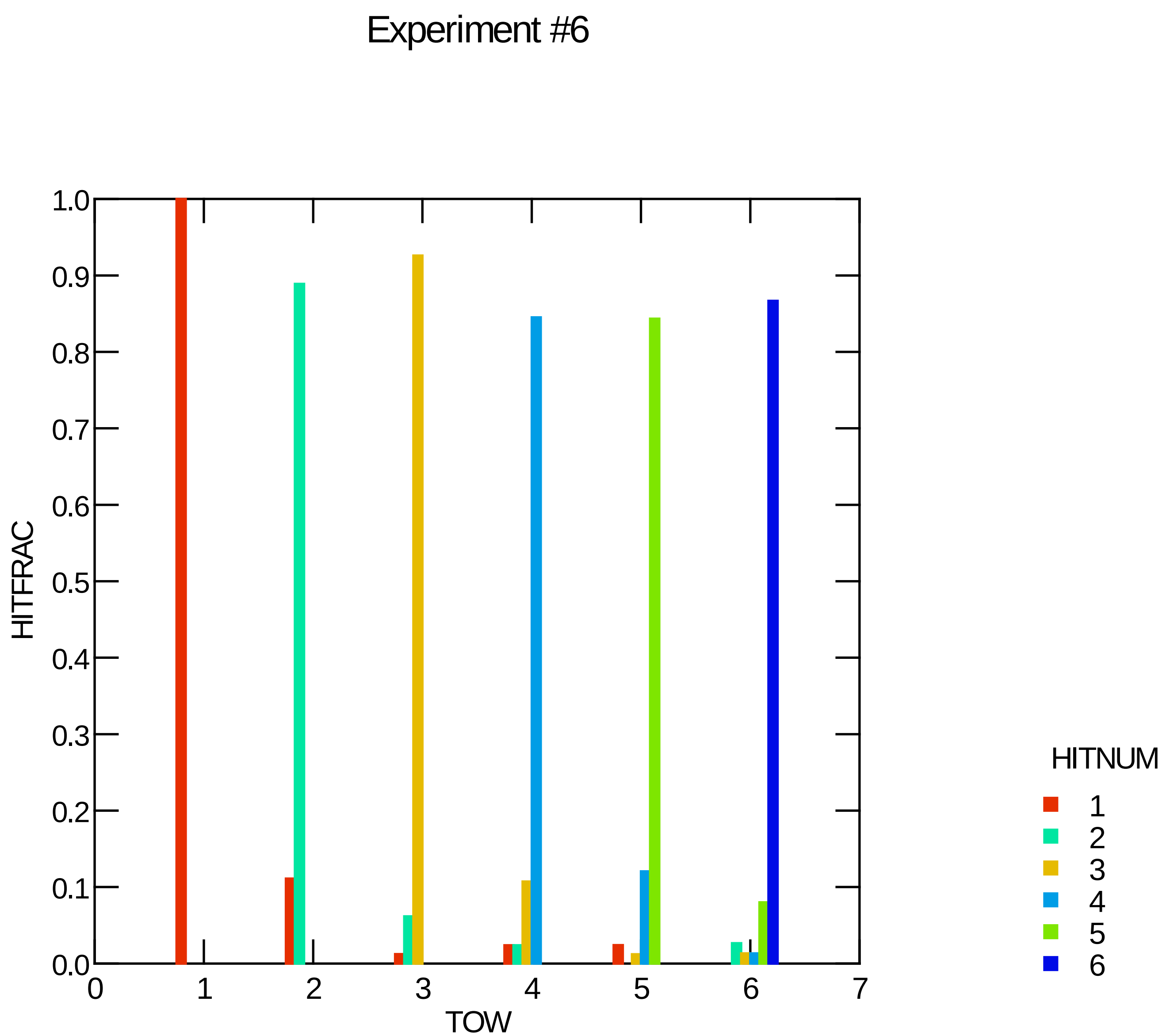


Tow	Area Swept	Efftv Area	C_5%	C_50%	C_pred	OBS	C_95%
CI 1	682690.0	261011.9	30.	46.	45.	46.	65.
CI 2	724422.0	200259.1	23.	35.	35.	26.	51.
CI 3	655756.0	130296.5	14.	23.	23.	26.	35.
CI 4	615450.0	90080.8	9.	16.	16.	17.	25.
CI 5	658380.0	84510.7	9.	15.	15.	23.	24.
CI 6	667457.0	58153.5	6.	11.	10.	4.	18.

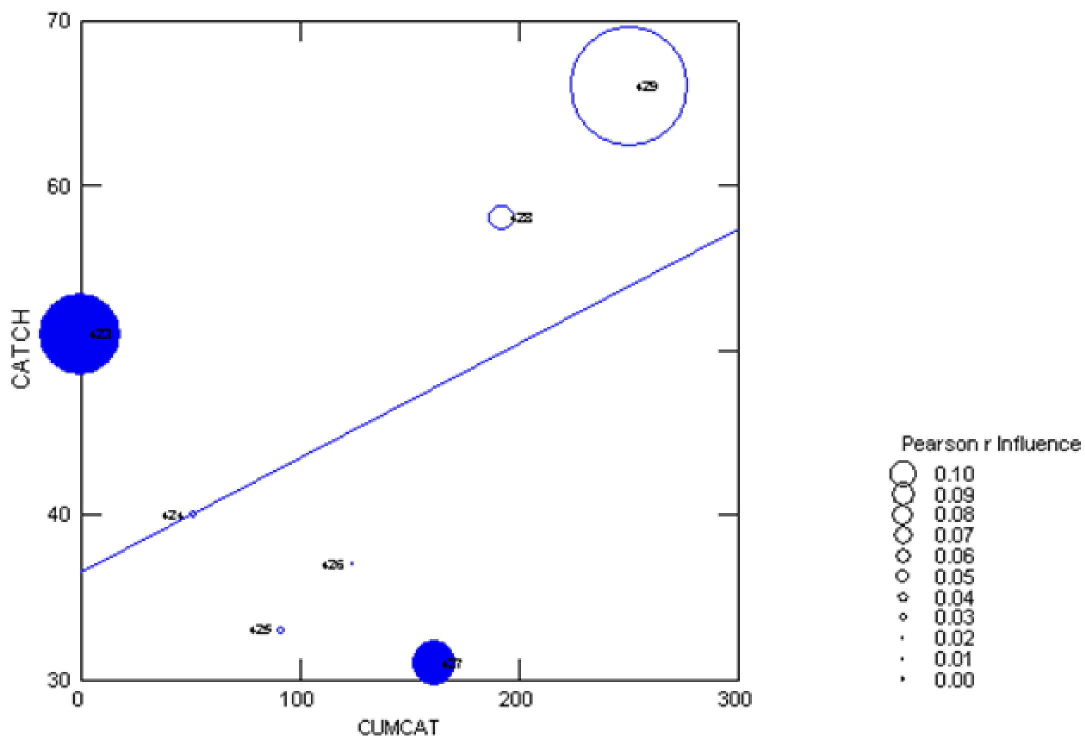

Count
100
90
80
70
60
50
40
30
20
10
70
60
50
40
30
20
10
0
ROW
0
2
4
6
8
10
12
COL
TOW
7
6
5
4
3
2
1
0

experiment #6

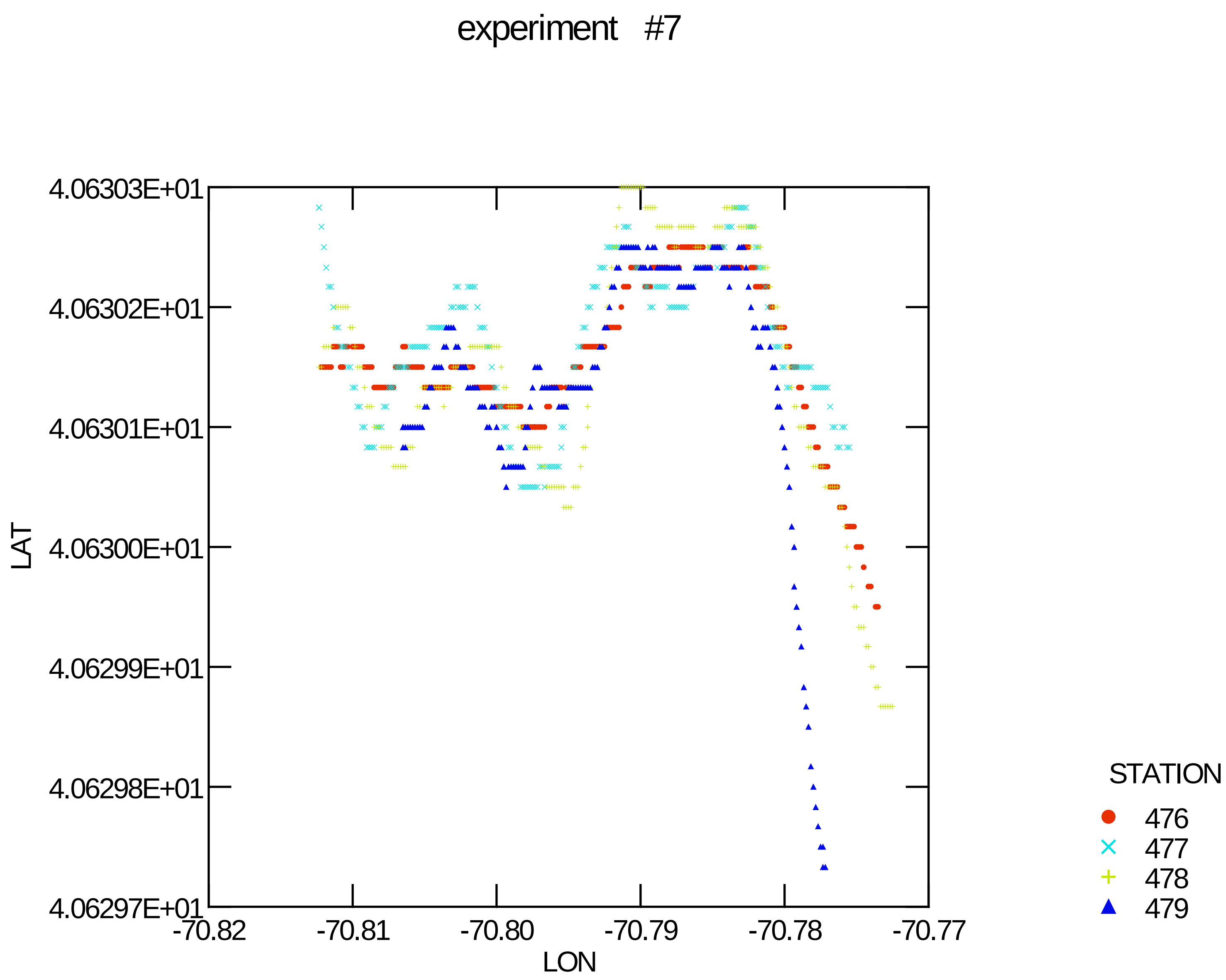



Experiment #6
HITFRAC
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
1
2
3
4
5
6
7
TOW
HITNUM
1
2
3
4
5
6

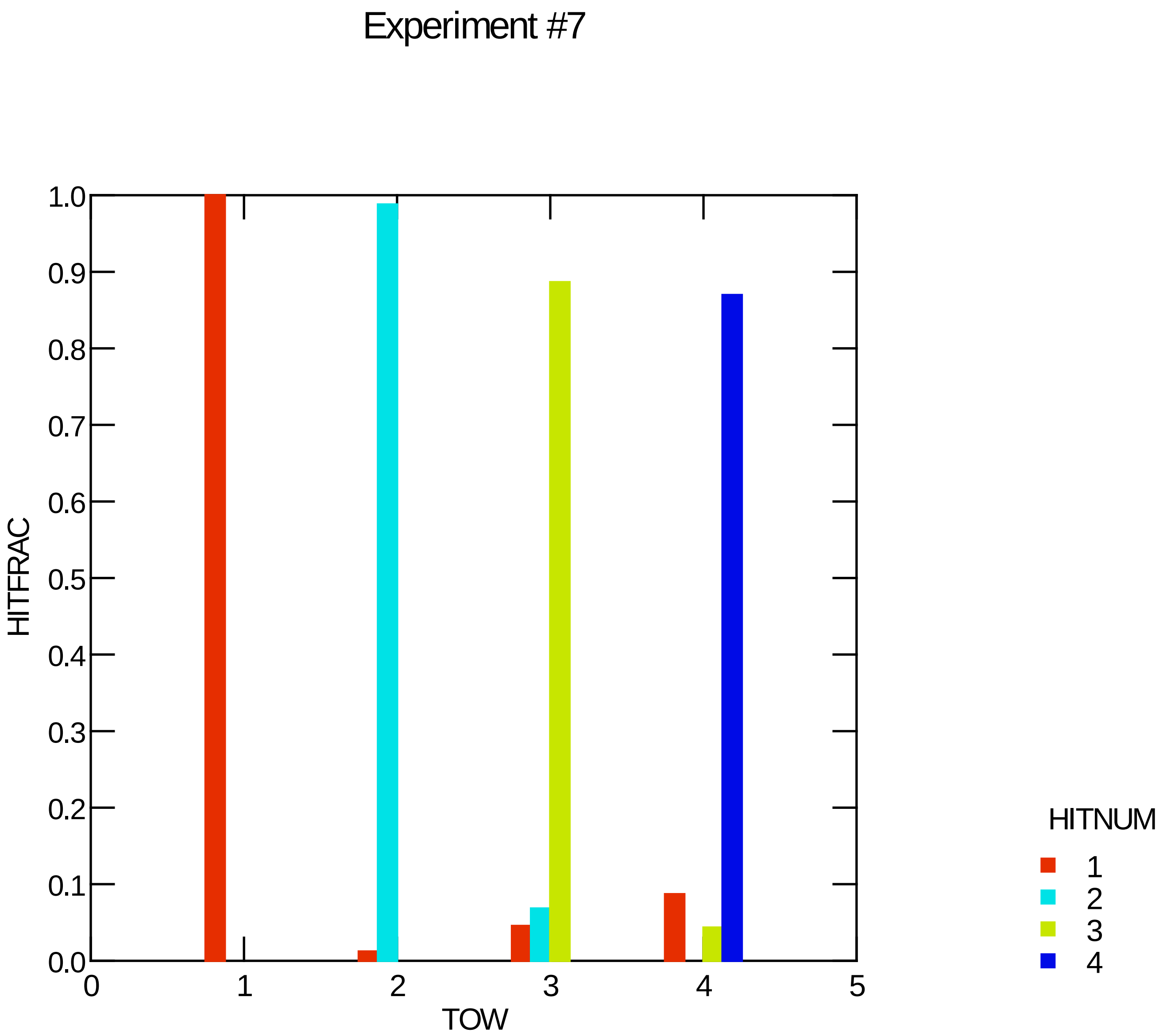
Experiment #6

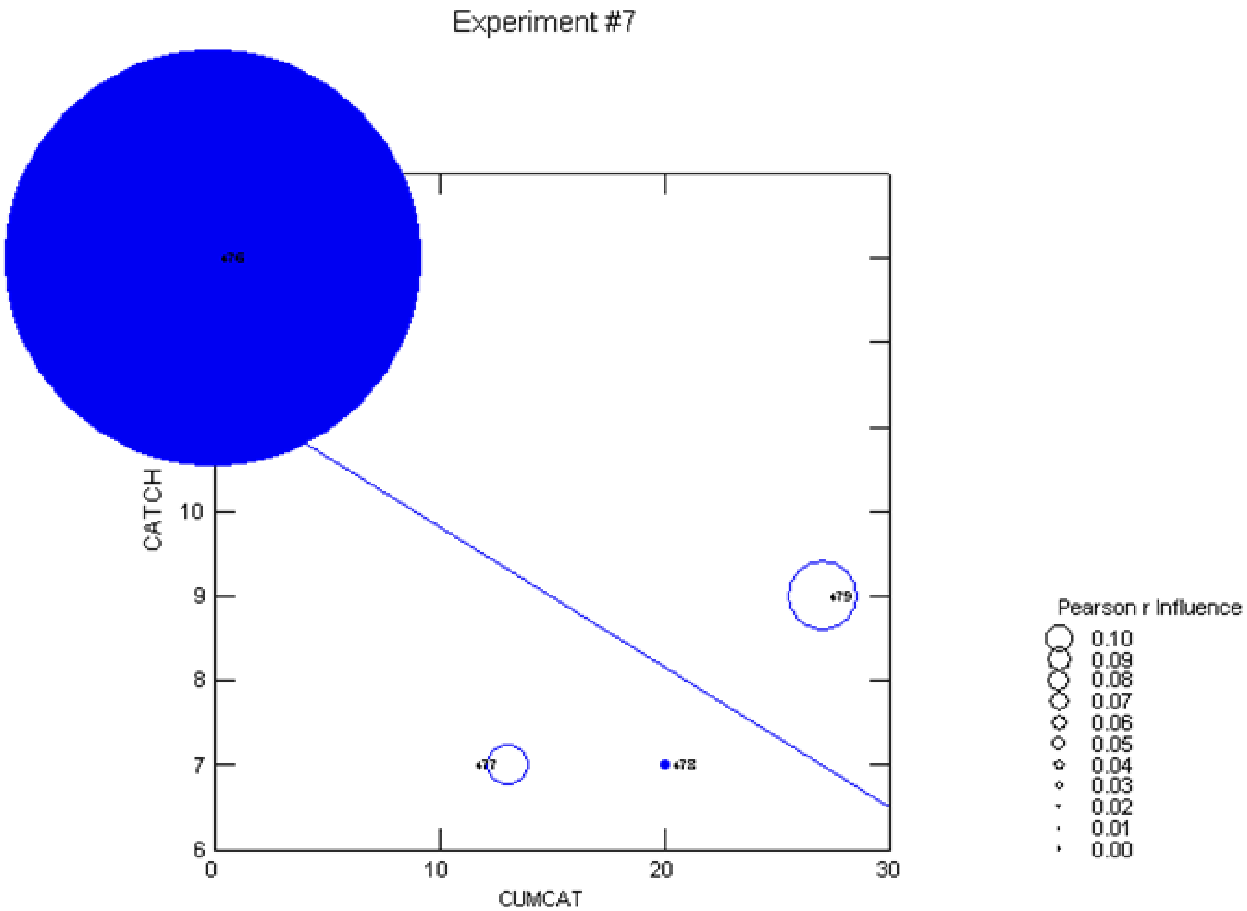


	Tow	Area Swept	Efftv Area	C_5%	C_50%	C_pred	OBS	C_95%
CI	1	1149328.0	57466.9	28.	47.	47.	51.	71.
CI	2	1228838.0	59257.8	29.	48.	48.	40.	73.
CI	3	1101188.0	50926.9	25.	41.	41.	33.	63.
CI	4	1180802.0	52736.3	26.	43.	43.	37.	65.
CI	5	1158107.0	49689.5	24.	40.	40.	31.	62.
CI	6	1031628.0	42518.2	20.	35.	34.	58.	53.

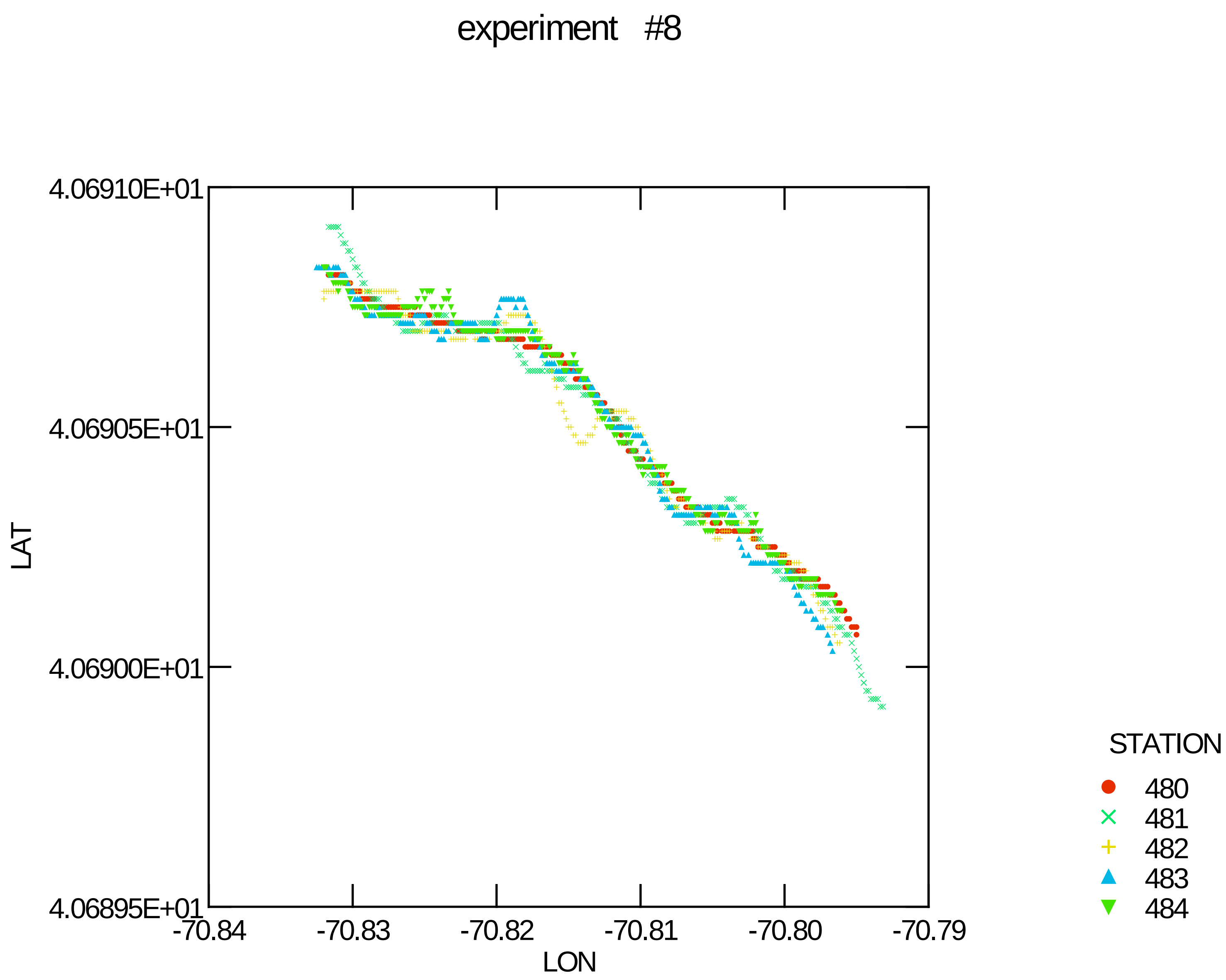


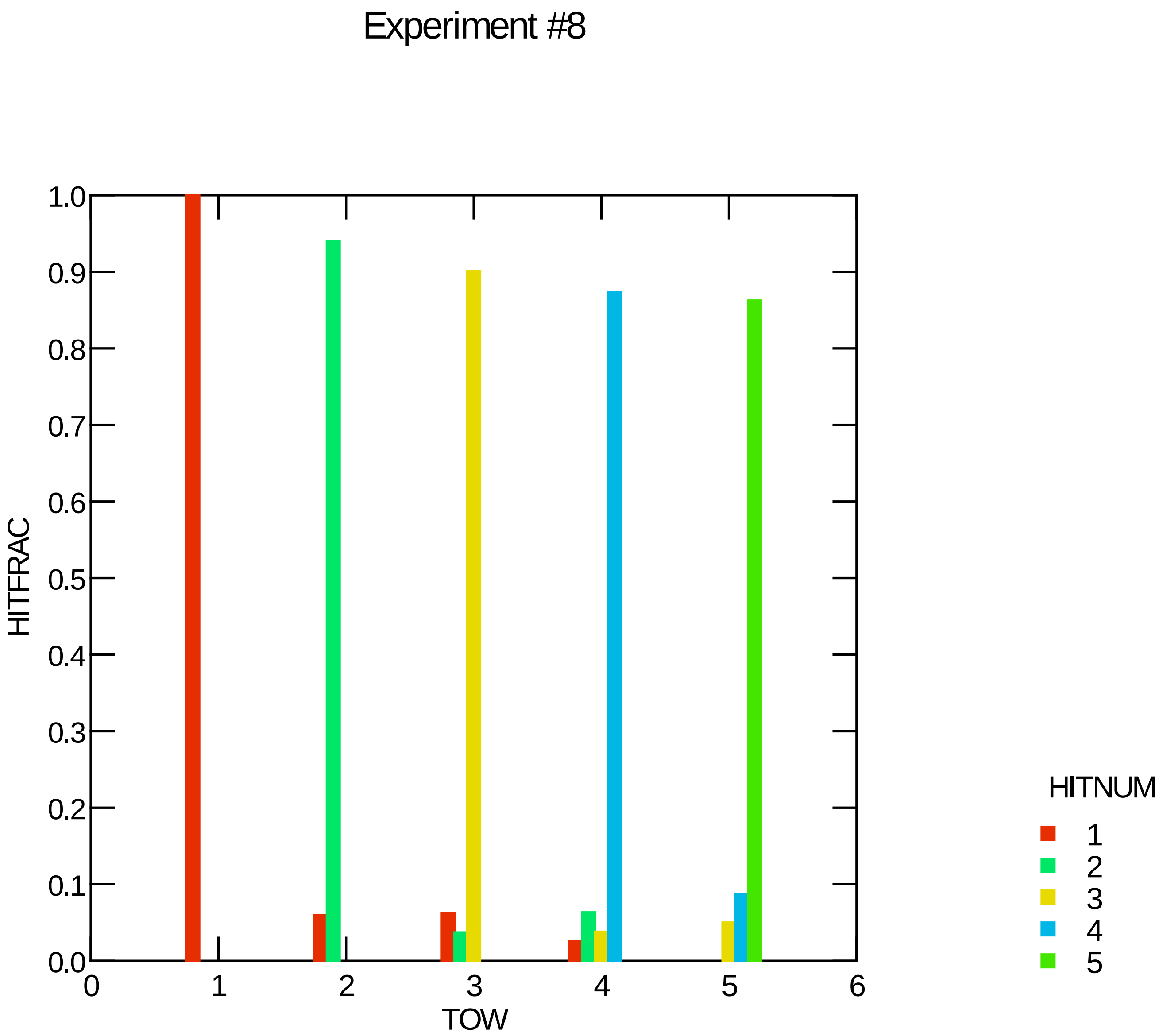
experiment #7
LAT
4.06303E+01
4.06302E+01
4.06301E+01
4.06300E+01
4.06299E+01
4.06298E+01
4.06297E+01
-70.82
-70.81
-70.80
-70.79
-70.78
-70.77
LON
STATION
476
477
478
479


Experiment #7
HITFRAC
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
1
2
3
4
5
TOW
HITNUM
1
2
3
4



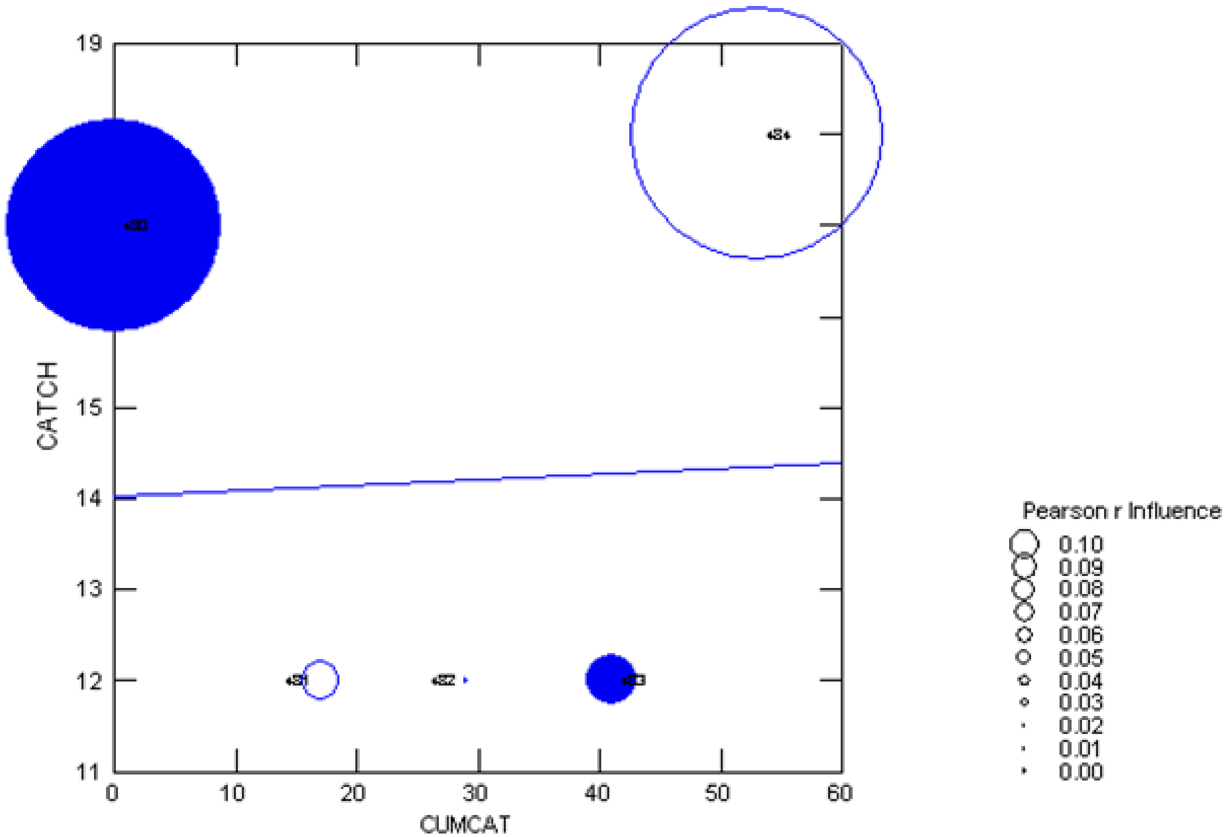
Tow		Area Swept	Efftv Area	C_5%	C_50%	C_pred	OBS	C_95%
CI	1	928448.0	107975.1	7.	12.	11.	13.	17.
CI	2	894369.0	94451.2	6.	10.	9.	7.	16.
CI	3	966692.0	94029.9	6.	10.	9.	7.	16.
CI	4	719680.0	64567.9	4.	7.	6.	9.	12.


experiment #8
4.06910E+01
4.06905E+01
4.06900E+01
4.06895E+01
LAT
-70.84
-70.83
-70.82
-70.81
-70.80
-70.79
LON
STATION
480
481
482
483
484



Experiment #8
HITFRAC
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
1
2
3
4
5
6
TOW
HITNUM
1
2
3
4
5

Experiment #8



Tow		Area Swept	Efftv Area	C_5%	C_50%	C_pred	OBS	C_95%
CI	1	926410.0	46320.6	10.	16.	15.	17.	23.
CI	2	969823.0	46667.1	10.	16.	16.	12.	23.
CI	3	899735.0	41741.6	9.	15.	14.	12.	21.
CI	4	891727.0	39852.1	9.	14.	13.	12.	21.
CI	5	904538.0	38716.8	8.	14.	13.	18.	20.

Appendix A1b: Analysis of Depletion Experiments

DISCUSSION DOCUMENT FOR SARC
APRIL 12, 2010

This information is distributed solely for the purpose of pre-dissemination peer review. It has not been formally disseminated by NOAA. It does not represent any final agency determination or policy.

Prepared by Paul Rago

F/V Mary K Depletion Exp#1- Monkfish Cooperative Survey 2009 Cookie sweep

```
 Initial Values of parameters
    .00009               =Mean  density of monkfish per sq ft
    .60000               =Efficiency of trawl
 800.00000               =K parameter for negative binomial dist
    .79900              =Gamma parameter;  initial guess=trawl width/cell width
 Bounds on parameters
  Param #            Lower Bound                Upper Bound
          1   1.000000000000000E-007   2.000000000000000E-002
          2   5.000000000000000E-002   9.500000000000000E-001
          3   5.000000000000000E-001     2000.100000000000000
          4   8.000000000000000E-001   8.001000000000000E-001

 max # tows=          6
 Max number of hits =           6

 Value of likelihood function at initial guess:
     .000090     .600000  800.000000     .799000       44.0247337183

  Starting Pt    Density  Efficiency      K Parameter   Gamma Par  Likelihood Fc
 n
       Init Cond     .000214     .327869     .500000     .800000       27.252829
 Restart from IC     .000214     .327869     .500000     .800000       27.252829
 At 0.75 Current     .000214     .327611     .500000     .800002       27.252829
 At 1.25 Current     .000209     .342985   61.461972     .800001       18.847179
      At Current     .000209     .343162   60.701874     .800002       18.847125
 At 1.25 IniCond     .000215     .327795     .500000     .800077       27.252829
      At Current     .000215     .327795     .500000     .800077       27.252829
 At 0.75 IniCond     .000214     .327697     .500000     .800100       27.252829
      At Current     .000214     .327697     .500000     .800100       27.252829

BEST soln=      .00021      .34316    60.70187      .80000   18.8471245429
   Ave Density/ft^2        .0002091
   Efficiency              .3431617
   K Parameter            60.70187
   Gamma Parameter          .80000

Profile range for m=         .0001715726         .0002532903
Profile range for e=         .2555851981         .4721314370
Profile range for k=   -10784.9992906401     -164.6256330889
Profile range for g=         .5432191982        1.0672223640

 Profile likelihood for Gamma:
                index   gamma   LogLikelihood
  Gamma Profile:    1   .50000       18.86886
  Gamma Profile:    2   .51250       18.87012
  Gamma Profile:    3   .52500       18.86543
  Gamma Profile:    4   .53750       18.86469
  Gamma Profile:    5   .55000       18.86293
  Gamma Profile:    6   .56250       18.84725
  Gamma Profile:    7   .57500       18.84734
  Gamma Profile:    8   .58750       18.84717
  Gamma Profile:    9   .60000       18.84847
  Gamma Profile:   10   .61250       18.84722
  Gamma Profile:   11   .62500       18.84749
  Gamma Profile:   12   .63750       18.84717
```

```
 Gamma Profile:   13   .65000       18.84728
 Gamma Profile:   14   .66250       18.84740
 Gamma Profile:   15   .67500       18.84718
 Gamma Profile:   16   .68750       18.84719
 Gamma Profile:   17   .70000       18.84739
 Gamma Profile:   18   .71250       18.84721
 Gamma Profile:   19   .72500       18.84729
 Gamma Profile:   20   .73750       18.84718
 Gamma Profile:   21   .75000       18.84719
 Gamma Profile:   22   .76250       18.84724
 Gamma Profile:   23   .77500       18.84719
 Gamma Profile:   24   .78750       18.84719
 Gamma Profile:   25   .80000       18.84712
 Gamma Profile:   26   .81250       18.84717
 Gamma Profile:   27   .82500       18.84713
 Gamma Profile:   28   .83750       18.84717
 Gamma Profile:   29   .85000       18.84714
 Gamma Profile:   30   .86250       18.84716
 Gamma Profile:   31   .87500       18.84717
 Gamma Profile:   32   .88750       18.84717
 Gamma Profile:   33   .90000       18.84717
 Gamma Profile:   34   .91250       18.84716
 Gamma Profile:   35   .92500       18.84712
 Gamma Profile:   36   .93750       18.84717
 Gamma Profile:   37   .95000       18.84717
 Gamma Profile:   38   .96250       18.84719
 Gamma Profile:   39   .97500       18.84716
 Gamma Profile:   40   .98750       18.84714
 Gamma Profile:   41  1.00000       18.84715
Profile likelihood for Efficiency:
               index   Effic   LogLikelihood
 Effic Profile:    1   .01000       22.06406
 Effic Profile:    2   .01000       22.06406
 Effic Profile:    3   .01000       22.06406
 Effic Profile:    4   .01000       22.06406
 Effic Profile:    5   .01000       22.06406
 Effic Profile:    6   .01000       22.06406
 Effic Profile:    7   .01000       22.06413
 Effic Profile:    8   .02466       21.88798
 Effic Profile:    9   .04916       21.58858
 Effic Profile:   10   .07366       21.28423
 Effic Profile:   11   .09816       20.97710
 Effic Profile:   12   .12266       20.67023
 Effic Profile:   13   .14716       20.36733
 Effic Profile:   14   .17166       20.07335
 Effic Profile:   15   .19616       19.79407
 Effic Profile:   16   .22066       19.53641
 Effic Profile:   17   .24516       19.30788
 Effic Profile:   18   .26966       19.11665
 Effic Profile:   19   .29416       18.97099
 Effic Profile:   20   .31866       18.87886
 Effic Profile:   21   .34316       18.84712
 Effic Profile:   22   .36766       18.88100
 Effic Profile:   23   .39216       18.98079
 Effic Profile:   24   .41666       19.14321
 Effic Profile:   25   .44116       19.35908
 Effic Profile:   26   .46566       19.61470
 Effic Profile:   27   .49016       19.89593
 Effic Profile:   28   .51466       20.19067
 Effic Profile:   29   .53916       20.48992
 Effic Profile:   30   .56366       20.78736
 Effic Profile:   31   .58816       21.07873
 Effic Profile:   32   .61266       21.36156
 Effic Profile:   33   .63716       21.63418
 Effic Profile:   34   .66166       21.89580
 Effic Profile:   35   .68616       22.14609
 Effic Profile:   36   .71066       22.38502
 Effic Profile:   37   .73516       22.61278
 Effic Profile:   38   .75966       22.82971
 Effic Profile:   39   .78416       23.03620
 Effic Profile:   40   .80866       23.23267
```

```
  Effic Profile:   41   .83316       23.41956

 Profile likelihood for Density:
                 index   Density  LogLikelihood
Density Profile:    1      .00004289    32.73495102
Density Profile:    2      .00004289    32.73495102
Density Profile:    3      .00004289    32.73495102
Density Profile:    4      .00004289    32.73495102
Density Profile:    5      .00004289    32.73495102
Density Profile:    6      .00004289    32.73495102
Density Profile:    7      .00004289    32.73495102
Density Profile:    8      .00004289    32.73495102
Density Profile:    9      .00004289    32.73495102
Density Profile:   10      .00004289    32.73495102
Density Profile:   11      .00004289    32.73495102
Density Profile:   12      .00004783    31.79147550
Density Profile:   13      .00006575    29.36791727
Density Profile:   14      .00008368    27.36068118
Density Profile:   15      .00010160    25.53776767
Density Profile:   16      .00011953    23.80610519
Density Profile:   17      .00013745    22.14996151
Density Profile:   18      .00015538    20.66477128
Density Profile:   19      .00017330    19.56606110
Density Profile:   20      .00019122    18.99376927
Density Profile:   21      .00020915    18.84712454
Density Profile:   22      .00022707    18.93911522
Density Profile:   23      .00024500    19.13170480
Density Profile:   24      .00026292    19.35074839
Density Profile:   25      .00028085    19.56341772
Density Profile:   26      .00029877    19.75789000
Density Profile:   27      .00031670    19.93152506
Density Profile:   28      .00033462    20.08523770
Density Profile:   29      .00035254    20.22122056
Density Profile:   30      .00037047    20.34177710
Density Profile:   31      .00038839    20.44904864
Density Profile:   32      .00040632    20.54497397
Density Profile:   33      .00042424    20.63108459
Density Profile:   34      .00044217    20.70878269
Density Profile:   35      .00046009    20.78082648
Density Profile:   36      .00047802    20.84332867
Density Profile:   37      .00049594    20.90188410
Density Profile:   38      .00051386    20.95555728
Density Profile:   39      .00053179    21.00498311
Density Profile:   40      .00054971    21.05056544
Density Profile:   41      .00056764    21.09278604
```

Experiment #2

F/V Mary K Depletion Exp#2- Monkfish Cooperative Survey 2009 Cookie sweep

```
 Initial Values of parameters
    .00009                    =Mean  density of monkfish per sq ft
    .60000                    =Efficiency of trawl
 800.00000                    =K parameter for negative binomial dist
    .79900                    =Gamma parameter;  initial guess=trawl width/cell width
 Bounds on parameters
  Param #            Lower Bound                Upper Bound
          1   1.000000000000000E-007   2.000000000000000E-002
          2   5.000000000000000E-002   9.500000000000000E-001
          3   5.000000000000000E-001     2000.100000000000000
          4   8.000000000000000E-001   8.001000000000000E-001

 max # tows=          3
 Max number of hits =          3

 Value of likelihood function at initial guess:
     .000090     .600000  800.000000     .799000       12.9583367180

  Starting Pt    Density  Efficiency      K Parameter   Gamma Par  Likelihood Fc
 n
       Init Cond     .000049     .949991 1862.923555     .800029        7.189986
 Restart from IC     .000049     .950000 1998.328785     .800100        7.189101
 At 0.75 Current     .000049     .950000 1999.483338     .800022        7.189511
 At 1.25 Current     .000049     .950000 2000.100000     .800093        7.189177
      At Current     .000049     .950000 2000.100000     .800100        7.189142
 At 1.25 IniCond     .000532     .050000     .500000     .800082       11.940938
      At Current     .000044     .950000     .500000     .800040       11.618120
 At 0.75 IniCond     .000049     .949999 1991.254583     .800001        7.189656
      At Current     .000049     .949999 1991.254583     .800001        7.189656

BEST soln=      .00005      .95000  1998.32878      .80010    7.1891009854
   Ave Density/ft^2        .0000492
   Efficiency              .9499999
   K Parameter           1998.32878
   Gamma Parameter           .80010

Profile range for m=         .0000361333         .0000650994
Profile range for e=         .7270126202        1.4798501708
Profile range for k=  -187550.6667816964   -33727.3512383339
Profile range for g=         .6117690540        1.1238158320

 Profile likelihood for Gamma:
                 index   gamma   LogLikelihood
  Gamma Profile:    1   .50000        9.98117
  Gamma Profile:    2   .51250        9.82899
  Gamma Profile:    3   .52500        9.67919
  Gamma Profile:    4   .53750        9.53196
  Gamma Profile:    5   .55000        9.38727
  Gamma Profile:    6   .56250        9.24524
  Gamma Profile:    7   .57500        9.10595
  Gamma Profile:    8   .58750        8.96947
  Gamma Profile:    9   .60000        8.83598
  Gamma Profile:   10   .61250        8.70544
  Gamma Profile:   11   .62500        8.57807
  Gamma Profile:   12   .63750        8.45390
  Gamma Profile:   13   .65000        8.33306
  Gamma Profile:   14   .66250        8.21563
  Gamma Profile:   15   .67500        8.10179
  Gamma Profile:   16   .68750        7.99161
  Gamma Profile:   17   .70000        7.88524
  Gamma Profile:   18   .71250        7.78282
  Gamma Profile:   19   .72500        7.68448
  Gamma Profile:   20   .73750        7.59040
  Gamma Profile:   21   .75000        7.50070
  Gamma Profile:   22   .76250        7.41560
  Gamma Profile:   23   .77500        7.33525
  Gamma Profile:   24   .78750        7.25987
  Gamma Profile:   25   .80000        7.18964
  Gamma Profile:   26   .81250        7.12483
```

```
  Gamma Profile:   27   .82500        7.06565
  Gamma Profile:   28   .83750        7.01238
  Gamma Profile:   29   .85000        6.96531
  Gamma Profile:   30   .86250        6.92474
  Gamma Profile:   31   .87500        6.89103
  Gamma Profile:   32   .88750        6.86454
  Gamma Profile:   33   .90000        6.84568
  Gamma Profile:   34   .91250        6.83491
  Gamma Profile:   35   .92500        6.83271
  Gamma Profile:   36   .93750        6.83966
  Gamma Profile:   37   .95000        6.85636
  Gamma Profile:   38   .96250        6.88351
  Gamma Profile:   39   .97500        6.92186
  Gamma Profile:   40   .98750        6.97229
  Gamma Profile:   41  1.00000        7.03577
 Profile likelihood for Efficiency:
                 index   Effic   LogLikelihood
  Effic Profile:    1   .46000        9.61531
  Effic Profile:    2   .48450        9.53437
  Effic Profile:    3   .50900        9.45042
  Effic Profile:    4   .53350        9.36327
  Effic Profile:    5   .55800        9.27268
  Effic Profile:    6   .58250        9.17839
  Effic Profile:    7   .60700        9.08012
  Effic Profile:    8   .63150        8.97750
  Effic Profile:    9   .65600        8.87013
  Effic Profile:   10   .68050        8.75750
  Effic Profile:   11   .70500        8.63897
  Effic Profile:   12   .72950        8.51370
  Effic Profile:   13   .75400        8.38056
  Effic Profile:   14   .77850        8.23781
  Effic Profile:   15   .80300        8.08957
  Effic Profile:   16   .82750        7.91119
  Effic Profile:   17   .85200        7.74270
  Effic Profile:   18   .87650        7.58525
  Effic Profile:   19   .90100        7.44008
  Effic Profile:   20   .92550        7.30772
  Effic Profile:   21   .95000        7.18909
  Effic Profile:   22   .97450        7.08519
  Effic Profile:   23   .99900        6.99714
  Effic Profile:   24  1.00000        6.99393
  Effic Profile:   25  1.00000        6.99393
  Effic Profile:   26  1.00000        6.99393
  Effic Profile:   27  1.00000        6.99393
  Effic Profile:   28  1.00000        6.99393
  Effic Profile:   29  1.00000        6.99393
  Effic Profile:   30  1.00000        6.99393
  Effic Profile:   31  1.00000        6.99393
  Effic Profile:   32  1.00000        6.99393
  Effic Profile:   33  1.00000        6.99393
  Effic Profile:   34  1.00000        6.99393
  Effic Profile:   35  1.00000        6.99393
  Effic Profile:   36  1.00000        6.99393
  Effic Profile:   37  1.00000        6.99393
  Effic Profile:   38  1.00000        6.99393
  Effic Profile:   39  1.00000        6.99393
  Effic Profile:   40  1.00000        6.99393
  Effic Profile:   41  1.00000        6.99393

 Profile likelihood for Density:
                 index   Density  LogLikelihood
Density Profile:    1      .00000903    14.67708362
Density Profile:    2      .00000903    14.67708362
Density Profile:    3      .00000903    14.67708362
Density Profile:    4      .00000903    14.67708362
Density Profile:    5      .00000903    14.67708362
Density Profile:    6      .00000903    14.67708362
Density Profile:    7      .00000903    14.67708362
Density Profile:    8      .00000903    14.67708362
Density Profile:    9      .00000903    14.67708362
Density Profile:   10      .00000903    14.67708362
```

Density Profile:	11	.00000903	14.67708362
Density Profile:	12	.00000903	14.67708362
Density Profile:	13	.00001193	13.51857810
Density Profile:	14	.00001659	12.26187423
Density Profile:	15	.00002124	11.21068082
Density Profile:	16	.00002590	10.27035365
Density Profile:	17	.00003056	9.41030648
Density Profile:	18	.00003521	8.63382913
Density Profile:	19	.00003987	7.95897367
Density Profile:	20	.00004453	7.40291620
Density Profile:	21	.00004918	7.18909808
Density Profile:	22	.00005384	7.37641876
Density Profile:	23	.00005850	7.89757678
Density Profile:	24	.00006315	8.65841376
Density Profile:	25	.00006781	9.20058434
Density Profile:	26	.00007247	9.48268241
Density Profile:	27	.00007712	9.64930800
Density Profile:	28	.00008178	9.76904606
Density Profile:	29	.00008644	9.86166675
Density Profile:	30	.00009109	9.93638072
Density Profile:	31	.00009575	9.99836245
Density Profile:	32	.00010041	10.05082710
Density Profile:	33	.00010506	10.09593841
Density Profile:	34	.00010972	10.13524053
Density Profile:	35	.00011438	10.16981990
Density Profile:	36	.00011903	10.20051734
Density Profile:	37	.00012369	10.22798166
Density Profile:	38	.00012835	10.25269955
Density Profile:	39	.00013300	10.27509767
Density Profile:	40	.00013766	10.29547975
Density Profile:	41	.00014232	10.31411393

F/V Mary K Depletion Exp#3- Monkfish Cooperative Survey 2009 Cookie sweep

```
 Initial Values of parameters
    .00009                    =Mean  density of monkfish per sq ft
    .60000                    =Efficiency of trawl
 800.00000                    =K parameter for negative binomial dist
    .79900                    =Gamma parameter;  initial guess=trawl width/cell width
 Bounds on parameters
  Param #            Lower Bound               Upper Bound
          1   1.000000000000000E-007   2.000000000000000E-002
          2   5.000000000000000E-002   9.500000000000000E-001
          3   5.000000000000000E-001     2000.100000000000000
          4   8.000000000000000E-001   8.001000000000000E-001

 max # tows=          5
 Max number of hits =          5

 Value of likelihood function at initial guess:
     .000090     .600000  800.000000     .799000       14.0994794028

  Starting Pt    Density  Efficiency      K Parameter   Gamma Par  Likelihood Fc
 n
       Init Cond     .000092     .545448   36.092252     .800091       13.944755
 Restart from IC     .000092     .545448   36.092252     .800091       13.944755
 At 0.75 Current     .000092     .545530   35.800788     .800049       13.944757
 At 1.25 Current     .000092     .545382   35.812397     .800099       13.944759
      At Current     .000092     .545382   35.812397     .800099       13.944759
 At 1.25 IniCond     .000092     .545614   35.949027     .800100       13.944763
      At Current     .000092     .545614   35.949027     .800100       13.944763
 At 0.75 IniCond     .000092     .545762   36.242183     .800000       13.944825
      At Current     .000092     .545569   35.957433     .800000       13.944765

BEST soln=      .00009      .54545    36.09225      .80009   13.9447546404
   Ave Density/ft^2        .0000921
   Efficiency              .5454478
   K Parameter             36.09225
   Gamma Parameter           .80009

Profile range for m=         .0000692495         .0001213348
Profile range for e=         .3677967841         .7499060133
Profile range for k=    -6181.7413638744      -99.1528281636
Profile range for g=         .5803031893        1.0210431831

 Profile likelihood for Gamma:
                index   gamma   LogLikelihood
  Gamma Profile:    1   .50000       13.94477
  Gamma Profile:    2   .51250       13.96250
  Gamma Profile:    3   .52500       13.96113
  Gamma Profile:    4   .53750       13.96674
  Gamma Profile:    5   .55000       13.96781
  Gamma Profile:    6   .56250       13.96107
  Gamma Profile:    7   .57500       13.96278
  Gamma Profile:    8   .58750       13.95899
  Gamma Profile:    9   .60000       13.95870
  Gamma Profile:   10   .61250       13.95840
  Gamma Profile:   11   .62500       13.95581
  Gamma Profile:   12   .63750       13.95407
  Gamma Profile:   13   .65000       13.94473
  Gamma Profile:   14   .66250       13.95276
  Gamma Profile:   15   .67500       13.94974
  Gamma Profile:   16   .68750       13.95028
  Gamma Profile:   17   .70000       13.94938
  Gamma Profile:   18   .71250       13.94819
  Gamma Profile:   19   .72500       13.94737
  Gamma Profile:   20   .73750       13.94673
  Gamma Profile:   21   .75000       13.94599
  Gamma Profile:   22   .76250       13.94548
  Gamma Profile:   23   .77500       13.94512
  Gamma Profile:   24   .78750       13.94478
  Gamma Profile:   25   .80000       13.94476
  Gamma Profile:   26   .81250       13.94476
  Gamma Profile:   27   .82500       13.94477
```

```
  Gamma Profile:   28   .83750       13.94474
  Gamma Profile:   29   .85000       13.94478
  Gamma Profile:   30   .86250       13.94477
  Gamma Profile:   31   .87500       13.94476
  Gamma Profile:   32   .88750       13.94476
  Gamma Profile:   33   .90000       13.94475
  Gamma Profile:   34   .91250       13.94477
  Gamma Profile:   35   .92500       13.94476
  Gamma Profile:   36   .93750       13.94476
  Gamma Profile:   37   .95000       14.06950
  Gamma Profile:   38   .96250       14.06820
  Gamma Profile:   39   .97500       14.05346
  Gamma Profile:   40   .98750       14.06817
  Gamma Profile:   41  1.00000       13.94476
 Profile likelihood for Efficiency:
                 index   Effic   LogLikelihood
  Effic Profile:    1   .05545       17.42447
  Effic Profile:    2   .07995       17.24145
  Effic Profile:    3   .10445       17.05217
  Effic Profile:    4   .12895       16.85664
  Effic Profile:    5   .15345       16.65516
  Effic Profile:    6   .17795       16.44815
  Effic Profile:    7   .20245       16.23624
  Effic Profile:    8   .22695       16.02039
  Effic Profile:    9   .25145       15.80185
  Effic Profile:   10   .27595       15.58227
  Effic Profile:   11   .30045       15.36369
  Effic Profile:   12   .32495       15.14857
  Effic Profile:   13   .34945       14.93980
  Effic Profile:   14   .37395       14.74065
  Effic Profile:   15   .39845       14.55473
  Effic Profile:   16   .42295       14.38596
  Effic Profile:   17   .44745       14.23837
  Effic Profile:   18   .47195       14.11620
  Effic Profile:   19   .49645       14.02374
  Effic Profile:   20   .52095       13.96518
  Effic Profile:   21   .54545       13.94475
  Effic Profile:   22   .56995       13.96649
  Effic Profile:   23   .59445       14.03433
  Effic Profile:   24   .61895       14.15199
  Effic Profile:   25   .64345       14.32279
  Effic Profile:   26   .66795       14.54890
  Effic Profile:   27   .69245       14.84101
  Effic Profile:   28   .71695       15.20452
  Effic Profile:   29   .74145       15.63987
  Effic Profile:   30   .76595       16.12482
  Effic Profile:   31   .79045       16.59080
  Effic Profile:   32   .81495       17.04521
  Effic Profile:   33   .83945       17.48475
  Effic Profile:   34   .86395       17.90852
  Effic Profile:   35   .88845       18.31713
  Effic Profile:   36   .91295       18.71207
  Effic Profile:   37   .93745       19.09527
  Effic Profile:   38   .96195       19.46891
  Effic Profile:   39   .98645       19.83540
  Effic Profile:   40  1.00000       20.03604
  Effic Profile:   41  1.00000       20.03604

 Profile likelihood for Density:
                 index   Density  LogLikelihood
Density Profile:    1      .00001731    25.56181150
Density Profile:    2      .00001731    25.56181150
Density Profile:    3      .00001731    25.56181150
Density Profile:    4      .00001731    25.56181150
Density Profile:    5      .00001731    25.56181150
Density Profile:    6      .00001731    25.56181150
Density Profile:    7      .00001731    25.56181150
Density Profile:    8      .00001731    25.56181150
Density Profile:    9      .00001731    25.56181150
Density Profile:   10      .00001731    25.56181150
Density Profile:   11      .00001731    25.56181151
```

Density Profile:	12	.00001731	25.56181151
Density Profile:	13	.00002273	23.47801918
Density Profile:	14	.00003140	21.46240278
Density Profile:	15	.00004007	19.80730625
Density Profile:	16	.00004874	18.33316968
Density Profile:	17	.00005740	16.98222693
Density Profile:	18	.00006607	15.77141495
Density Profile:	19	.00007474	14.78670111
Density Profile:	20	.00008341	14.15102425
Density Profile:	21	.00009207	13.94475464
Density Profile:	22	.00010074	14.10296967
Density Profile:	23	.00010941	14.46286550
Density Profile:	24	.00011807	14.88937456
Density Profile:	25	.00012674	15.29159145
Density Profile:	26	.00013541	15.61675777
Density Profile:	27	.00014408	15.86659576
Density Profile:	28	.00015274	16.06204295
Density Profile:	29	.00016141	16.21935583
Density Profile:	30	.00017008	16.34908008
Density Profile:	31	.00017875	16.45819755
Density Profile:	32	.00018741	16.55143156
Density Profile:	33	.00019608	16.63215148
Density Profile:	34	.00020475	16.70278845
Density Profile:	35	.00021342	16.76518950
Density Profile:	36	.00022208	16.82076681
Density Profile:	37	.00023075	16.87059240
Density Profile:	38	.00023942	16.91553998
Density Profile:	39	.00024808	16.95631280
Density Profile:	40	.00025675	16.99511030
Density Profile:	41	.00026542	17.03349548

F/V Mary K Depletion Exp#4- Monkfish Cooperative Survey 2009 Cookie sweep

```
 Initial Values of parameters
    .00009                    =Mean  density of monkfish per sq ft
    .60000                    =Efficiency of trawl
 800.00000                    =K parameter for negative binomial dist
    .79900                    =Gamma parameter;  initial guess=trawl width/cell width
 Bounds on parameters
  Param #            Lower Bound                Upper Bound
          1   1.000000000000000E-007   2.000000000000000E-002
          2   5.000000000000000E-002   9.500000000000000E-001
          3   5.000000000000000E-001     2000.100000000000000
          4   8.000000000000000E-001   8.001000000000000E-001

 max # tows=          5
 Max number of hits =          5

 Value of likelihood function at initial guess:
     .000090     .600000  800.000000     .799000       16.5239544254

  Starting Pt    Density  Efficiency      K Parameter   Gamma Par  Likelihood Fc
 n
       Init Cond     .000102     .682002  868.548230     .800001       14.863495
 Restart from IC     .000102     .682016 1981.628861     .800000       14.861226
 At 0.75 Current     .000102     .682277 1662.014562     .800011       14.861580
 At 1.25 Current     .000102     .682246 1704.920199     .800099       14.861468
      At Current     .000102     .682246 1704.920199     .800099       14.861468
 At 1.25 IniCond     .000102     .682832  921.197851     .800100       14.863254
      At Current     .000102     .682239 1992.557789     .800099       14.861188
 At 0.75 IniCond     .000098     .653701     .500000     .800100       20.203233
      At Current     .000098     .653701     .500000     .800100       20.203233

BEST soln=      .00010      .68224  1992.55779      .80010   14.8611882004
   Ave Density/ft^2        .0001022
   Efficiency              .6822388
   K Parameter           1992.55779
   Gamma Parameter            .80010

Profile range for m=         .0000827484         .0001243961
Profile range for e=         .5255430255         .8457045331
Profile range for k= -3486279.5321977080   -60759.9211378478
Profile range for g=         .6471605847         .9582943972

 Profile likelihood for Gamma:
                index   gamma   LogLikelihood
  Gamma Profile:    1   .50000       15.34617
  Gamma Profile:    2   .51250       15.19854
  Gamma Profile:    3   .52500       15.07721
  Gamma Profile:    4   .53750       14.98244
  Gamma Profile:    5   .55000       14.91467
  Gamma Profile:    6   .56250       14.87414
  Gamma Profile:    7   .57500       14.86122
  Gamma Profile:    8   .58750       14.86120
  Gamma Profile:    9   .60000       14.86126
  Gamma Profile:   10   .61250       14.86124
  Gamma Profile:   11   .62500       14.86122
  Gamma Profile:   12   .63750       14.86124
  Gamma Profile:   13   .65000       14.86123
  Gamma Profile:   14   .66250       14.86122
  Gamma Profile:   15   .67500       14.86122
  Gamma Profile:   16   .68750       14.86124
  Gamma Profile:   17   .70000       14.86120
  Gamma Profile:   18   .71250       14.86118
  Gamma Profile:   19   .72500       14.86120
  Gamma Profile:   20   .73750       14.86120
  Gamma Profile:   21   .75000       14.86121
  Gamma Profile:   22   .76250       14.86121
  Gamma Profile:   23   .77500       14.86123
  Gamma Profile:   24   .78750       14.86122
  Gamma Profile:   25   .80000       14.86119
  Gamma Profile:   26   .81250       14.86122
  Gamma Profile:   27   .82500       14.86120
```

```
  Gamma Profile:   28   .83750       14.86120
  Gamma Profile:   29   .85000       14.86121
  Gamma Profile:   30   .86250       14.86122
  Gamma Profile:   31   .87500       14.86124
  Gamma Profile:   32   .88750       14.86124
  Gamma Profile:   33   .90000       14.86123
  Gamma Profile:   34   .91250       14.86125
  Gamma Profile:   35   .92500       14.86121
  Gamma Profile:   36   .93750       14.86120
  Gamma Profile:   37   .95000       14.86122
  Gamma Profile:   38   .96250       14.86122
  Gamma Profile:   39   .97500       14.86122
  Gamma Profile:   40   .98750       14.86124
  Gamma Profile:   41  1.00000       14.86120
 Profile likelihood for Efficiency:
                 index   Effic   LogLikelihood
  Effic Profile:    1   .19224       18.35356
  Effic Profile:    2   .21674       18.19560
  Effic Profile:    3   .24124       18.03269
  Effic Profile:    4   .26574       17.86483
  Effic Profile:    5   .29024       17.69195
  Effic Profile:    6   .31474       17.51414
  Effic Profile:    7   .33924       17.33153
  Effic Profile:    8   .36374       17.14430
  Effic Profile:    9   .38824       16.95286
  Effic Profile:   10   .41274       16.75761
  Effic Profile:   11   .43724       16.55930
  Effic Profile:   12   .46174       16.35874
  Effic Profile:   13   .48624       16.15703
  Effic Profile:   14   .51074       15.95560
  Effic Profile:   15   .53524       15.75611
  Effic Profile:   16   .55974       15.56042
  Effic Profile:   17   .58424       15.45261
  Effic Profile:   18   .60874       15.19643
  Effic Profile:   19   .63324       15.01121
  Effic Profile:   20   .65774       14.89889
  Effic Profile:   21   .68224       14.86119
  Effic Profile:   22   .70674       14.89962
  Effic Profile:   23   .73124       15.01523
  Effic Profile:   24   .75574       15.20930
  Effic Profile:   25   .78024       15.48290
  Effic Profile:   26   .80474       15.83695
  Effic Profile:   27   .82924       16.27203
  Effic Profile:   28   .85374       16.78852
  Effic Profile:   29   .87824       17.38679
  Effic Profile:   30   .90274       18.06661
  Effic Profile:   31   .92724       18.82760
  Effic Profile:   32   .95174       19.66895
  Effic Profile:   33   .97624       20.58926
  Effic Profile:   34  1.00000       21.55651
  Effic Profile:   35  1.00000       21.55651
  Effic Profile:   36  1.00000       21.55651
  Effic Profile:   37  1.00000       21.55651
  Effic Profile:   38  1.00000       21.55651
  Effic Profile:   39  1.00000       21.55651
  Effic Profile:   40  1.00000       21.55651
  Effic Profile:   41  1.00000       21.55651

 Profile likelihood for Density:
                 index   Density  LogLikelihood
Density Profile:    1      .00002069    25.01742185
Density Profile:    2      .00002069    25.01742185
Density Profile:    3      .00002069    25.01742185
Density Profile:    4      .00002069    25.01742185
Density Profile:    5      .00002069    25.01742185
Density Profile:    6      .00002069    25.01742185
Density Profile:    7      .00002069    25.01742185
Density Profile:    8      .00002069    25.01742185
Density Profile:    9      .00002069    25.01742185
Density Profile:   10      .00002069    25.01742185
Density Profile:   11      .00002069    25.01742185
```

Density Profile:	12	.00002284	24.28149099
Density Profile:	13	.00003165	22.27642647
Density Profile:	14	.00004046	20.75743609
Density Profile:	15	.00004928	19.46661618
Density Profile:	16	.00005809	18.33493713
Density Profile:	17	.00006690	17.33333182
Density Profile:	18	.00007571	16.45626096
Density Profile:	19	.00008453	15.71509755
Density Profile:	20	.00009334	15.18135167
Density Profile:	21	.00010215	14.86118820
Density Profile:	22	.00011096	15.13632710
Density Profile:	23	.00011978	15.87662831
Density Profile:	24	.00012859	16.26990592
Density Profile:	25	.00013740	16.73038242
Density Profile:	26	.00014621	17.12874931
Density Profile:	27	.00015503	17.47482022
Density Profile:	28	.00016384	17.77746554
Density Profile:	29	.00017265	18.04419522
Density Profile:	30	.00018146	18.28107844
Density Profile:	31	.00019028	18.49298675
Density Profile:	32	.00019909	18.68364905
Density Profile:	33	.00020790	18.85609296
Density Profile:	34	.00021671	19.01403498
Density Profile:	35	.00022553	19.16436738
Density Profile:	36	.00023434	19.30793532
Density Profile:	37	.00024315	19.44496702
Density Profile:	38	.00025196	19.57578981
Density Profile:	39	.00026078	19.70074728
Density Profile:	40	.00026959	19.82011445
Density Profile:	41	.00027840	19.93430026

F/V Endurance Depletion Exp#5- Monkfish Cooperative Survey 2009 Cookie sweep

```
 Initial Values of parameters
    .00009              =Mean  density of monkfish per sq ft
    .60000              =Efficiency of trawl
 800.00000              =K parameter for negative binomial dist
    .79900              =Gamma parameter;  initial guess=trawl width/cell width
 Bounds on parameters
  Param #            Lower Bound                Upper Bound
          1   1.000000000000000E-007   2.000000000000000E-002
          2   5.000000000000000E-002   9.500000000000000E-001
          3   5.000000000000000E-001     2000.100000000000000
          4   8.000000000000000E-001   8.001000000000000E-001

 max # tows=          6
 Max number of hits =           6

 Value of likelihood function at initial guess:
     .000090     .600000  800.000000     .799000       40.9830258445

  Starting Pt    Density  Efficiency      K Parameter   Gamma Par  Likelihood Fc
 n
       Init Cond     .000170     .429534     .500000     .800096       26.553342
 Restart from IC     .000170     .429403     .500000     .800096       26.553342
 At 0.75 Current     .000174     .382392   30.409138     .800006       20.015653
 At 1.25 Current     .000174     .382461   30.604524     .800079       20.015675
      At Current     .000174     .382329   30.759826     .800079       20.015641
 At 1.25 IniCond     .000752     .050000     .500000     .800094       26.846228
      At Current     .000752     .050000     .500000     .800096       26.846228
 At 0.75 IniCond     .000170     .429437     .500000     .800100       26.553342
      At Current     .000170     .429437     .500000     .800100       26.553342

BEST soln=      .00017      .38233    30.75983      .80008   20.0156405995
   Ave Density/ft^2        .0001737
   Efficiency              .3823286
   K Parameter             30.75983
   Gamma Parameter           .80008

Profile range for m=         .0001384769         .0002175830
Profile range for e=         .2647723973         .5501045631
Profile range for k=    -4221.3216735437      -68.4412971559
Profile range for g=         .5861721632        1.0145777592

 Profile likelihood for Gamma:
                index   gamma   LogLikelihood
  Gamma Profile:    1   .50000       20.01777
  Gamma Profile:    2   .51250       20.03655
  Gamma Profile:    3   .52500       20.02794
  Gamma Profile:    4   .53750       20.01905
  Gamma Profile:    5   .55000       20.01565
  Gamma Profile:    6   .56250       20.01567
  Gamma Profile:    7   .57500       20.02812
  Gamma Profile:    8   .58750       20.03666
  Gamma Profile:    9   .60000       20.01565
  Gamma Profile:   10   .61250       20.01573
  Gamma Profile:   11   .62500       20.01569
  Gamma Profile:   12   .63750       20.01928
  Gamma Profile:   13   .65000       20.01817
  Gamma Profile:   14   .66250       20.01576
  Gamma Profile:   15   .67500       20.01568
  Gamma Profile:   16   .68750       20.01565
  Gamma Profile:   17   .70000       20.01566
  Gamma Profile:   18   .71250       20.01566
  Gamma Profile:   19   .72500       20.01563
  Gamma Profile:   20   .73750       20.01567
  Gamma Profile:   21   .75000       20.01566
  Gamma Profile:   22   .76250       20.01564
  Gamma Profile:   23   .77500       20.01567
  Gamma Profile:   24   .78750       20.01570
  Gamma Profile:   25   .80000       20.01564
  Gamma Profile:   26   .81250       20.01564
  Gamma Profile:   27   .82500       20.01566
```

```
  Gamma Profile:   28   .83750       20.01567
  Gamma Profile:   29   .85000       20.01564
  Gamma Profile:   30   .86250       20.01566
  Gamma Profile:   31   .87500       20.01567
  Gamma Profile:   32   .88750       20.01566
  Gamma Profile:   33   .90000       20.01563
  Gamma Profile:   34   .91250       20.01568
  Gamma Profile:   35   .92500       20.01566
  Gamma Profile:   36   .93750       20.01566
  Gamma Profile:   37   .95000       20.01567
  Gamma Profile:   38   .96250       20.01565
  Gamma Profile:   39   .97500       20.01567
  Gamma Profile:   40   .98750       20.01569
  Gamma Profile:   41  1.00000       20.01566
 Profile likelihood for Efficiency:
                  index   Effic   LogLikelihood
  Effic Profile:    1   .01000       23.60693
  Effic Profile:    2   .01000       23.60693
  Effic Profile:    3   .01000       23.60693
  Effic Profile:    4   .01000       23.60693
  Effic Profile:    5   .01000       23.60693
  Effic Profile:    6   .01483       23.56199
  Effic Profile:    7   .03933       23.32904
  Effic Profile:    8   .06383       23.08756
  Effic Profile:    9   .08833       22.83729
  Effic Profile:   10   .11283       22.57814
  Effic Profile:   11   .13733       22.31008
  Effic Profile:   12   .16183       22.03347
  Effic Profile:   13   .18633       21.74923
  Effic Profile:   14   .21083       21.45908
  Effic Profile:   15   .23533       21.16659
  Effic Profile:   16   .25983       20.87809
  Effic Profile:   17   .28433       20.60447
  Effic Profile:   18   .30883       20.36254
  Effic Profile:   19   .33333       20.17315
  Effic Profile:   20   .35783       20.05490
  Effic Profile:   21   .38233       20.01564
  Effic Profile:   22   .40683       20.05030
  Effic Profile:   23   .43133       20.14553
  Effic Profile:   24   .45583       20.28647
  Effic Profile:   25   .48033       20.46015
  Effic Profile:   26   .50483       20.65624
  Effic Profile:   27   .52933       20.86695
  Effic Profile:   28   .55383       21.08641
  Effic Profile:   29   .57833       21.31011
  Effic Profile:   30   .60283       21.53481
  Effic Profile:   31   .62733       21.75799
  Effic Profile:   32   .65183       21.97782
  Effic Profile:   33   .67633       22.19299
  Effic Profile:   34   .70083       22.40280
  Effic Profile:   35   .72533       22.60661
  Effic Profile:   36   .74983       22.80418
  Effic Profile:   37   .77433       22.99558
  Effic Profile:   38   .79883       23.18090
  Effic Profile:   39   .82333       23.36042
  Effic Profile:   40   .84783       23.53441
  Effic Profile:   41   .87233       26.88127

 Profile likelihood for Density:
                  index   Density  LogLikelihood
Density Profile:    1      .00003462    32.92238134
Density Profile:    2      .00003462    32.92238134
Density Profile:    3      .00003462    32.92238134
Density Profile:    4      .00003462    32.92238134
Density Profile:    5      .00003462    32.92238134
Density Profile:    6      .00003462    32.92238134
Density Profile:    7      .00003462    32.92238134
Density Profile:    8      .00003462    32.92238134
Density Profile:    9      .00003462    32.92238134
Density Profile:   10      .00003462    32.92238134
Density Profile:   11      .00003462    32.92238140
```

Density Profile:	12	.00003466	32.91023408
Density Profile:	13	.00005011	29.83649894
Density Profile:	14	.00006557	27.79873024
Density Profile:	15	.00008102	26.08502144
Density Profile:	16	.00009647	24.56107926
Density Profile:	17	.00011193	23.18231048
Density Profile:	18	.00012738	21.95273184
Density Profile:	19	.00014283	20.93142824
Density Profile:	20	.00015829	20.24507404
Density Profile:	21	.00017374	20.01564060
Density Profile:	22	.00018919	20.19415482
Density Profile:	23	.00020465	20.58213623
Density Profile:	24	.00022010	20.98920048
Density Profile:	25	.00023555	21.32803782
Density Profile:	26	.00025101	21.59403664
Density Profile:	27	.00026646	21.80434246
Density Profile:	28	.00028191	21.97447841
Density Profile:	29	.00029737	22.11497305
Density Profile:	30	.00031282	22.23327327
Density Profile:	31	.00032827	22.33435793
Density Profile:	32	.00034372	22.42182813
Density Profile:	33	.00035918	22.49837958
Density Profile:	34	.00037463	22.56600908
Density Profile:	35	.00039008	22.62617920
Density Profile:	36	.00040554	22.68011009
Density Profile:	37	.00042099	22.72874896
Density Profile:	38	.00043644	22.77289119
Density Profile:	39	.00045190	22.81307395
Density Profile:	40	.00046735	22.84986412
Density Profile:	41	.00048280	22.88368105

F/V Endurance Depletion Exp#6- Monkfish Cooperative Survey 2009 Roller sweep

```
 Initial Values of parameters
    .00009                        =Mean  density of monkfish per sq ft
    .60000                        =Efficiency of trawl
 800.00000                        =K parameter for negative binomial dist
    .79900                        =Gamma parameter;  initial guess=trawl width/cell width
 Bounds on parameters
  Param #            Lower Bound                Upper Bound
           1   1.000000000000000E-007   2.000000000000000E-002
           2   5.000000000000000E-002   9.500000000000000E-001
           3   5.000000000000000E-001     2000.100000000000000
           4   8.000000000000000E-001   8.001000000000000E-001

 max # tows=          6
 Max number of hits =          6

 Value of likelihood function at initial guess:
     .000090     .600000  800.000000     .799000      173.3437473240

  Starting Pt    Density  Efficiency      K Parameter   Gamma Par  Likelihood Fc
 n
       Init Cond     .000817     .050000     .500000     .800000       30.895870
 Restart from IC     .000817     .050000     .500000     .800000       30.895870
 At 0.75 Current     .000816     .050000     .500000     .800032       30.895871
 At 1.25 Current     .000811     .050000   17.641123     .800002       23.285576
      At Current     .000811     .050000   17.641123     .800002       23.285576
 At 1.25 IniCond     .000816     .050000     .500000     .800096       30.895873
      At Current     .000816     .050000     .500000     .800096       30.895873
 At 0.75 IniCond     .000816     .050000     .500000     .800000       30.895870
      At Current     .000816     .050000     .500000     .800000       30.895870

BEST soln=      .00081      .05000    17.64112      .80000   23.2855757860
   Ave Density/ft^2        .0008114
   Efficiency              .0500004
   K Parameter             17.64112
   Gamma Parameter           .80000

Profile range for m=         .0006480096         .0010221376
Profile range for e=         .0387413616         .0640136992
Profile range for k=       -6.4127423076      144.3646782037
Profile range for g=        -.6363943855        1.8487032289

 Profile likelihood for Gamma:
                index   gamma   LogLikelihood
  Gamma Profile:    1   .50000       23.06111
  Gamma Profile:    2   .51250       23.06966
  Gamma Profile:    3   .52500       23.07817
  Gamma Profile:    4   .53750       23.08683
  Gamma Profile:    5   .55000       23.09555
  Gamma Profile:    6   .56250       23.10431
  Gamma Profile:    7   .57500       23.11314
  Gamma Profile:    8   .58750       23.12210
  Gamma Profile:    9   .60000       23.13116
  Gamma Profile:   10   .61250       23.14022
  Gamma Profile:   11   .62500       23.14942
  Gamma Profile:   12   .63750       23.15868
  Gamma Profile:   13   .65000       23.16797
  Gamma Profile:   14   .66250       23.17781
  Gamma Profile:   15   .67500       23.18692
  Gamma Profile:   16   .68750       23.19649
  Gamma Profile:   17   .70000       23.20608
  Gamma Profile:   18   .71250       23.21578
  Gamma Profile:   19   .72500       23.22551
  Gamma Profile:   20   .73750       23.23529
  Gamma Profile:   21   .75000       23.24535
  Gamma Profile:   22   .76250       23.25518
  Gamma Profile:   23   .77500       23.26535
  Gamma Profile:   24   .78750       23.27556
  Gamma Profile:   25   .80000       23.28557
  Gamma Profile:   26   .81250       23.29587
  Gamma Profile:   27   .82500       23.30617
```

```
  Gamma Profile:   28   .83750       23.31675
  Gamma Profile:   29   .85000       23.32692
  Gamma Profile:   30   .86250       23.33761
  Gamma Profile:   31   .87500       23.34806
  Gamma Profile:   32   .88750       23.35870
  Gamma Profile:   33   .90000       23.36948
  Gamma Profile:   34   .91250       23.38019
  Gamma Profile:   35   .92500       23.39108
  Gamma Profile:   36   .93750       23.40201
  Gamma Profile:   37   .95000       23.41291
  Gamma Profile:   38   .96250       23.42390
  Gamma Profile:   39   .97500       23.43491
  Gamma Profile:   40   .98750       23.44624
  Gamma Profile:   41  1.00000       23.45737
 Profile likelihood for Efficiency:
                index   Effic   LogLikelihood
  Effic Profile:    1   .01000       22.86302
  Effic Profile:    2   .01000       22.86302
  Effic Profile:    3   .01000       22.86302
  Effic Profile:    4   .01000       22.86302
  Effic Profile:    5   .01000       22.86302
  Effic Profile:    6   .01000       22.86302
  Effic Profile:    7   .01000       22.86302
  Effic Profile:    8   .01000       22.86302
  Effic Profile:    9   .01000       22.86302
  Effic Profile:   10   .01000       22.86302
  Effic Profile:   11   .01000       22.86302
  Effic Profile:   12   .01000       22.86302
  Effic Profile:   13   .01000       22.86302
  Effic Profile:   14   .01000       22.86302
  Effic Profile:   15   .01000       22.86302
  Effic Profile:   16   .01000       22.86302
  Effic Profile:   17   .01000       22.86302
  Effic Profile:   18   .01000       22.86302
  Effic Profile:   19   .01000       22.86302
  Effic Profile:   20   .02550       23.00131
  Effic Profile:   21   .05000       23.28557
  Effic Profile:   22   .07450       23.63625
  Effic Profile:   23   .09900       24.03563
  Effic Profile:   24   .12350       30.95560
  Effic Profile:   25   .14800       30.98451
  Effic Profile:   26   .17250       31.01823
  Effic Profile:   27   .19700       31.05693
  Effic Profile:   28   .22150       31.10079
  Effic Profile:   29   .24600       31.14997
  Effic Profile:   30   .27050       31.20463
  Effic Profile:   31   .29500       31.26491
  Effic Profile:   32   .31950       31.33092
  Effic Profile:   33   .34400       31.40279
  Effic Profile:   34   .36850       31.48057
  Effic Profile:   35   .39300       31.56432
  Effic Profile:   36   .41750       31.65406
  Effic Profile:   37   .44200       31.74975
  Effic Profile:   38   .46650       31.85133
  Effic Profile:   39   .49100       31.95866
  Effic Profile:   40   .51550       32.07156
  Effic Profile:   41   .54000       32.18975

 Profile likelihood for Density:
                index   Density  LogLikelihood
Density Profile:    1      .00016200    29.22905893
Density Profile:    2      .00016200    29.22905893
Density Profile:    3      .00016200    29.22905893
Density Profile:    4      .00016200    29.22905893
Density Profile:    5      .00016200    29.22905893
Density Profile:    6      .00016200    29.22905893
Density Profile:    7      .00016200    29.22905893
Density Profile:    8      .00016200    29.22905893
Density Profile:    9      .00016200    29.22905893
Density Profile:   10      .00016200    29.22905893
Density Profile:   11      .00016200    29.22905893
```

Density Profile:	12	.00016200	29.22905893
Density Profile:	13	.00023050	26.66922005
Density Profile:	14	.00030311	25.21226919
Density Profile:	15	.00037572	24.45850971
Density Profile:	16	.00044833	24.02839287
Density Profile:	17	.00052094	23.75902407
Density Profile:	18	.00059355	25.84850426
Density Profile:	19	.00066616	24.52353492
Density Profile:	20	.00073877	23.60057050
Density Profile:	21	.00081138	23.28557579
Density Profile:	22	.00088399	23.54255147
Density Profile:	23	.00095660	24.12091652
Density Profile:	24	.00102921	24.79826094
Density Profile:	25	.00110182	25.46268567
Density Profile:	26	.00117443	26.07450602
Density Profile:	27	.00124704	26.62530074
Density Profile:	28	.00131965	27.11834033
Density Profile:	29	.00139226	27.55999882
Density Profile:	30	.00146487	27.95714181
Density Profile:	31	.00153748	28.31625721
Density Profile:	32	.00161009	28.64241924
Density Profile:	33	.00168270	28.94051584
Density Profile:	34	.00175531	29.21403369
Density Profile:	35	.00182792	29.46624412
Density Profile:	36	.00190053	29.69971373
Density Profile:	37	.00197314	29.91681427
Density Profile:	38	.00204575	30.11922781
Density Profile:	39	.00211836	30.30866756
Density Profile:	40	.00219097	30.48642788
Density Profile:	41	.00226358	30.65378127

F/V Endurance Depletion Exp#7- Monkfish Cooperative Survey 2009 COOKIE sweep

```
 Initial Values of parameters
    .00009                        =Mean  density of monkfish per sq ft
    .60000                        =Efficiency of trawl
 800.00000                        =K parameter for negative binomial dist
    .79900                        =Gamma parameter;  initial guess=trawl width/cell width
 Bounds on parameters
  Param #             Lower Bound                Upper Bound
           1   1.000000000000000E-007   2.000000000000000E-002
           2   5.000000000000000E-002   9.500000000000000E-001
           3   5.000000000000000E-001     2000.100000000000000
           4   8.000000000000000E-001   8.001000000000000E-001

 max # tows=          4
 Max number of hits =           4

 Value of likelihood function at initial guess:
     .000090     .600000  800.000000     .799000       39.6190825282

  Starting Pt    Density  Efficiency      K Parameter   Gamma Par  Likelihood Fc
 n
       Init Cond     .000164     .068396     .500000     .800001       14.520380
 Restart from IC     .000164     .068396     .500000     .800001       14.520380
 At 0.75 Current     .000217     .050597     .500000     .800033       14.520614
 At 1.25 Current     .000096     .122081  606.758726     .800000        9.394790
      At Current     .000097     .120066  598.376117     .800004        9.394684
 At 1.25 IniCond     .000168     .066605     .500000     .800064       14.520382
      At Current     .000164     .068228     .500000     .800063       14.520380
 At 0.75 IniCond     .000100     .116296 2000.020086     .800022        9.386830
      At Current     .000100     .116296 2000.020086     .800022        9.386830

BEST soln=      .00010      .11630  2000.02009      .80002    9.3868300530
   Ave Density/ft^2        .0000997
   Efficiency              .1162964
   K Parameter           2000.02009
   Gamma Parameter           .80002

Profile range for m=         .0000705456         .0001360520
Profile range for e=         .0792421718         .1670465201
Profile range for k=  -398821.7806384688   -59781.3312306910
Profile range for g=         .1090324463       12.9770168859

 Profile likelihood for Gamma:
                index   gamma   LogLikelihood
  Gamma Profile:    1   .50000        9.38683
  Gamma Profile:    2   .51250        9.38686
  Gamma Profile:    3   .52500        9.38687
  Gamma Profile:    4   .53750        9.38683
  Gamma Profile:    5   .55000        9.38683
  Gamma Profile:    6   .56250        9.38682
  Gamma Profile:    7   .57500        9.38683
  Gamma Profile:    8   .58750        9.38685
  Gamma Profile:    9   .60000        9.38683
  Gamma Profile:   10   .61250        9.38787
  Gamma Profile:   11   .62500        9.38770
  Gamma Profile:   12   .63750        9.38783
  Gamma Profile:   13   .65000        9.38762
  Gamma Profile:   14   .66250        9.38757
  Gamma Profile:   15   .67500        9.38759
  Gamma Profile:   16   .68750        9.38752
  Gamma Profile:   17   .70000        9.38737
  Gamma Profile:   18   .71250        9.38722
  Gamma Profile:   19   .72500        9.38711
  Gamma Profile:   20   .73750        9.38719
  Gamma Profile:   21   .75000        9.38705
  Gamma Profile:   22   .76250        9.38695
  Gamma Profile:   23   .77500        9.38685

  Gamma Profile:   24   .78750        9.38683
  Gamma Profile:   25   .80000        9.38682
  Gamma Profile:   26   .81250        9.38685
```

```
  Gamma Profile:   27   .82500        9.38687
  Gamma Profile:   28   .83750        9.38688
  Gamma Profile:   29   .85000        9.38692
  Gamma Profile:   30   .86250        9.38688
  Gamma Profile:   31   .87500        9.38696
  Gamma Profile:   32   .88750        9.38690
  Gamma Profile:   33   .90000        9.38683
  Gamma Profile:   34   .91250        9.38683
  Gamma Profile:   35   .92500        9.38683
  Gamma Profile:   36   .93750        9.38683
  Gamma Profile:   37   .95000        9.38682
  Gamma Profile:   38   .96250        9.38682
  Gamma Profile:   39   .97500        9.38690
  Gamma Profile:   40   .98750        9.38689
  Gamma Profile:   41  1.00000        9.38683
 Profile likelihood for Efficiency:
                 index   Effic   LogLikelihood
  Effic Profile:    1   .01000        9.51380
  Effic Profile:    2   .01000        9.51380
  Effic Profile:    3   .01000        9.51380
  Effic Profile:    4   .01000        9.51380
  Effic Profile:    5   .01000        9.51380
  Effic Profile:    6   .01000        9.51380
  Effic Profile:    7   .01000        9.51380
  Effic Profile:    8   .01000        9.51380
  Effic Profile:    9   .01000        9.51380
  Effic Profile:   10   .01000        9.51380
  Effic Profile:   11   .01000        9.51380
  Effic Profile:   12   .01000        9.51380
  Effic Profile:   13   .01000        9.51380
  Effic Profile:   14   .01000        9.51380
  Effic Profile:   15   .01000        9.51380
  Effic Profile:   16   .01000        9.51380
  Effic Profile:   17   .01830        9.49515
  Effic Profile:   18   .04280        9.44860
  Effic Profile:   19   .06730        9.41460
  Effic Profile:   20   .09180        9.39389
  Effic Profile:   21   .11630        9.38683
  Effic Profile:   22   .14080        9.39429
  Effic Profile:   23   .16530        9.41644
  Effic Profile:   24   .18980        9.45407
  Effic Profile:   25   .21430        9.50768
  Effic Profile:   26   .23880        9.57794
  Effic Profile:   27   .26330        9.66541
  Effic Profile:   28   .28780        9.77065
  Effic Profile:   29   .31230       14.57124
  Effic Profile:   30   .33680       14.58250
  Effic Profile:   31   .36130       14.59494
  Effic Profile:   32   .38580       14.60856
  Effic Profile:   33   .41030       14.62335
  Effic Profile:   34   .43480       14.63928
  Effic Profile:   35   .45930       14.65631
  Effic Profile:   36   .48380       14.67439
  Effic Profile:   37   .50830       14.69345
  Effic Profile:   38   .53280       11.91269
  Effic Profile:   39   .55730       11.85145
  Effic Profile:   40   .58180       12.59604
  Effic Profile:   41   .60630       12.97016

 Profile likelihood for Density:
                 index   Density  LogLikelihood
Density Profile:    1      .00001764    14.93172055
Density Profile:    2      .00001764    14.93172055
Density Profile:    3      .00001764    14.93172055
Density Profile:    4      .00001764    14.93172055
Density Profile:    5      .00001764    14.93172055
Density Profile:    6      .00001764    14.93172055
Density Profile:    7      .00001764    14.93172055
Density Profile:    8      .00001764    14.93172055
Density Profile:    9      .00001764    14.93172055
Density Profile:   10      .00001764    14.93172055
```

Density Profile:	11	.00001764	14.93172055
Density Profile:	12	.00001764	14.93172055
Density Profile:	13	.00002160	13.77880118
Density Profile:	14	.00003137	11.30256698
Density Profile:	15	.00004113	10.07538587
Density Profile:	16	.00005089	9.65490459
Density Profile:	17	.00006066	9.49482062
Density Profile:	18	.00007042	9.42840370
Density Profile:	19	.00008018	9.40027994
Density Profile:	20	.00008995	9.38939803
Density Profile:	21	.00009971	9.38683005
Density Profile:	22	.00010947	9.38840543
Density Profile:	23	.00011923	9.39388620
Density Profile:	24	.00012900	9.39665734
Density Profile:	25	.00013876	9.40190813
Density Profile:	26	.00014852	9.40701493
Density Profile:	27	.00015829	9.41181456
Density Profile:	28	.00016805	9.41683211
Density Profile:	29	.00017781	9.42129484
Density Profile:	30	.00018758	9.42564952
Density Profile:	31	.00019734	9.42980524
Density Profile:	32	.00020710	9.43368563
Density Profile:	33	.00021686	9.43732971
Density Profile:	34	.00022663	9.47706666
Density Profile:	35	.00023639	9.58334337
Density Profile:	36	.00024615	9.75074392
Density Profile:	37	.00025592	9.97286639
Density Profile:	38	.00026568	10.21479092
Density Profile:	39	.00027544	10.45613707
Density Profile:	40	.00028521	10.69062374
Density Profile:	41	.00029497	10.91506885

F/V Endurance Depletion Exp#8- Monkfish Cooperative Survey 2009 ROLLER sweep

```
 Initial Values of parameters
    .00009                 =Mean  density of monkfish per sq ft
    .60000                 =Efficiency of trawl
 800.00000                 =K parameter for negative binomial dist
    .79900                 =Gamma parameter;  initial guess=trawl width/cell width
 Bounds on parameters
  Param #             Lower Bound                Upper Bound
          1   1.000000000000000E-007   2.000000000000000E-002
          2   5.000000000000000E-002   9.500000000000000E-001
          3   5.000000000000000E-001     2000.100000000000000
          4   8.000000000000000E-001   8.001000000000000E-001

 max # tows=          5
 Max number of hits =           5

 Value of likelihood function at initial guess:
     .000090     .600000  800.000000     .799000       44.0176941086

  Starting Pt    Density  Efficiency      K Parameter   Gamma Par  Likelihood Fc
 n
       Init Cond     .000335     .050000     .500000     .800000       20.418132
 Restart from IC     .000335     .050000     .500000     .800000       20.418132
 At 0.75 Current     .000336     .050000     .500000     .800029       20.418133
 At 1.25 Current     .000333     .050009 1974.408224     .800000       12.834802
      At Current     .000333     .050005 1976.180254     .800000       12.834715
 At 1.25 IniCond     .000336     .050000     .500000     .800096       20.418134
      At Current     .000336     .050000     .500000     .800096       20.418134
 At 0.75 IniCond     .000333     .050000 1991.802224     .800000       12.834665
      At Current     .000333     .050000 1994.905678     .800000       12.834636

BEST soln=      .00033      .05000  1994.90568      .80000   12.8346363243
   Ave Density/ft^2        .0003328
   Efficiency              .0500001
   K Parameter           1994.90568
   Gamma Parameter            .80000

Profile range for m=         .0002611375         .0004168065
Profile range for e=         .0383579543         .0634661256
Profile range for k=********************   -53765.7363895542
Profile range for g=        -.3423246137        2.3707364499

 Profile likelihood for Gamma:
                index   gamma   LogLikelihood
  Gamma Profile:    1   .50000       12.70805
  Gamma Profile:    2   .51250       12.71268
  Gamma Profile:    3   .52500       12.71737
  Gamma Profile:    4   .53750       12.72212
  Gamma Profile:    5   .55000       12.72693
  Gamma Profile:    6   .56250       12.73177
  Gamma Profile:    7   .57500       12.73670
  Gamma Profile:    8   .58750       12.74168
  Gamma Profile:    9   .60000       12.74670
  Gamma Profile:   10   .61250       12.75178
  Gamma Profile:   11   .62500       12.75691
  Gamma Profile:   12   .63750       12.76210
  Gamma Profile:   13   .65000       12.76738
  Gamma Profile:   14   .66250       12.77266
  Gamma Profile:   15   .67500       12.77800
  Gamma Profile:   16   .68750       12.78340
  Gamma Profile:   17   .70000       12.78890
  Gamma Profile:   18   .71250       12.79442
  Gamma Profile:   19   .72500       12.80006
  Gamma Profile:   20   .73750       12.80569
  Gamma Profile:   21   .75000       12.81136
  Gamma Profile:   22   .76250       12.81709
  Gamma Profile:   23   .77500       12.82287
  Gamma Profile:   24   .78750       12.82875
  Gamma Profile:   25   .80000       12.83464
  Gamma Profile:   26   .81250       12.84063
  Gamma Profile:   27   .82500       12.84665
```

```
  Gamma Profile:   28   .83750       12.85275
  Gamma Profile:   29   .85000       12.85890
  Gamma Profile:   30   .86250       12.86508
  Gamma Profile:   31   .87500       12.87134
  Gamma Profile:   32   .88750       12.87766
  Gamma Profile:   33   .90000       12.88402
  Gamma Profile:   34   .91250       12.89044
  Gamma Profile:   35   .92500       12.89697
  Gamma Profile:   36   .93750       12.90349
  Gamma Profile:   37   .95000       12.91007
  Gamma Profile:   38   .96250       12.91672
  Gamma Profile:   39   .97500       12.92345
  Gamma Profile:   40   .98750       12.93021
  Gamma Profile:   41  1.00000       12.93707
 Profile likelihood for Efficiency:
                 index   Effic   LogLikelihood
  Effic Profile:    1   .01000       12.60228
  Effic Profile:    2   .01000       12.60228
  Effic Profile:    3   .01000       12.60228
  Effic Profile:    4   .01000       12.60228
  Effic Profile:    5   .01000       12.60228
  Effic Profile:    6   .01000       12.60228
  Effic Profile:    7   .01000       12.60228
  Effic Profile:    8   .01000       12.60228
  Effic Profile:    9   .01000       12.60228
  Effic Profile:   10   .01000       12.60228
  Effic Profile:   11   .01000       12.60228
  Effic Profile:   12   .01000       12.60228
  Effic Profile:   13   .01000       12.60228
  Effic Profile:   14   .01000       12.60228
  Effic Profile:   15   .01000       12.60228
  Effic Profile:   16   .01000       12.60228
  Effic Profile:   17   .01000       12.60228
  Effic Profile:   18   .01000       12.60228
  Effic Profile:   19   .01000       12.60308
  Effic Profile:   20   .02550       12.67566
  Effic Profile:   21   .05000       12.83463
  Effic Profile:   22   .07450       13.04949
  Effic Profile:   23   .09900       13.32233
  Effic Profile:   24   .12350       13.65665
  Effic Profile:   25   .14800       14.05521
  Effic Profile:   26   .17250       20.48278
  Effic Profile:   27   .19700       20.50371
  Effic Profile:   28   .22150       20.52764
  Effic Profile:   29   .24600       20.55473
  Effic Profile:   30   .27050       20.58515
  Effic Profile:   31   .29500       20.61907
  Effic Profile:   32   .31950       20.65668
  Effic Profile:   33   .34400       20.69817
  Effic Profile:   34   .36850       20.74375
  Effic Profile:   35   .39300       20.79365
  Effic Profile:   36   .41750       20.84809
  Effic Profile:   37   .44200       20.90732
  Effic Profile:   38   .46650       20.97162
  Effic Profile:   39   .49100       21.04127
  Effic Profile:   40   .51550       21.11659
  Effic Profile:   41   .54000       21.19792

 Profile likelihood for Density:
                 index   Density  LogLikelihood
Density Profile:    1      .00006528    17.46294046
Density Profile:    2      .00006528    17.46294046
Density Profile:    3      .00006528    17.46294046
Density Profile:    4      .00006528    17.46294046
Density Profile:    5      .00006528    17.46294046
Density Profile:    6      .00006528    17.46294046
Density Profile:    7      .00006528    17.46294046
Density Profile:    8      .00006528    17.46294046
Density Profile:    9      .00006528    17.46294046
Density Profile:   10      .00006528    17.46294046
Density Profile:   11      .00006528    17.46294046
```

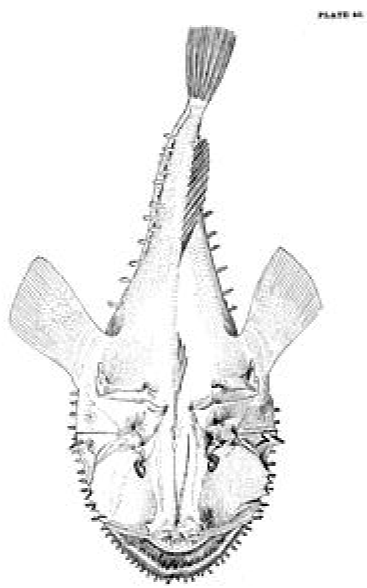
Density Profile:	12	.00006617	17.36979120
Density Profile:	13	.00009579	15.14080913
Density Profile:	14	.00012542	14.08811621
Density Profile:	15	.00015505	13.55803238
Density Profile:	16	.00018468	13.27897683
Density Profile:	17	.00021431	16.95863739
Density Profile:	18	.00024394	15.49417561
Density Profile:	19	.00027356	14.10377757
Density Profile:	20	.00030319	13.13309298
Density Profile:	21	.00033282	12.83463630
Density Profile:	22	.00036245	13.09709285
Density Profile:	23	.00039208	13.81427396
Density Profile:	24	.00042171	14.62438983
Density Profile:	25	.00045133	15.34839076
Density Profile:	26	.00048096	15.97379696
Density Profile:	27	.00051059	16.51280441
Density Profile:	28	.00054022	16.98068720
Density Profile:	29	.00056985	17.39070907
Density Profile:	30	.00059948	17.75348072
Density Profile:	31	.00062910	18.07731863
Density Profile:	32	.00065873	18.36874980
Density Profile:	33	.00068836	18.63286670
Density Profile:	34	.00071799	18.87377013
Density Profile:	35	.00074762	19.09474868
Density Profile:	36	.00077725	19.29847030
Density Profile:	37	.00080687	19.48712362
Density Profile:	38	.00083650	19.66255391
Density Profile:	39	.00086613	19.82626470
Density Profile:	40	.00089576	19.97956657
Density Profile:	41	.00092539	20.12354259

Appendix A2: SCALE Plot Collection Results for Northern and Southern Monkfish

VERY LARGE FILE
OVER 100 PAGES
LOOK BUT PLEASE DO NOT PRINT

Final Runs
Includes model Survey and Catch length frequency fits
5/14/2010

Southern Demersal Working Group

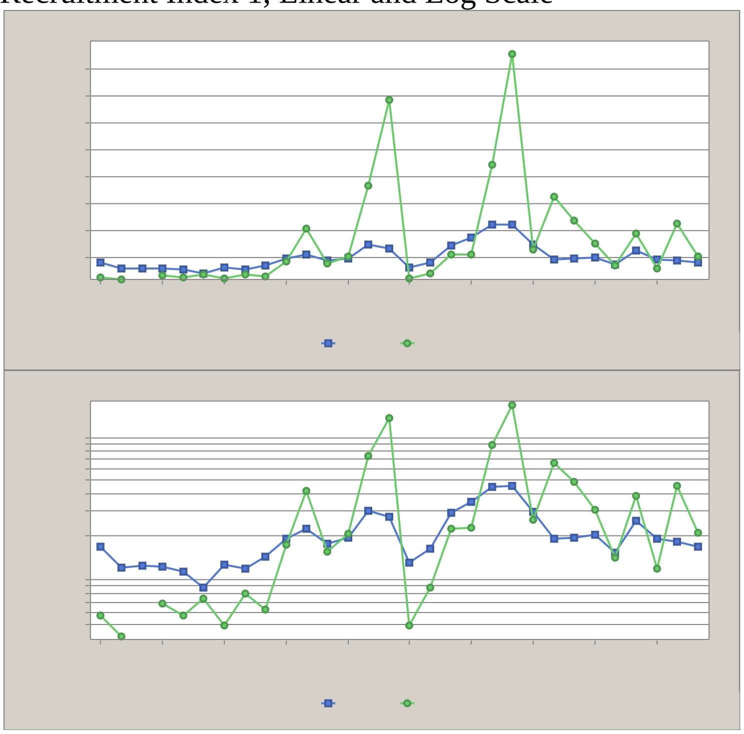


50th SAW/SARC

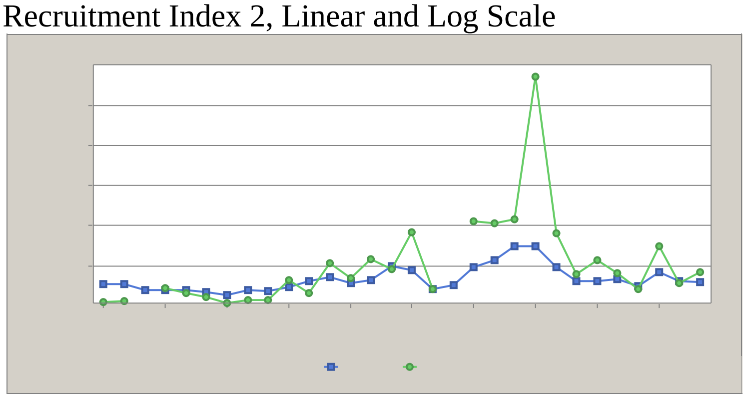
Northern Management Area Final Run 8

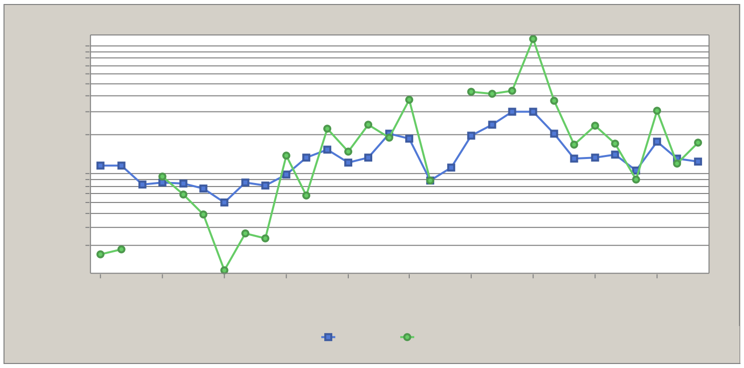
Recruitment Indices, Group Linear and Log Scale, 1 Index per Line (12 Plots)
Adult Indices, Group Linear and Log Scale, 1 Index per Line (8 Plots)
Survey Length Frequencies (210 Plots)
Catch Numbers, Catch Length Frequency (30 Plots)
Observed vs. Predicted Catch Weight (1 Plot)
Selectivity (1 Plots)
4-Plot: Population and Catch Numbers (60 Plots)
Fmult, Age 1 Recruitment, Observed vs. Predicted Catch Weight, and Total Biomass: Group 2 per Line (4 Plots)

Recruitment Index 1, Linear and Log Scale

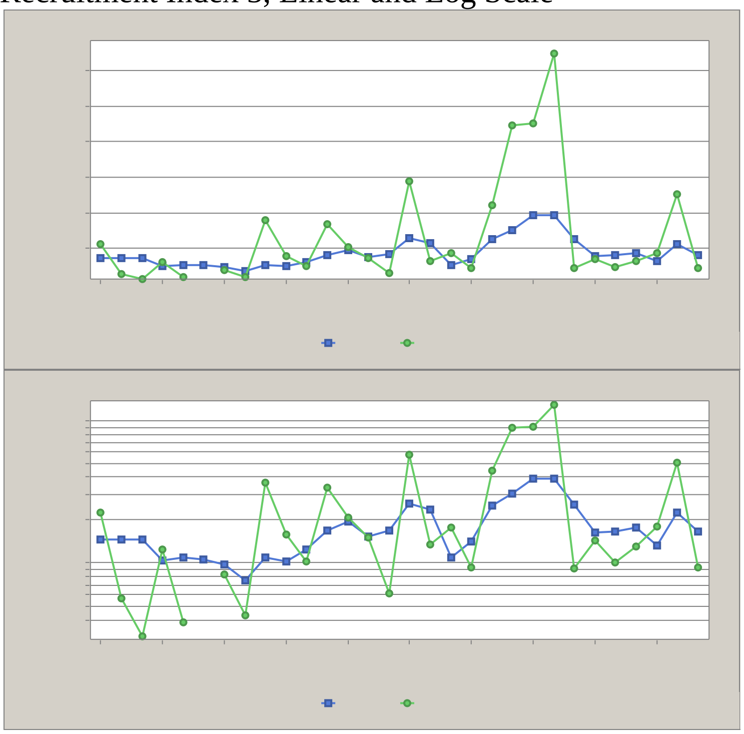


Recruitment Index 2, Linear and Log Scale

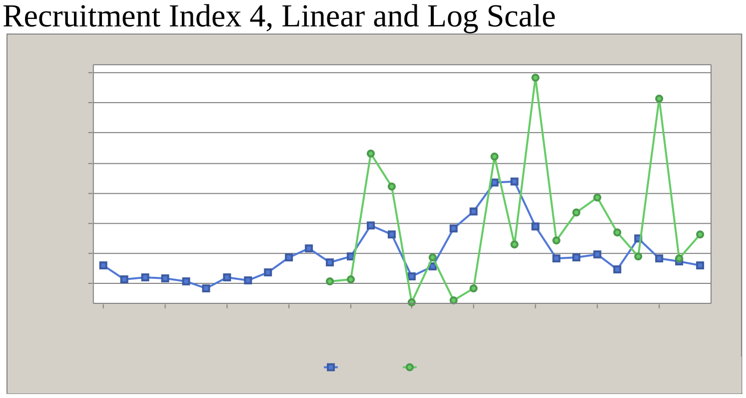


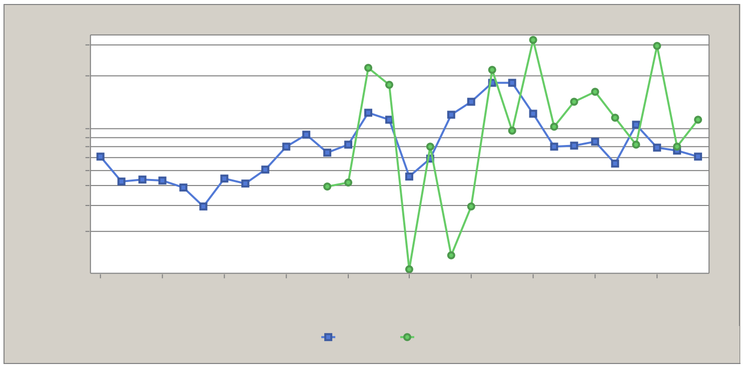


Recruitment Index 3, Linear and Log Scale

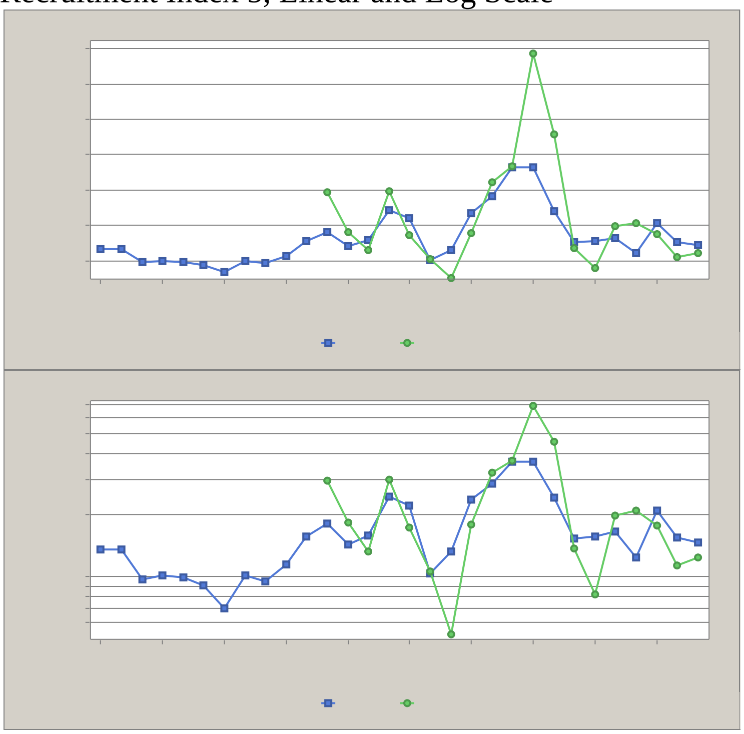


Recruitment Index 4, Linear and Log Scale





Recruitment Index 5, Linear and Log Scale



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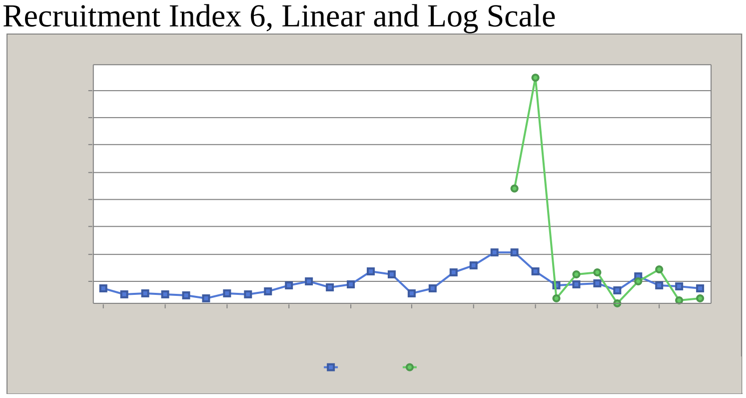
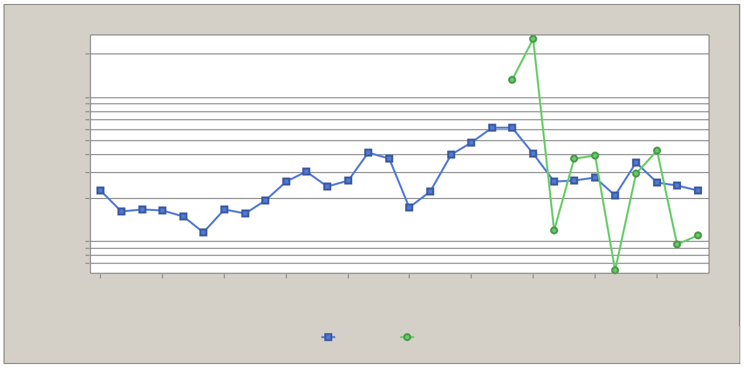
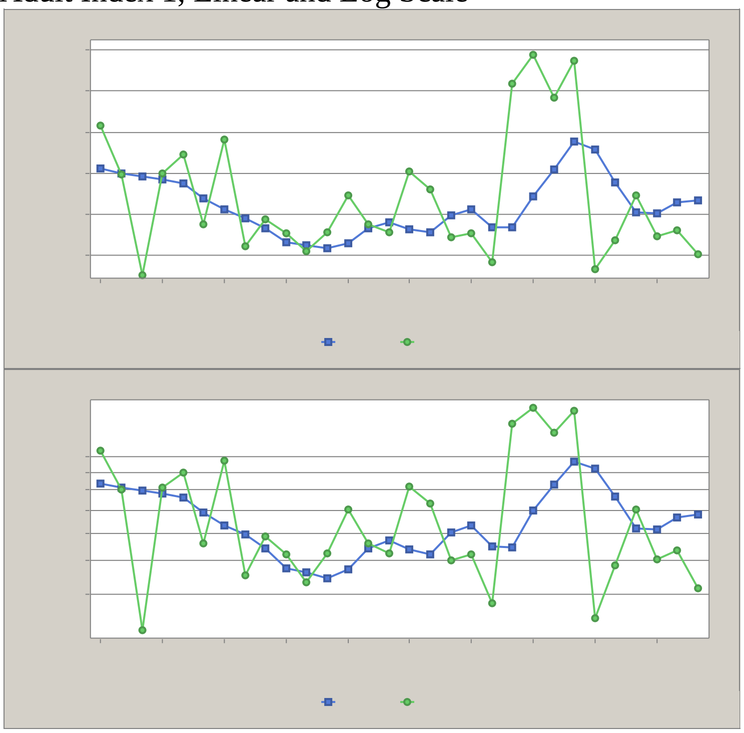
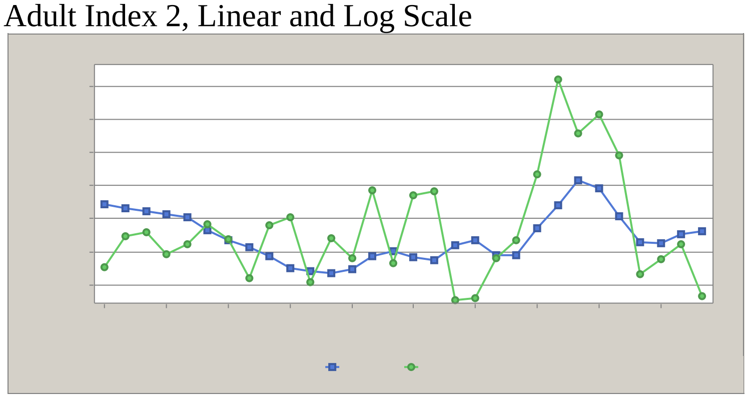


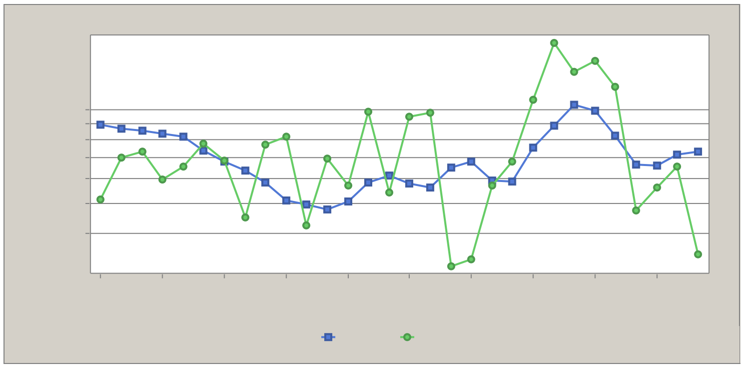


Adult Index 1, Linear and Log Scale



Adult Index 2, Linear and Log Scale





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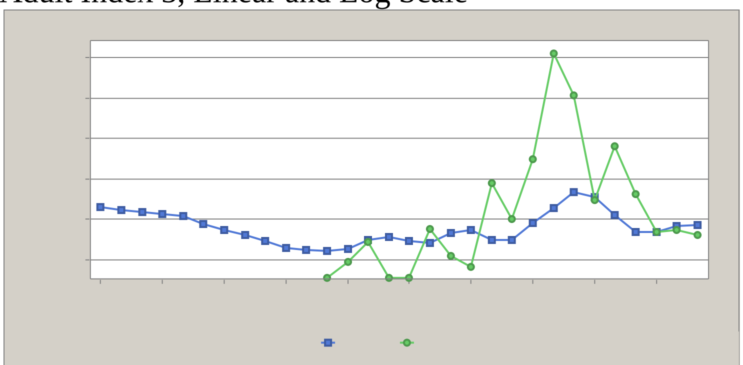

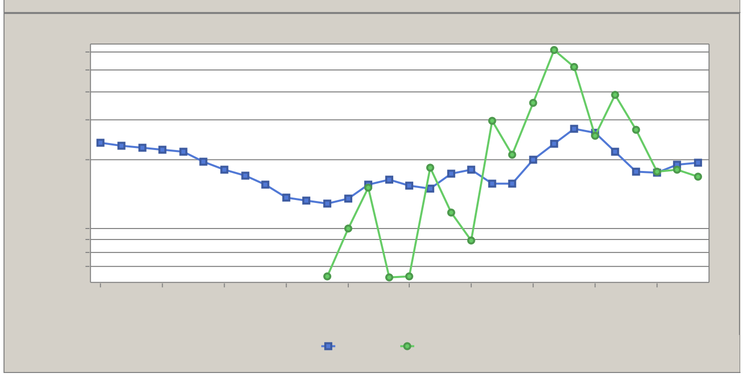

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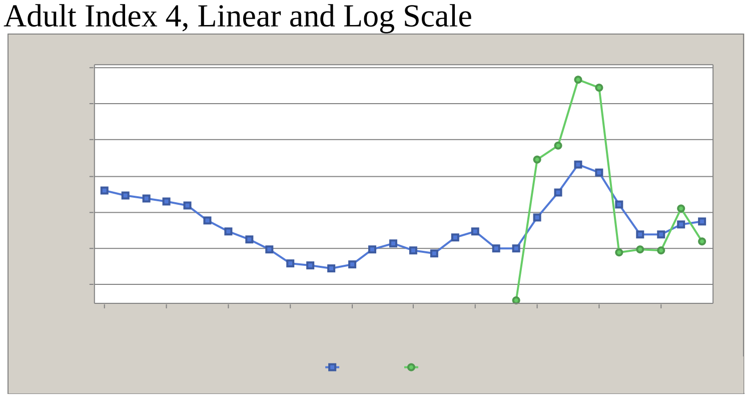
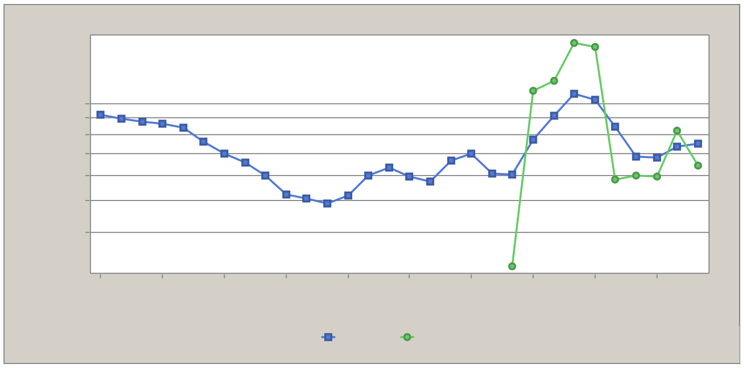
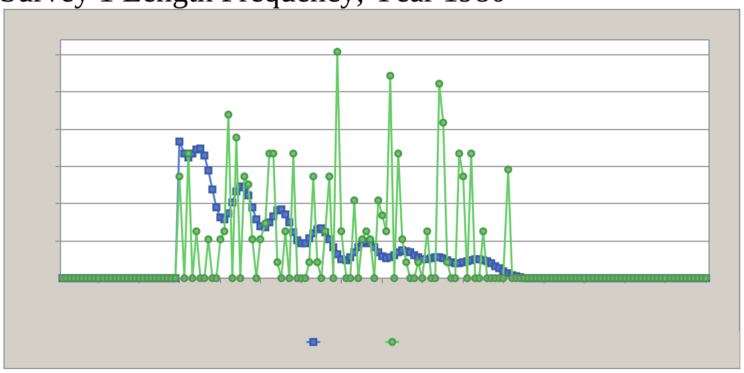
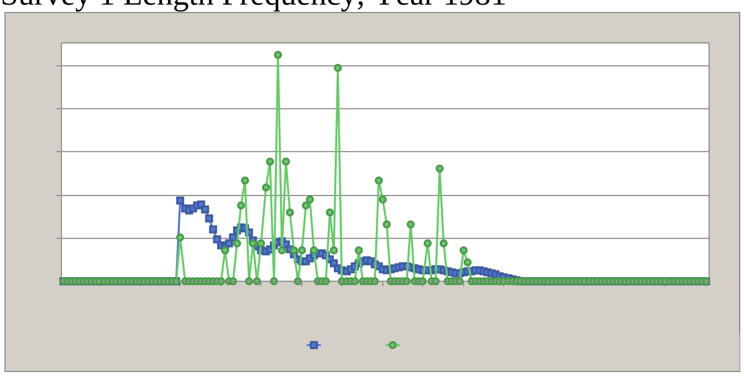




Survey 1 Length Frequency, Year 1980



Survey 1 Length Frequency, Year 1981



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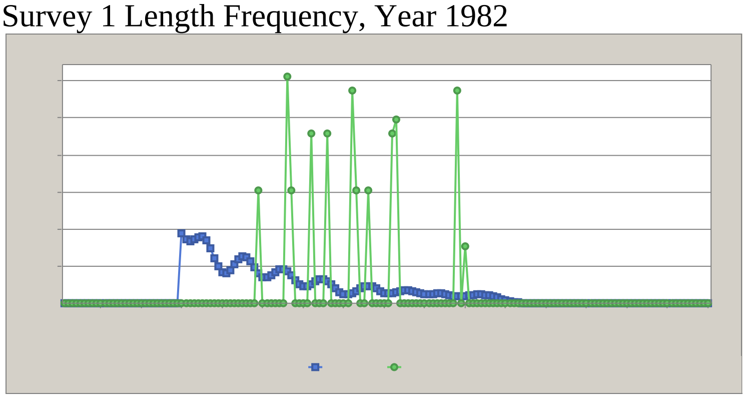

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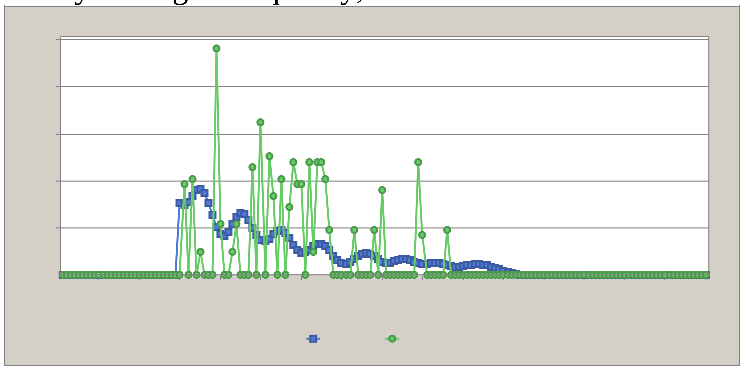

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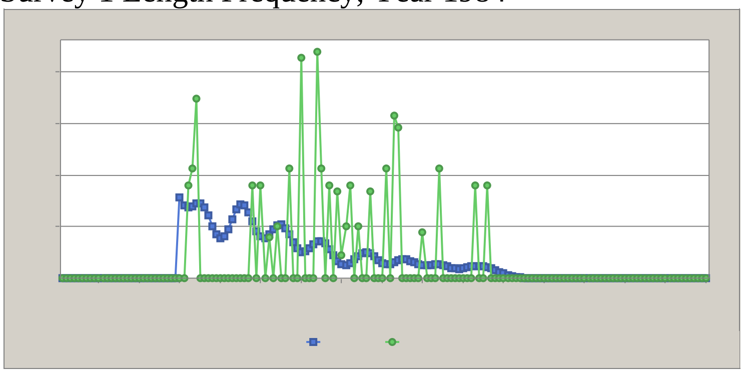

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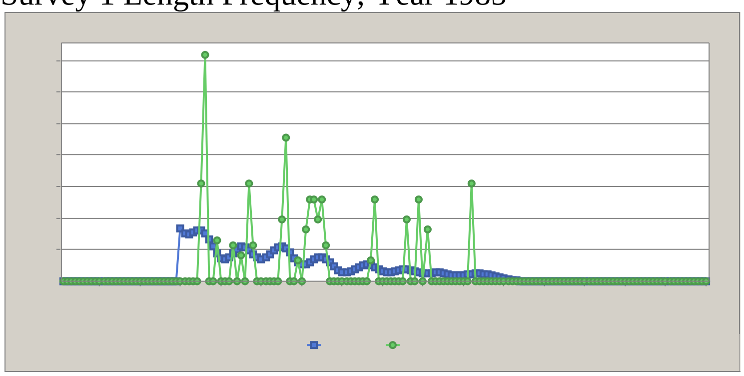

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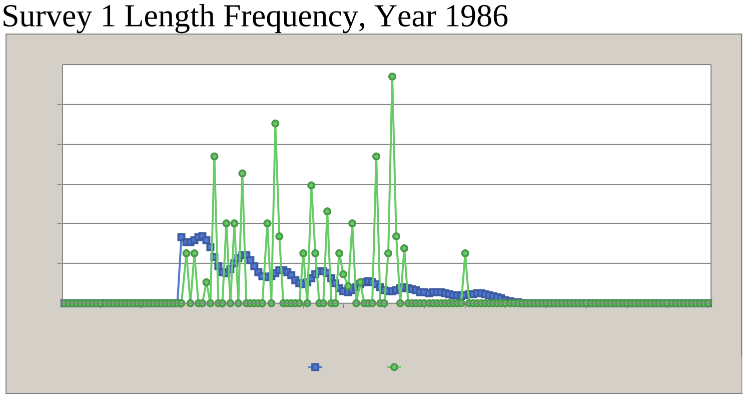

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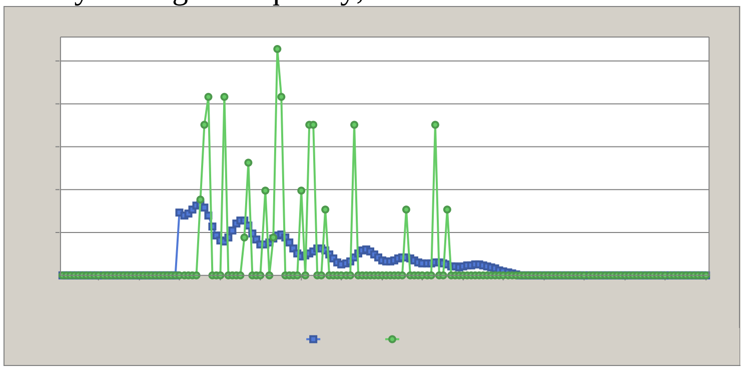

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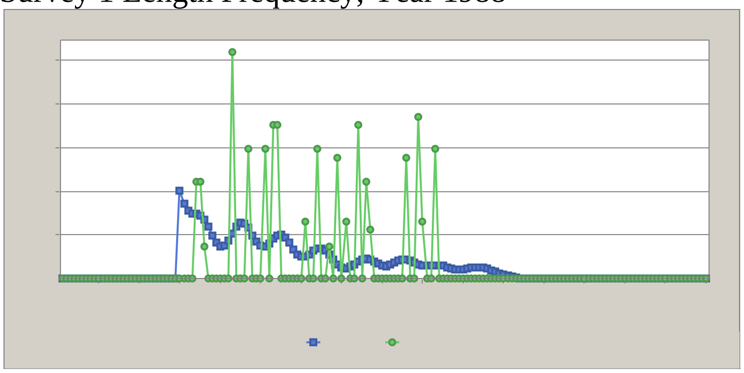

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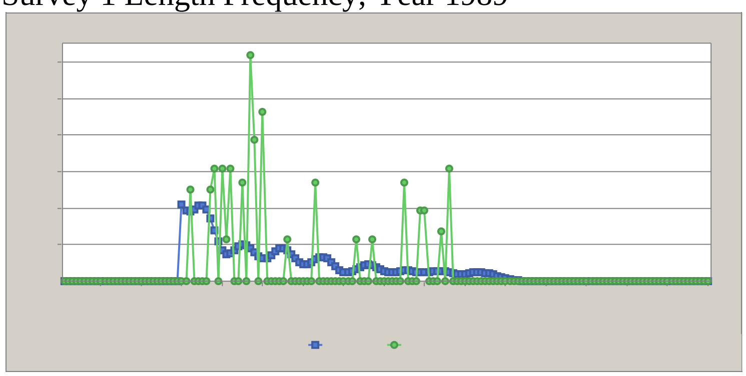

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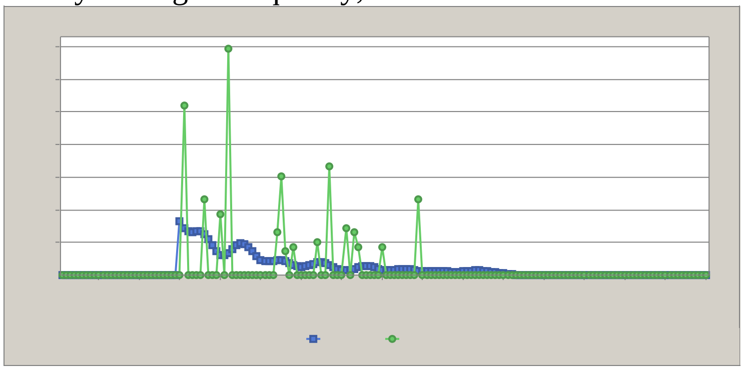

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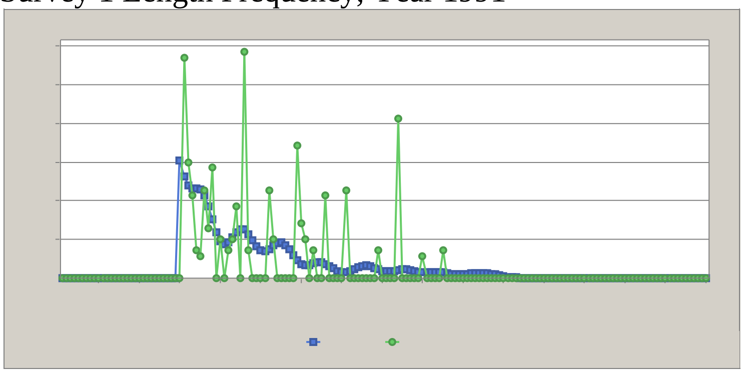

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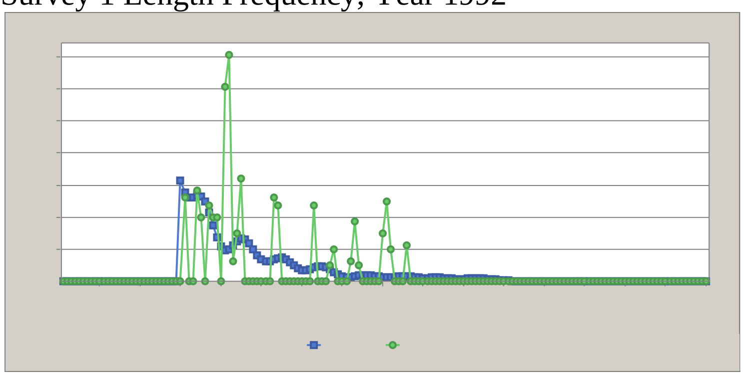

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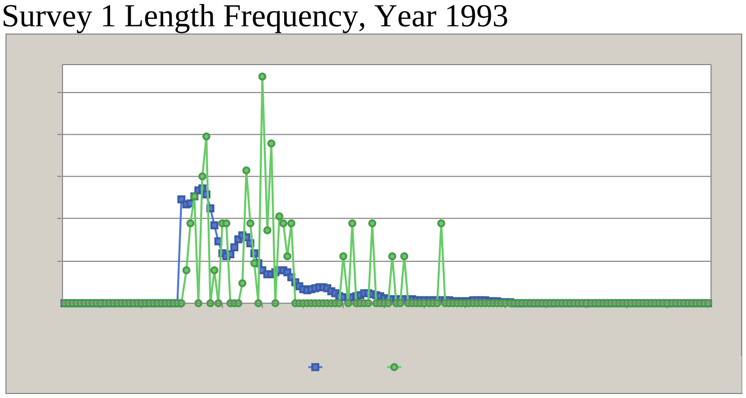

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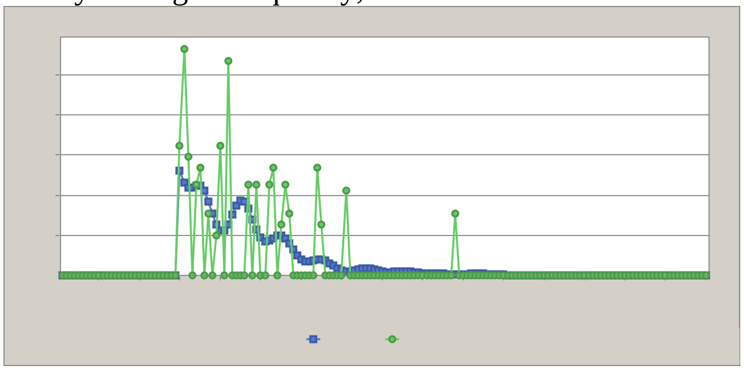

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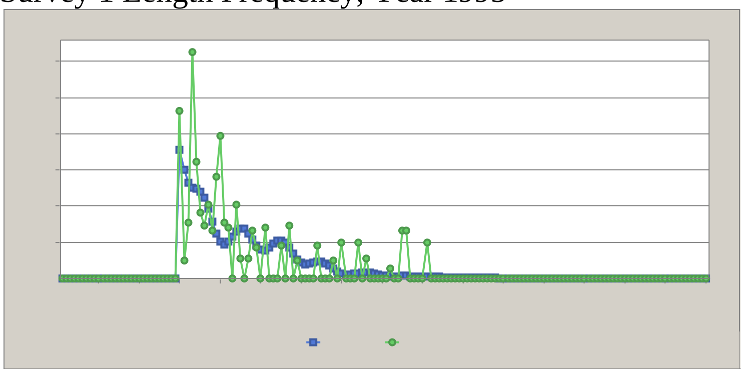

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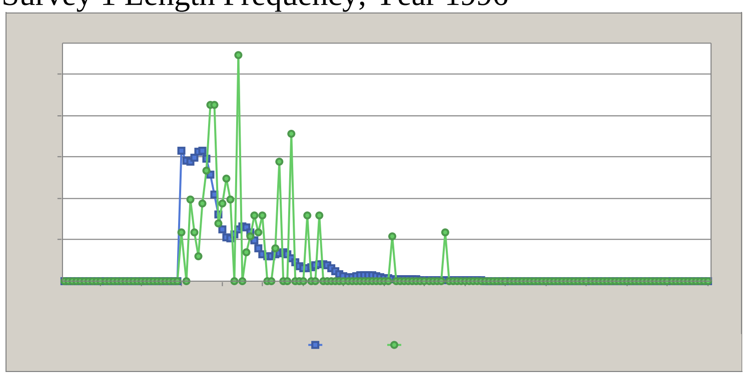

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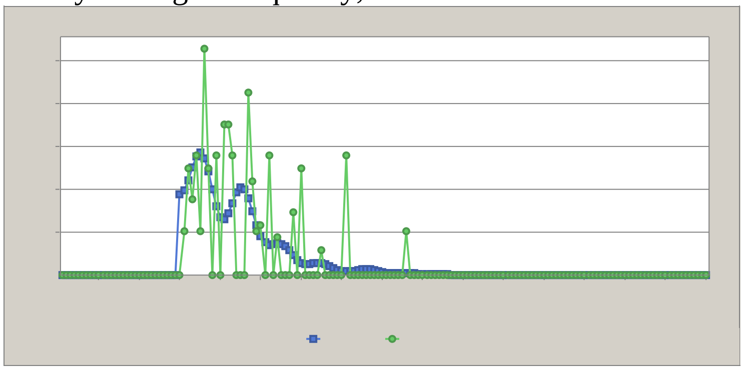

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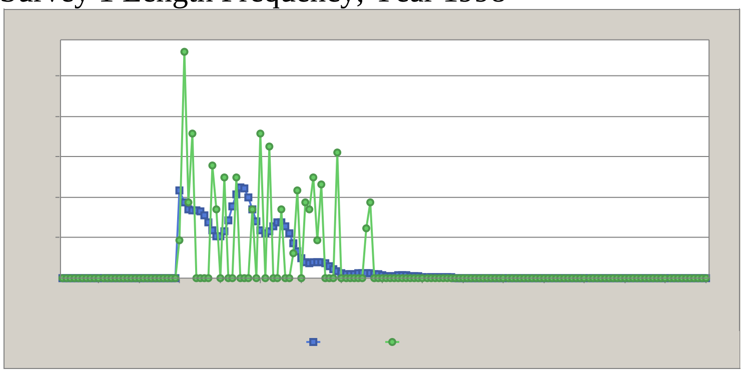

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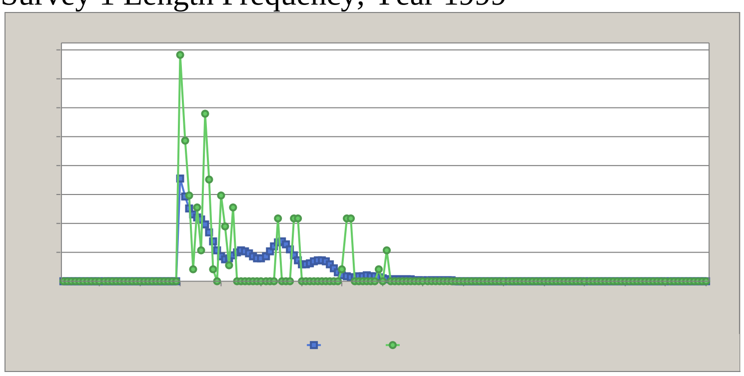

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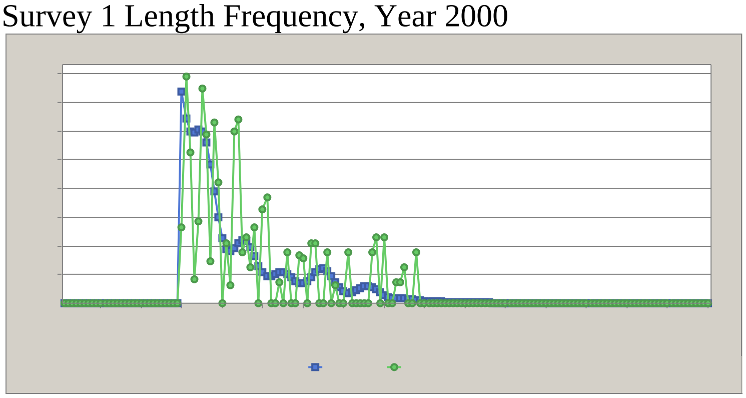

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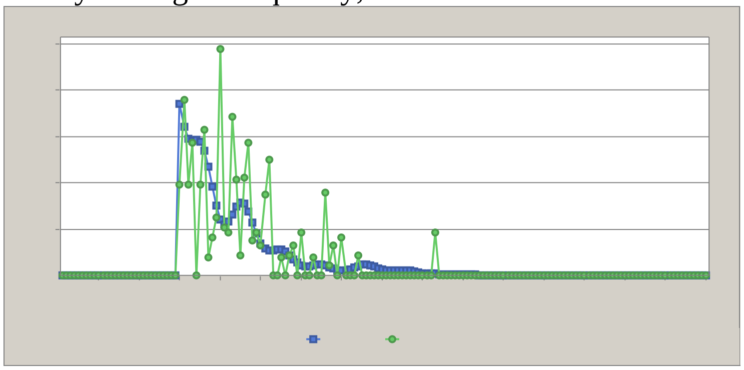

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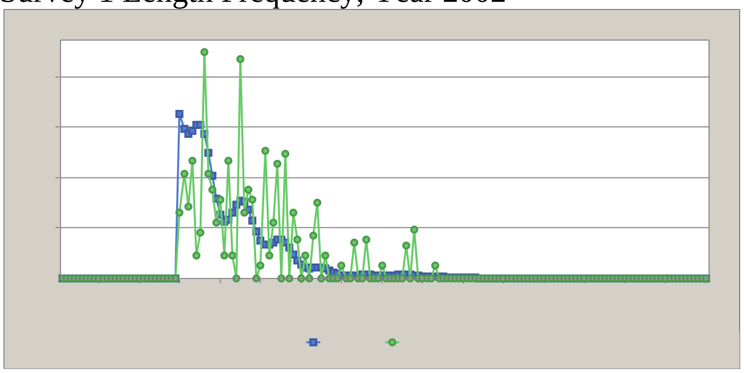

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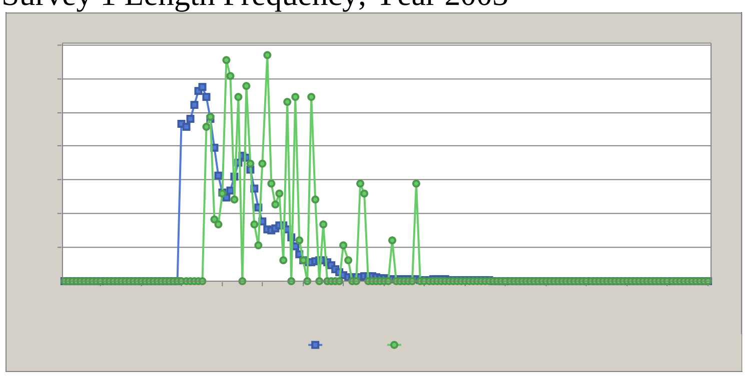

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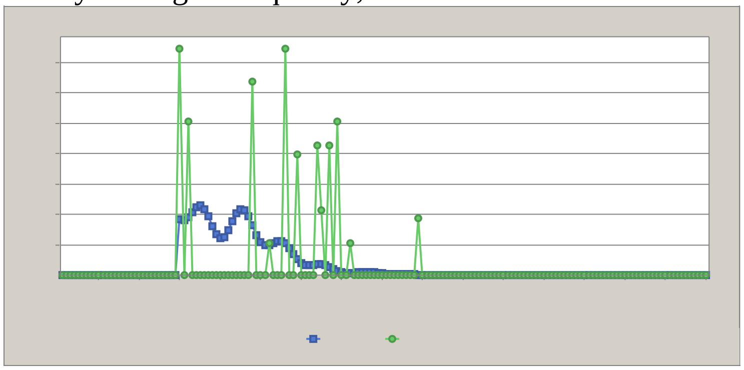

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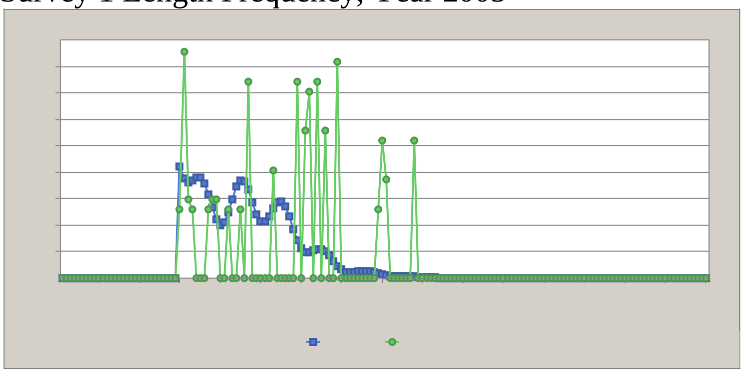

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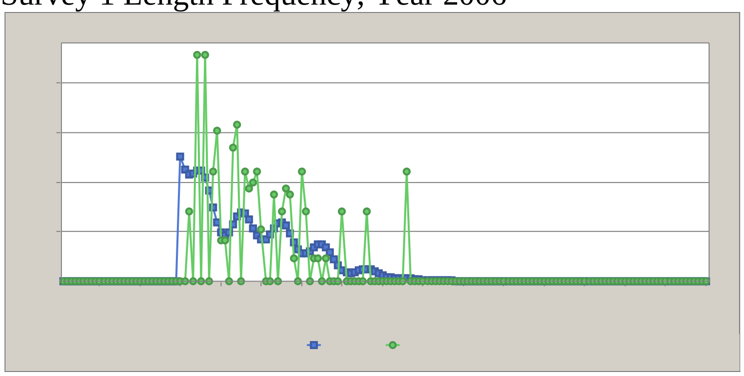

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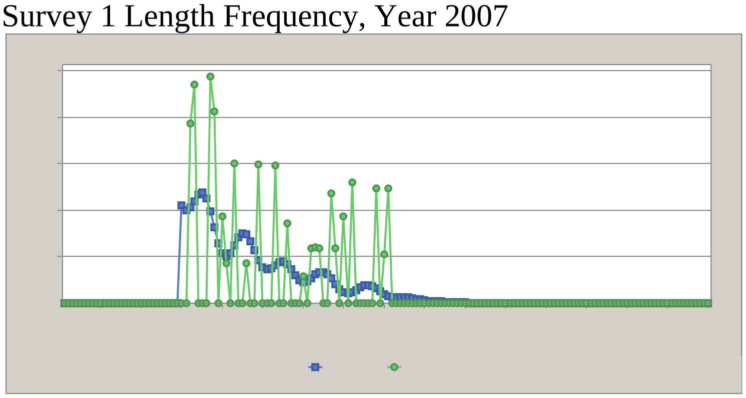
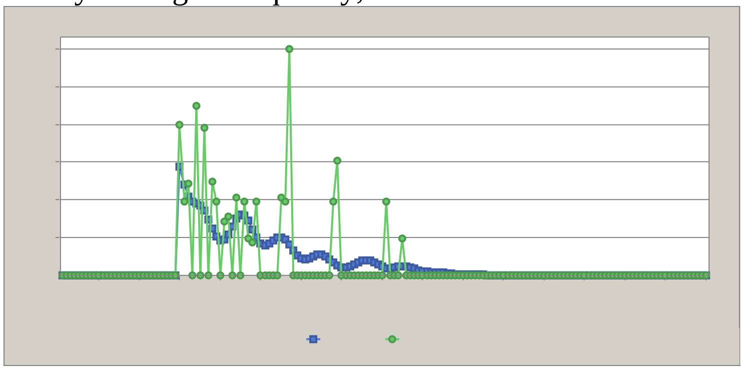


Survey 1 Length Frequency, Year 2008



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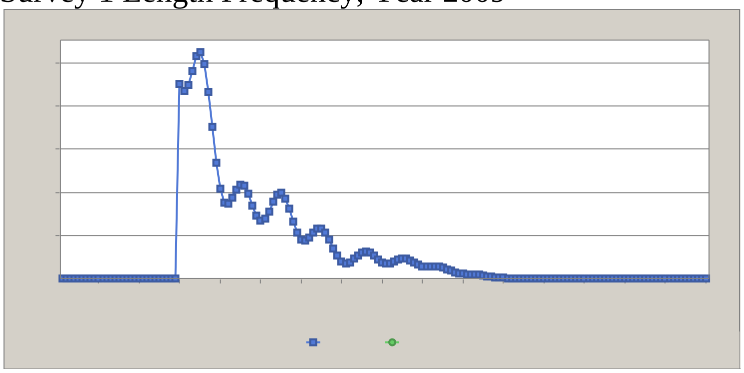
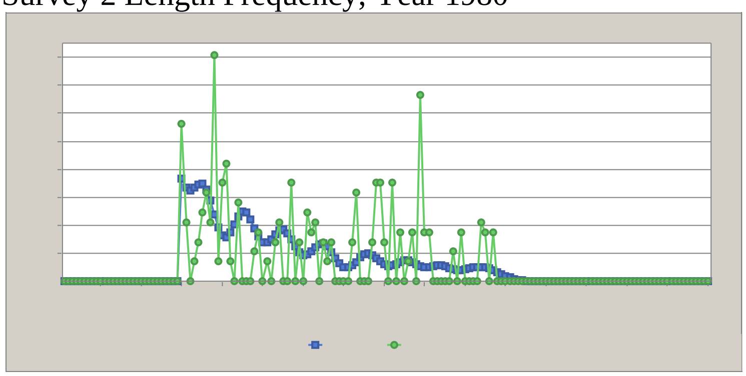


Survey 2 Length Frequency, Year 1980



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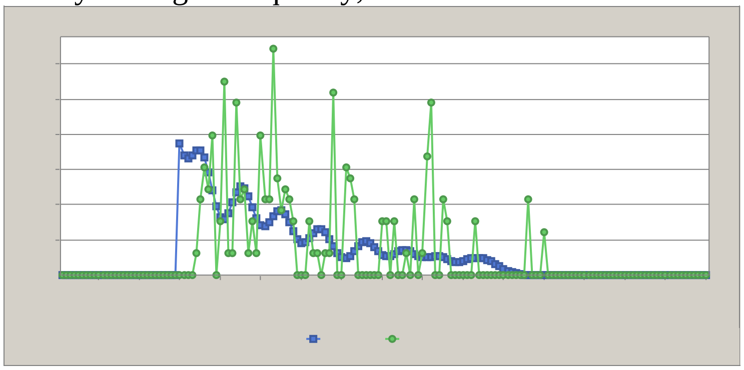

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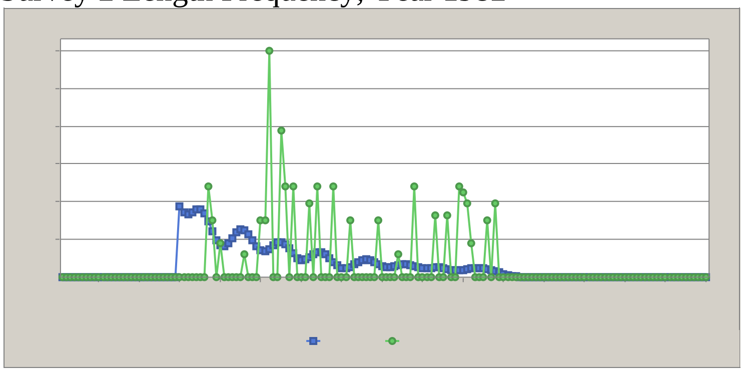

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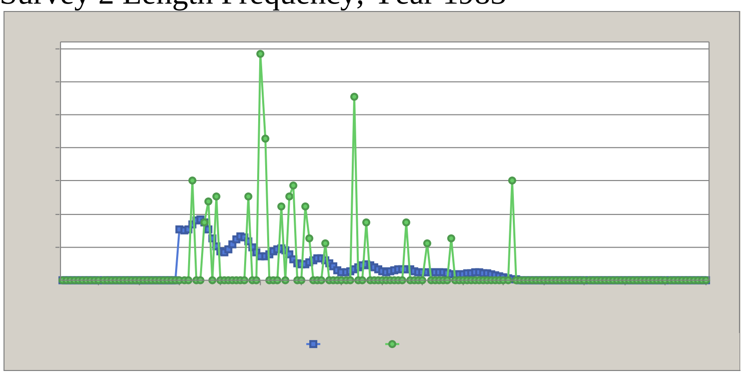

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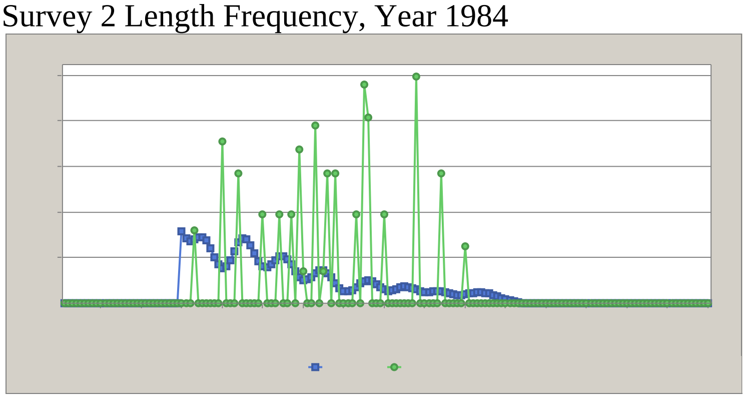

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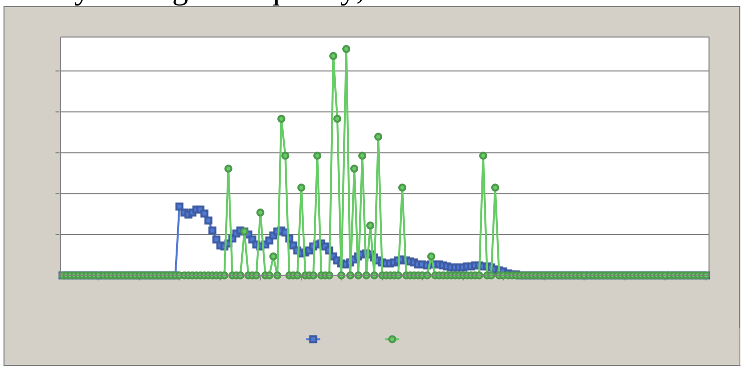

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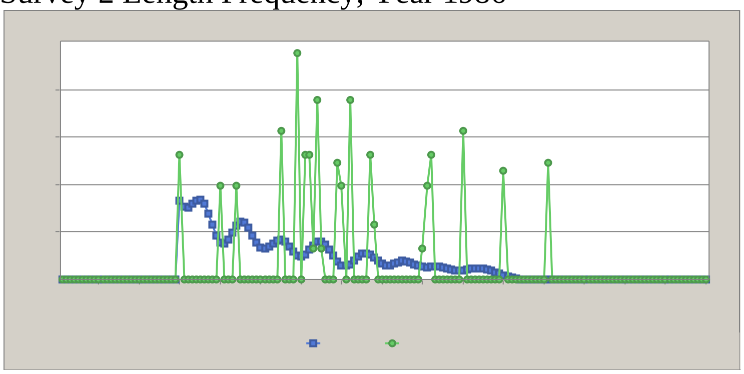

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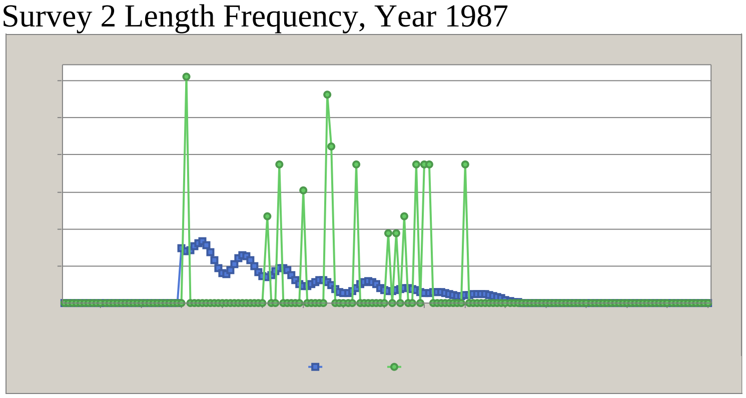

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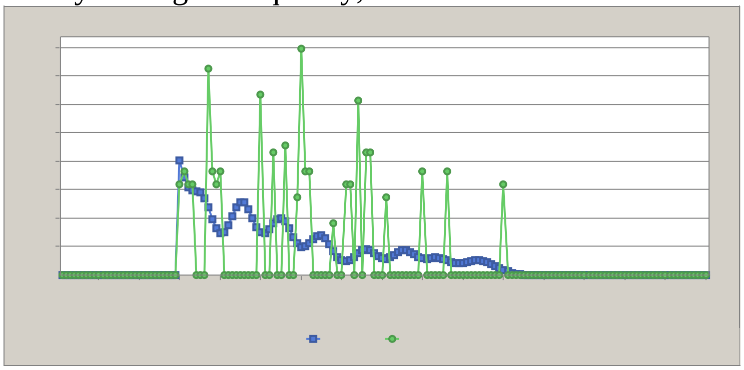

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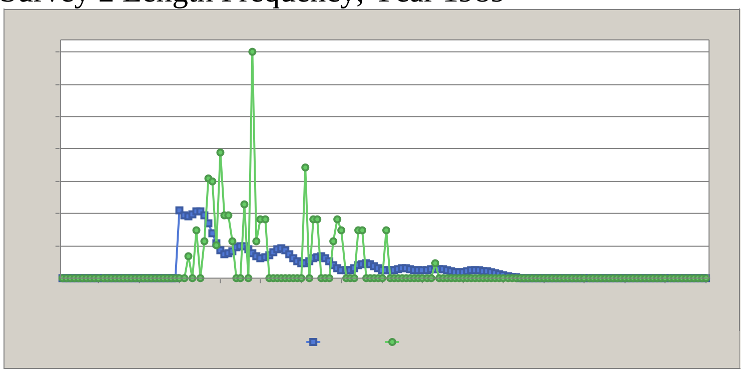

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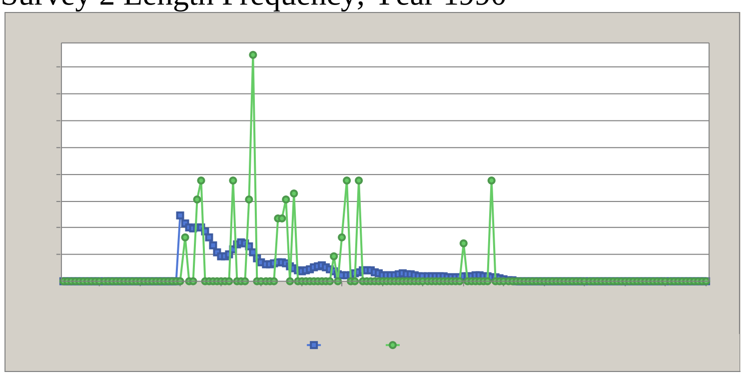

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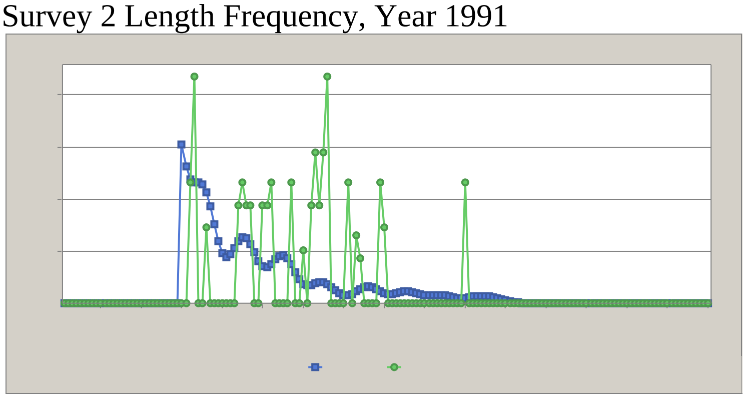

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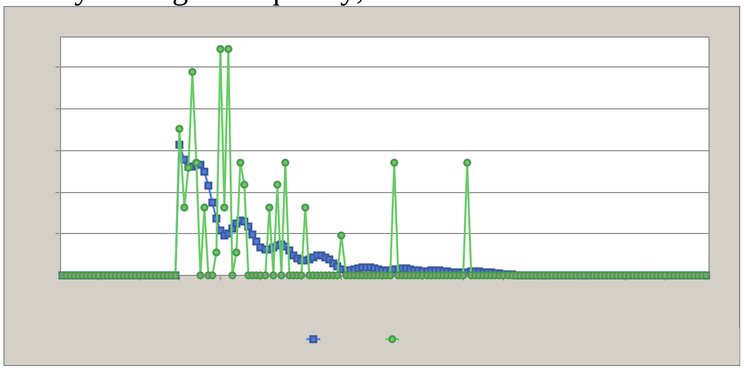

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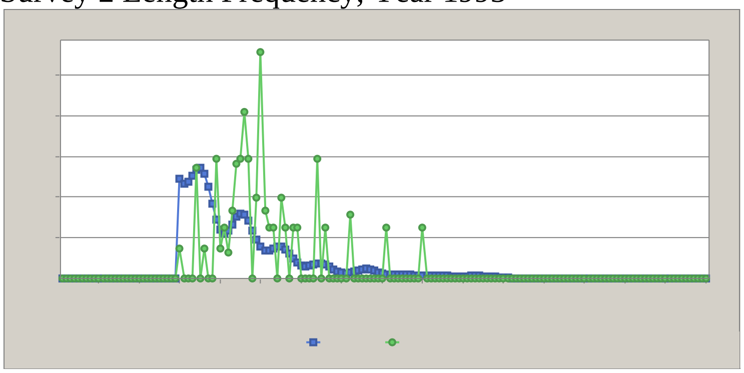

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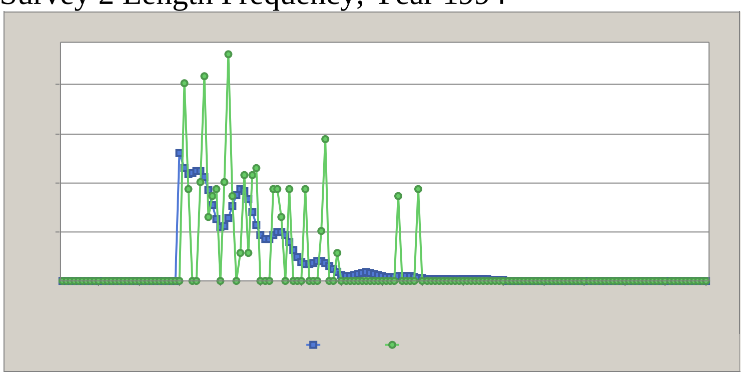

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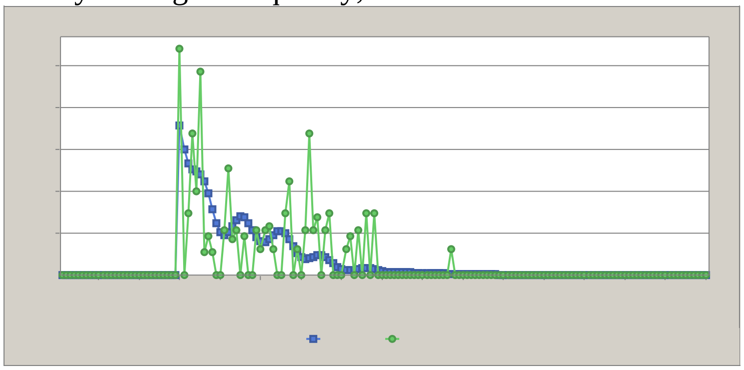

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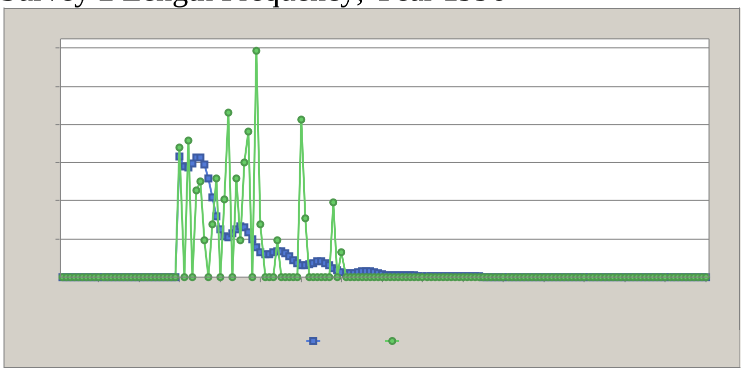

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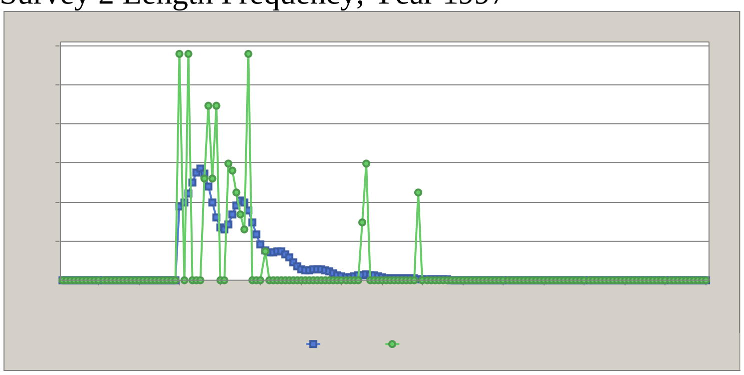

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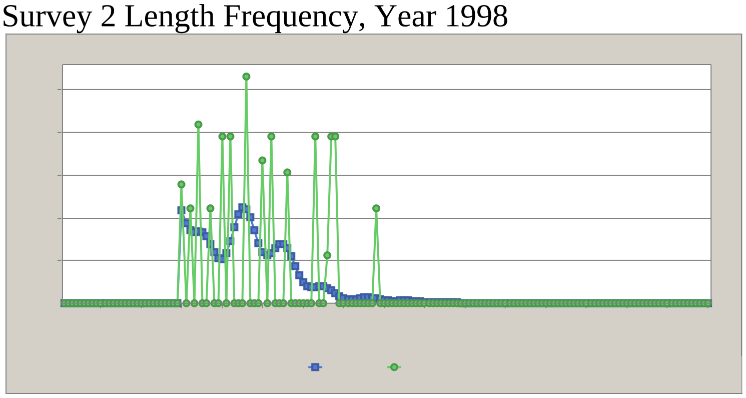

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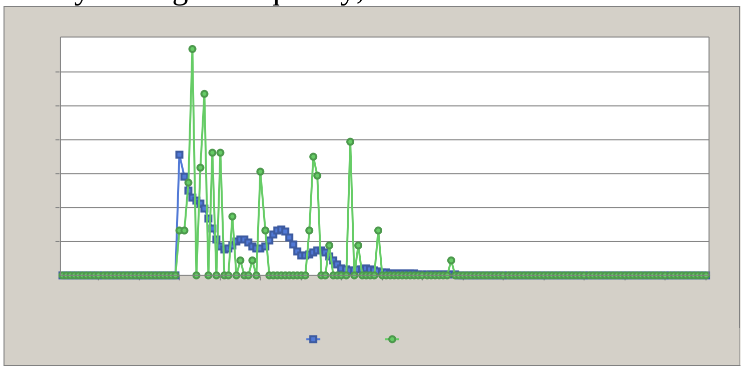

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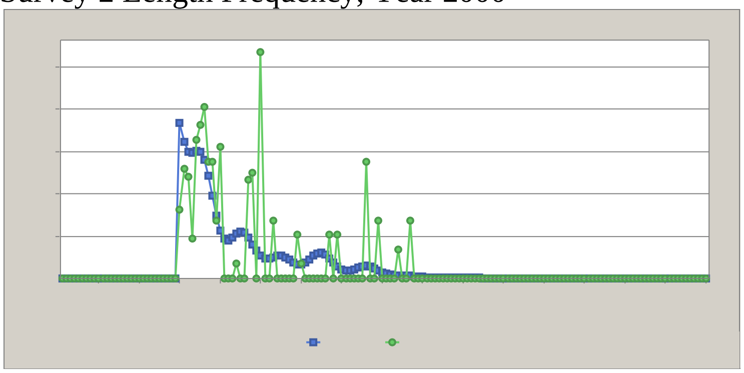

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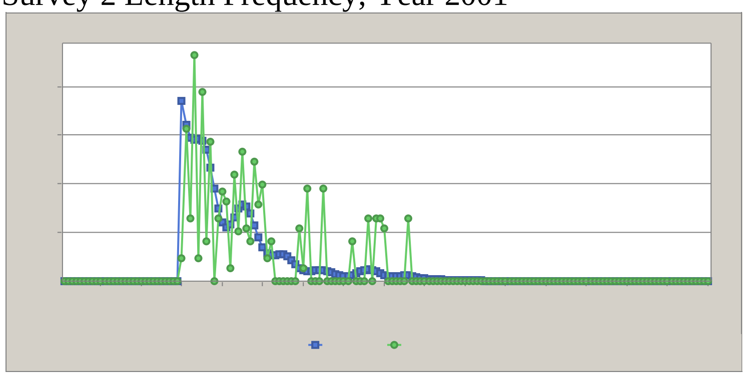

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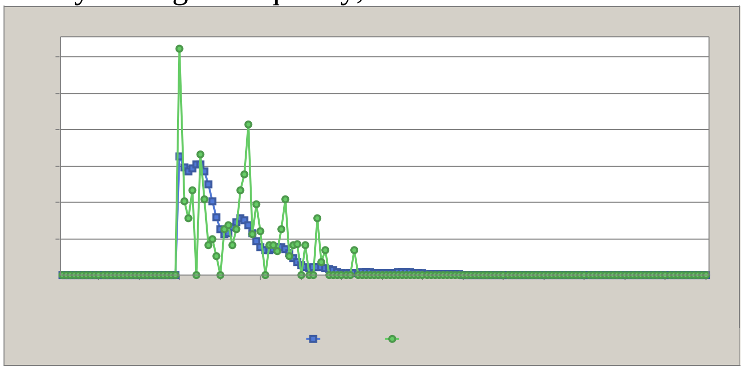

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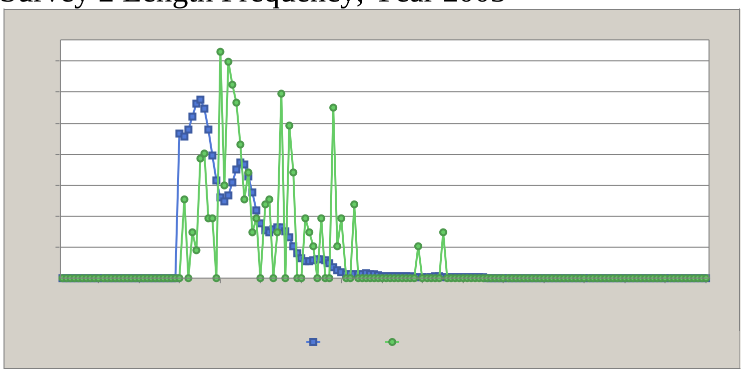

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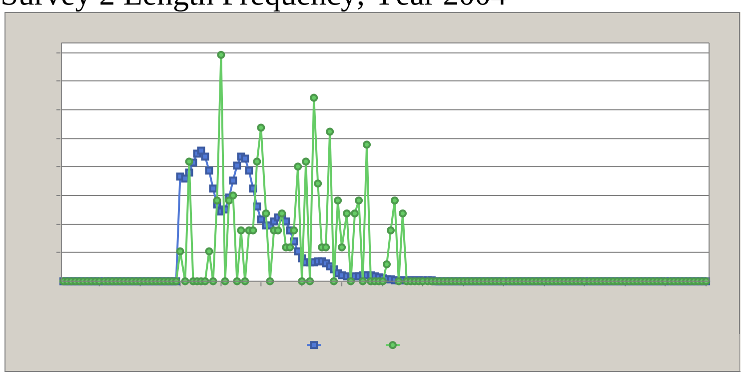

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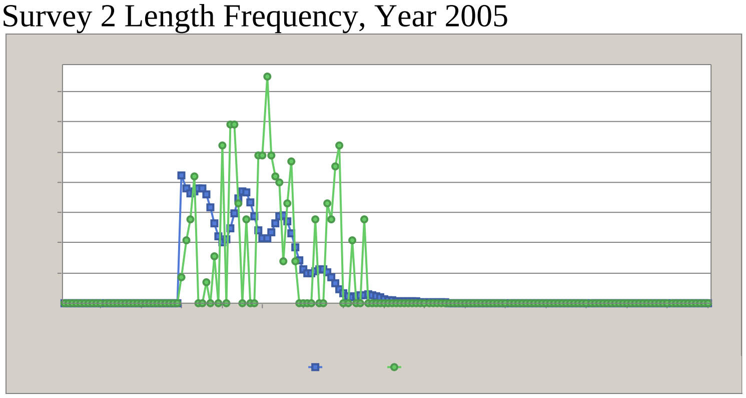

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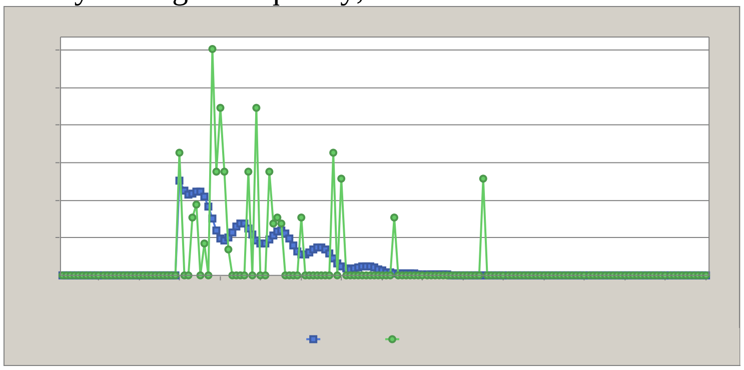
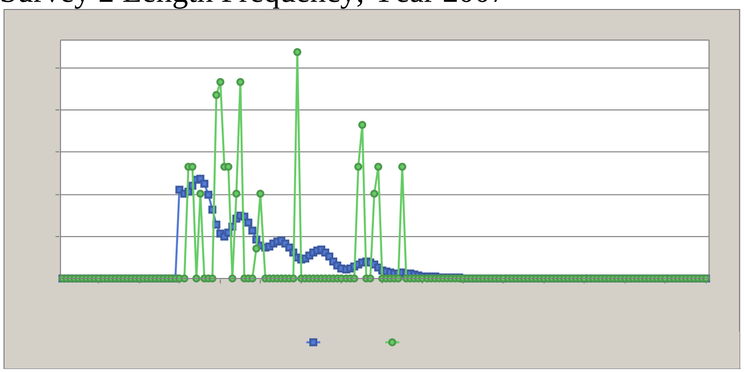
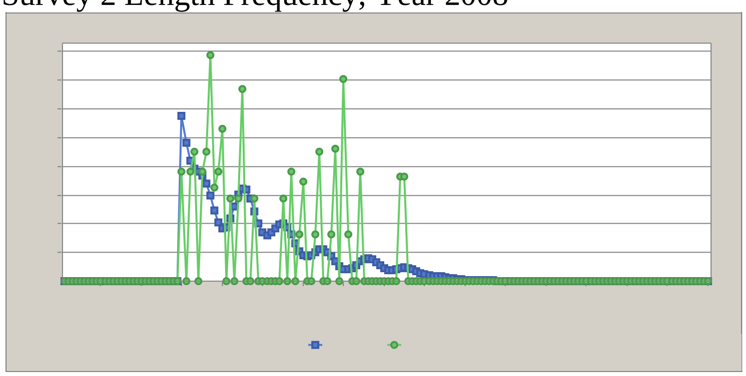


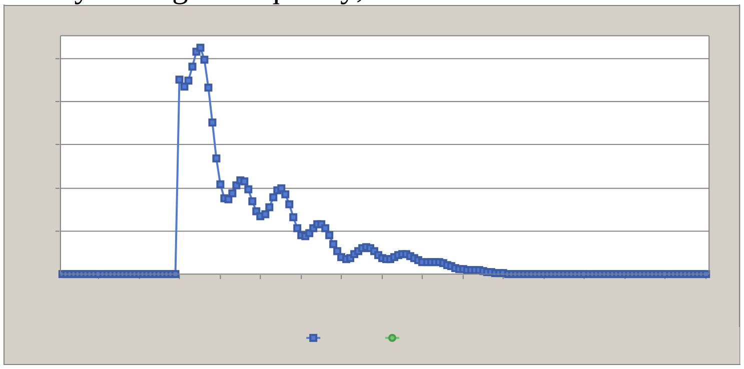
Survey 2 Length Frequency, Year 2007



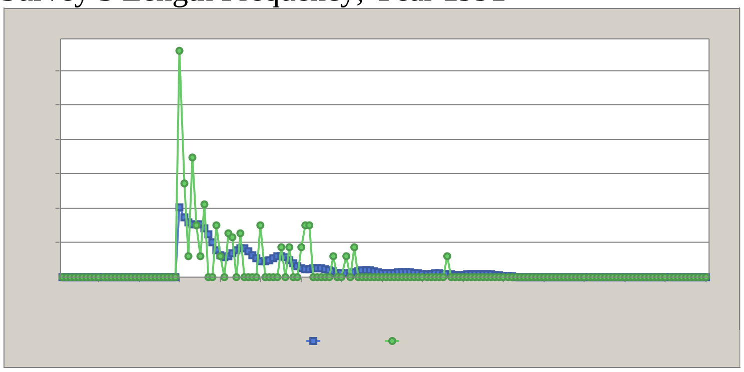
Survey 2 Length Frequency, Year 2008



Survey 2 Length Frequency, Year 2009



Survey 3 Length Frequency, Year 1991



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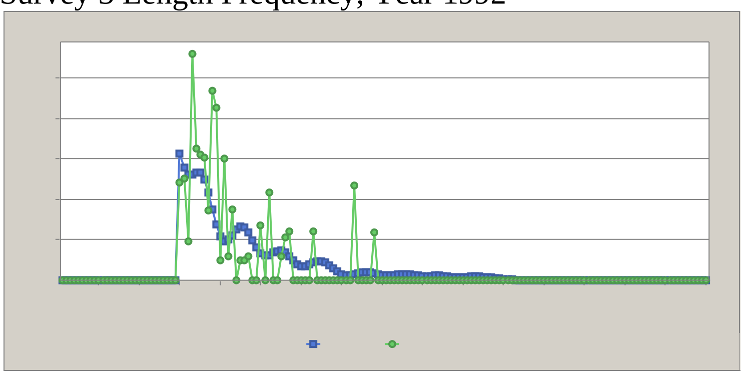

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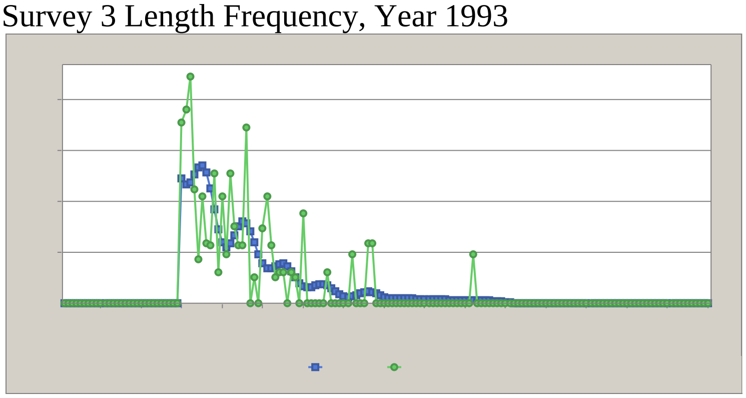

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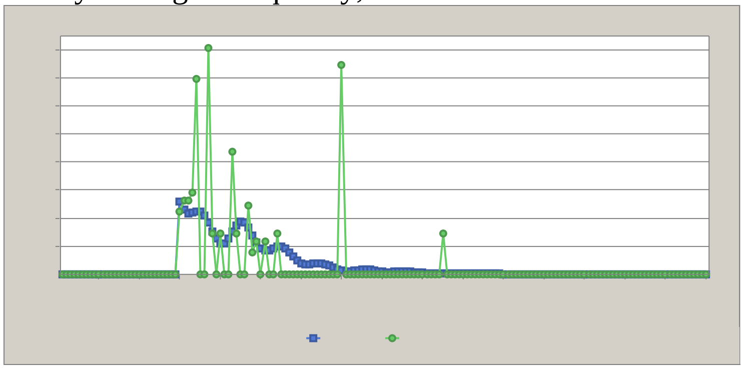

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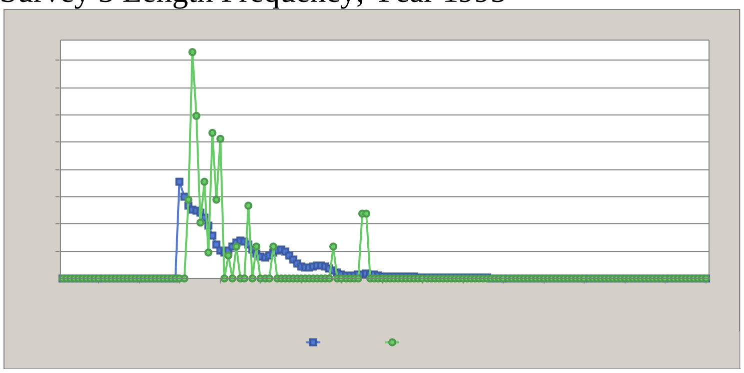

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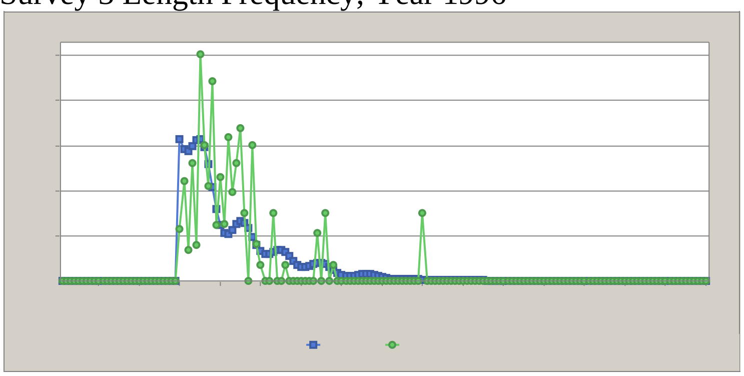

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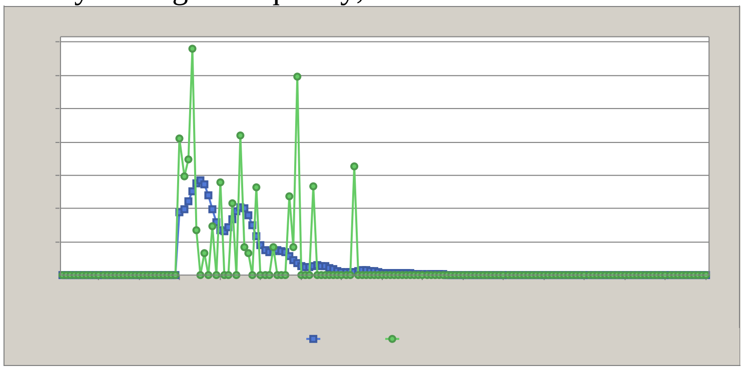

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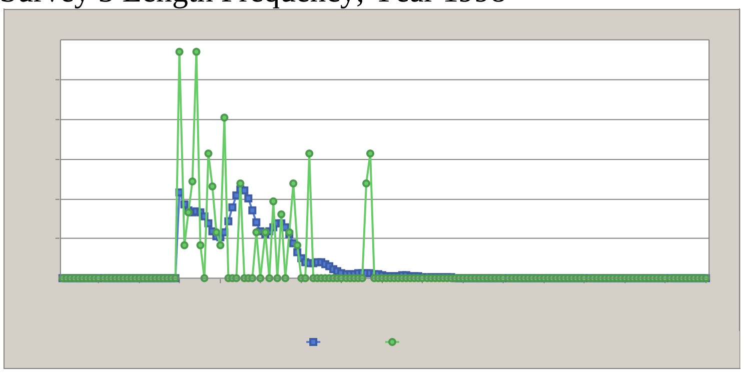

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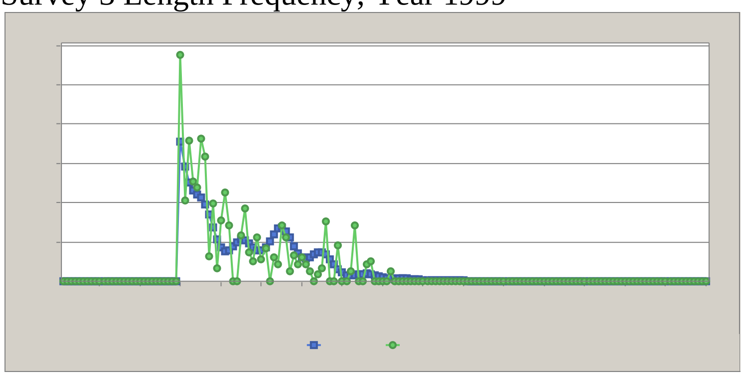

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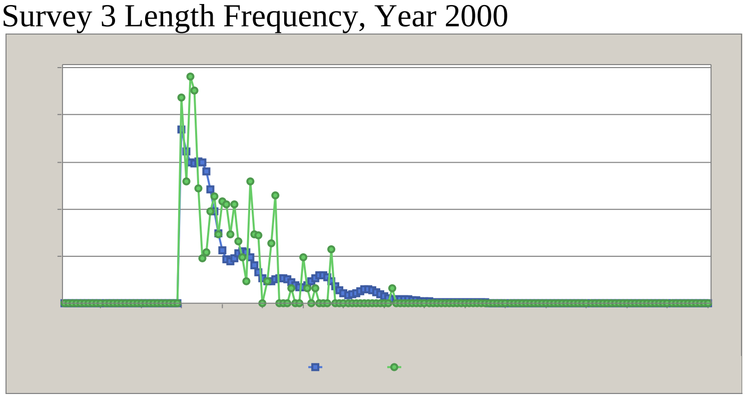
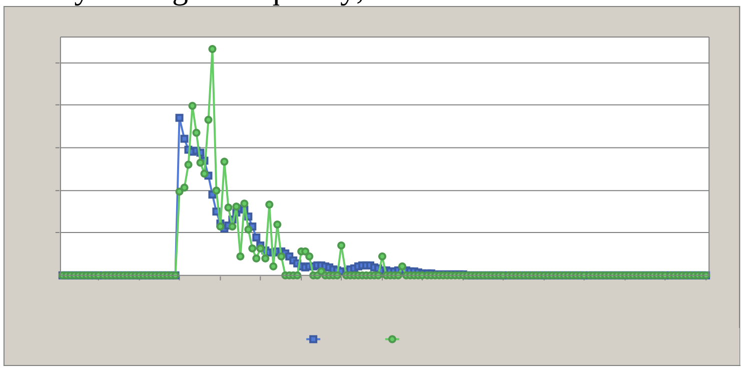
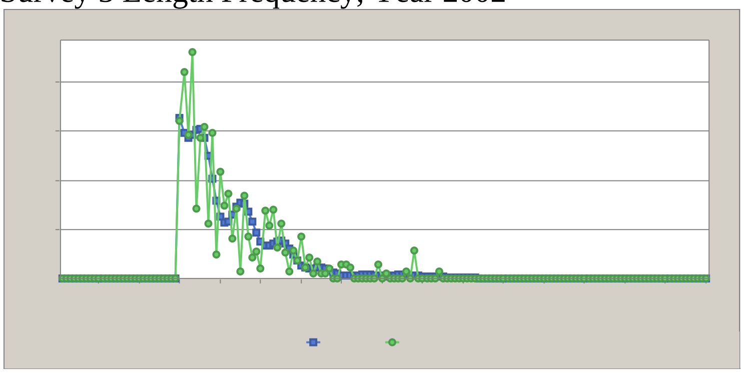


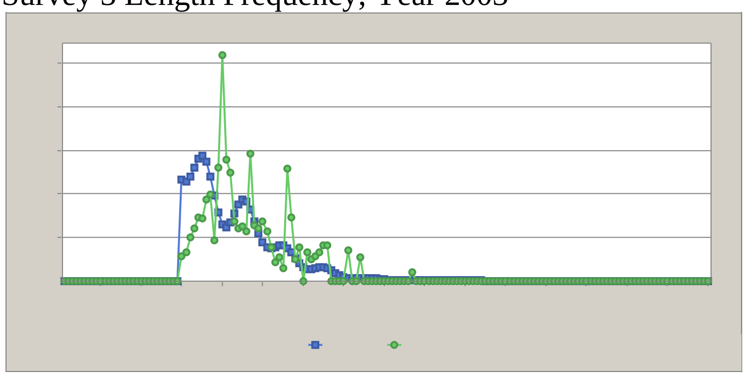
Survey 3 Length Frequency, Year 2001



Survey 3 Length Frequency, Year 2002



Survey 3 Length Frequency, Year 2003



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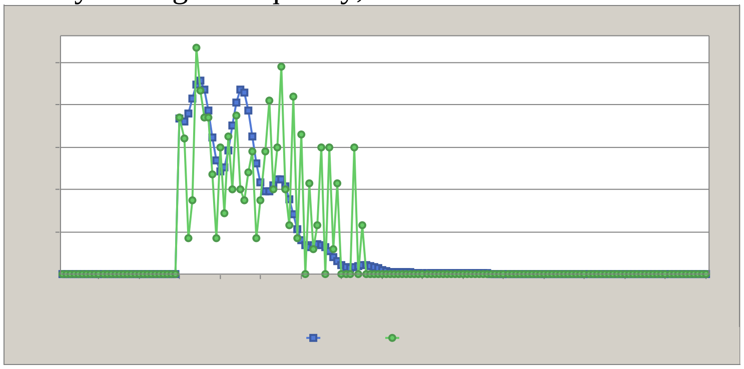

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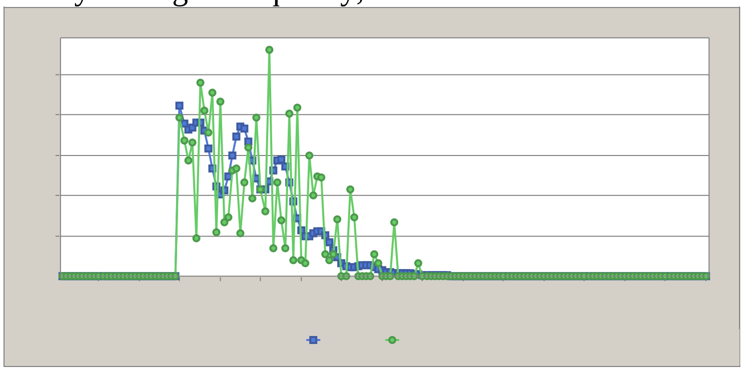

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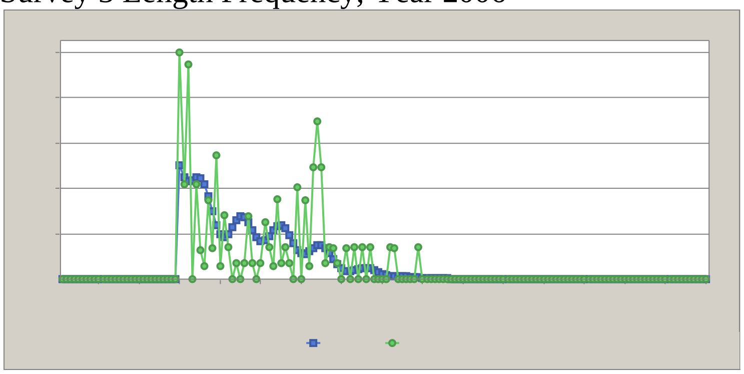
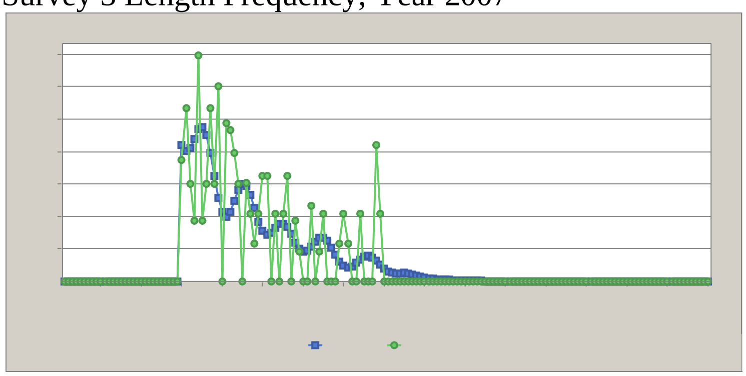
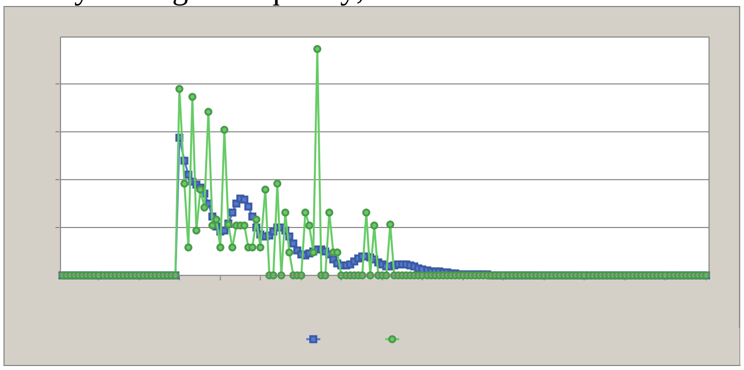


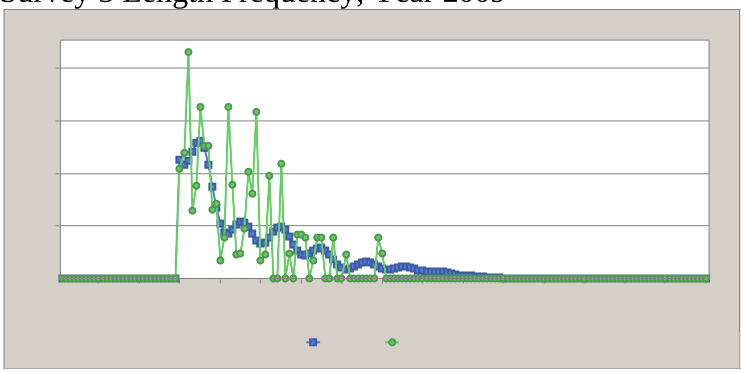
Survey 3 Length Frequency, Year 2007



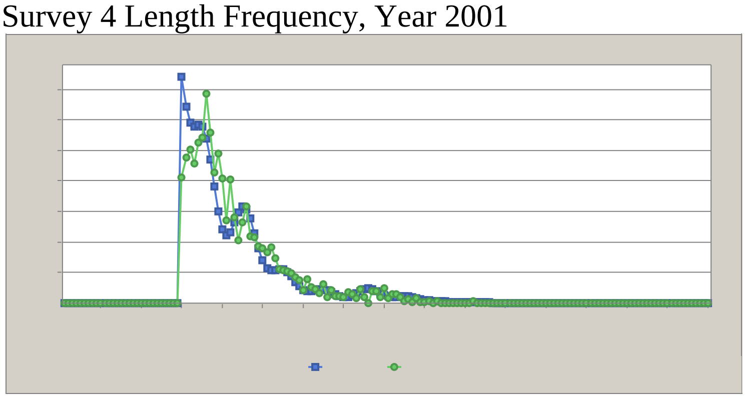
Survey 3 Length Frequency, Year 2008



Survey 3 Length Frequency, Year 2009



Survey 4 Length Frequency, Year 2001



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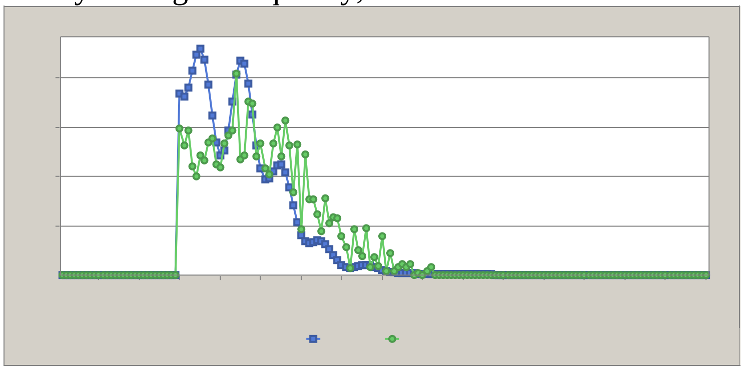
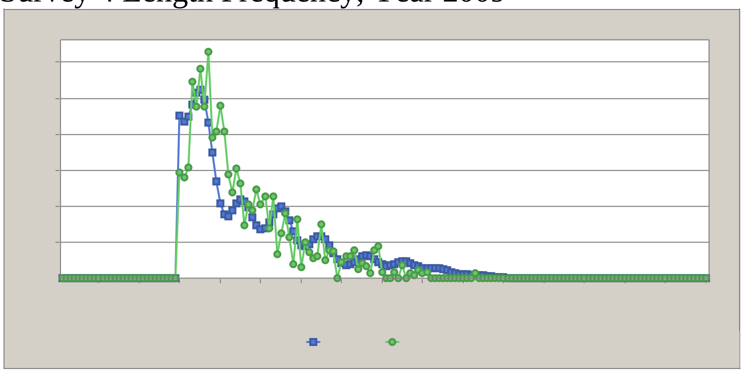
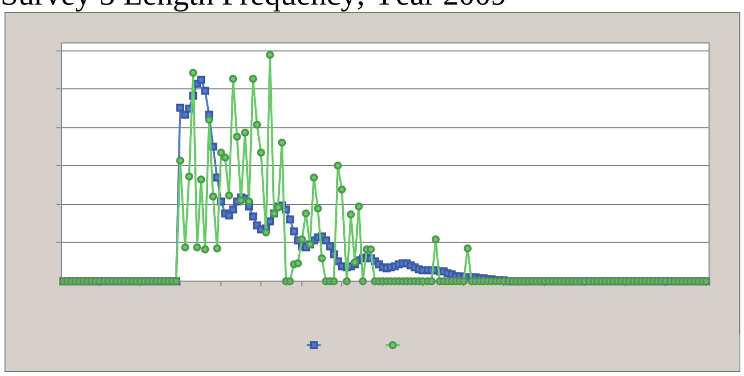


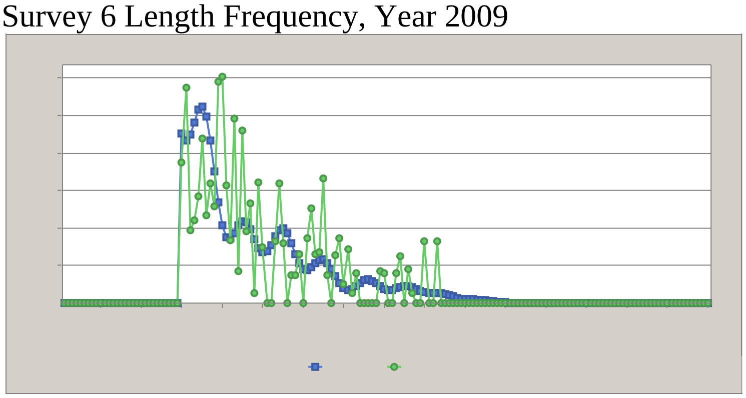
Survey 4 Length Frequency, Year 2009



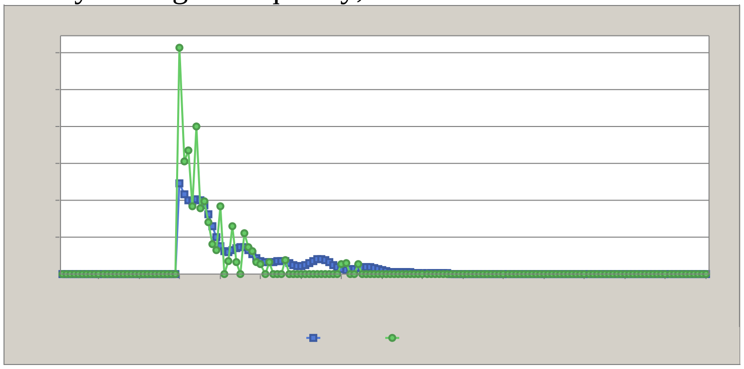
Survey 5 Length Frequency, Year 2009



Survey 6 Length Frequency, Year 2009



Survey 7 Length Frequency, Year 2000



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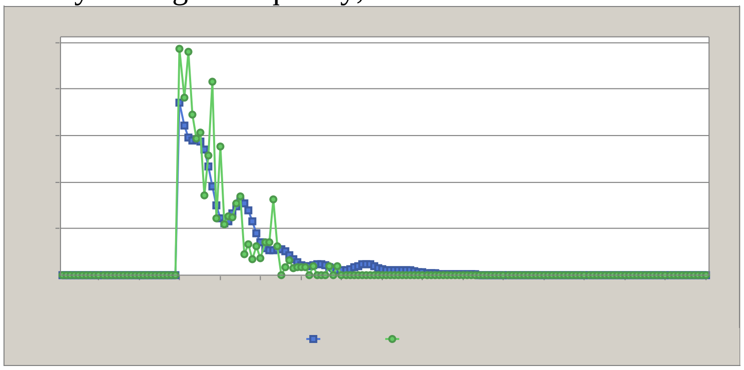

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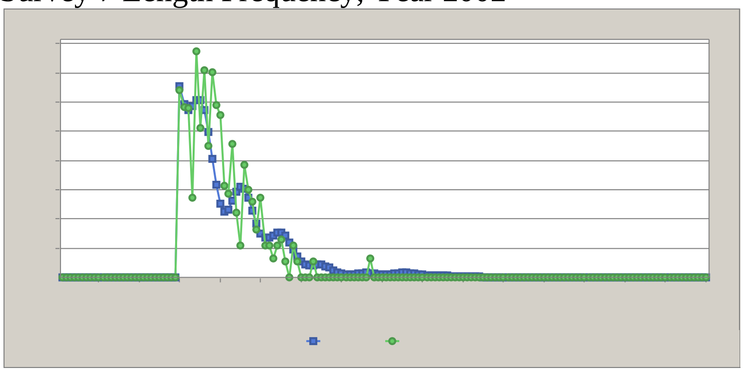

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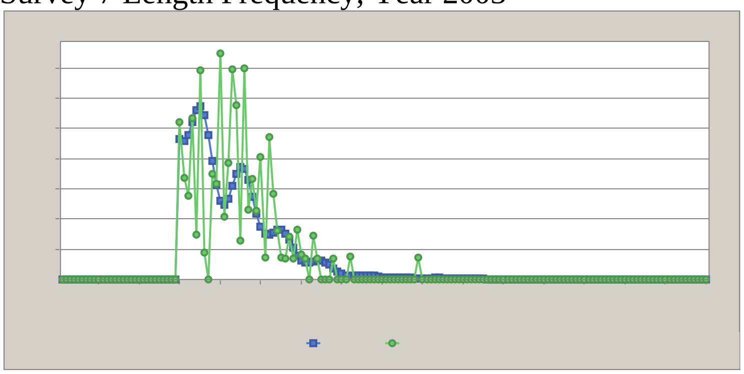

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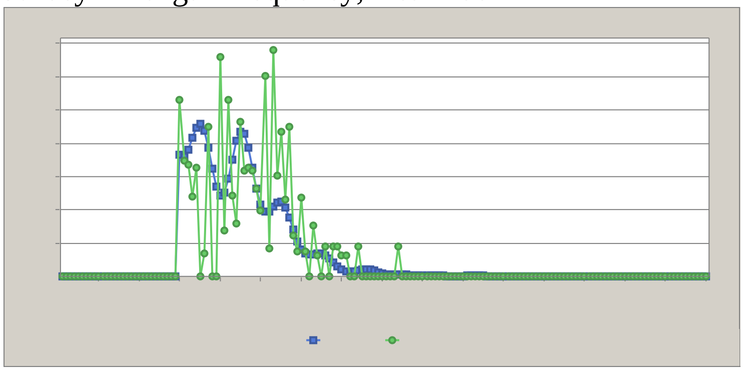

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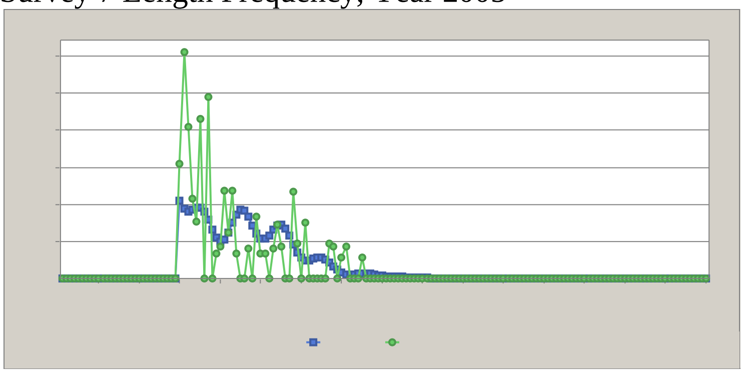

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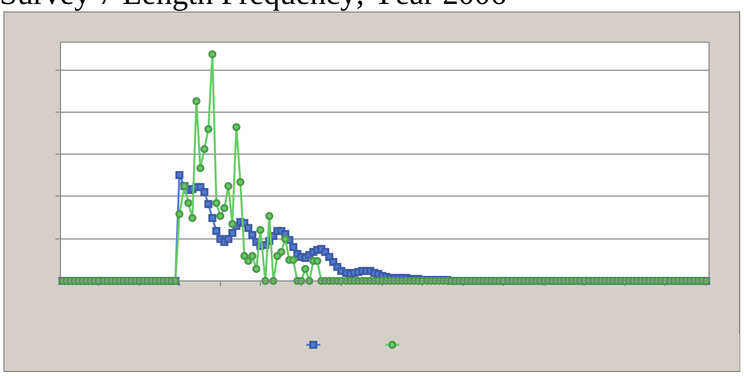

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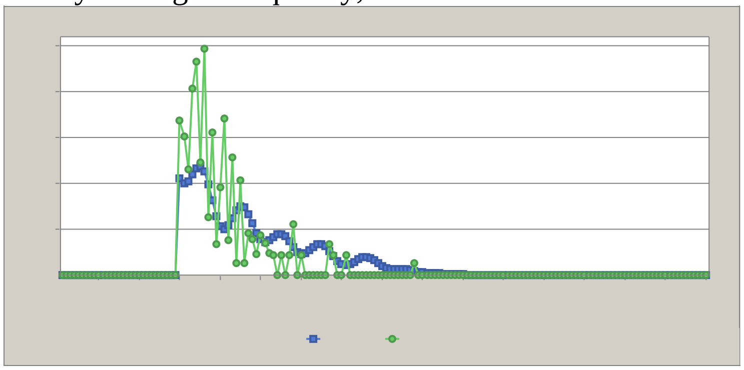

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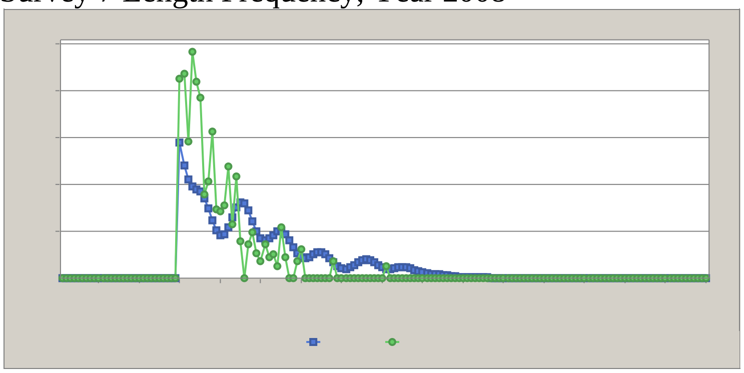

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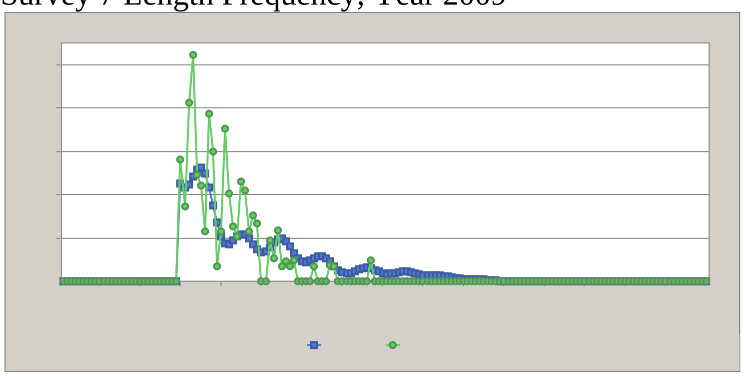
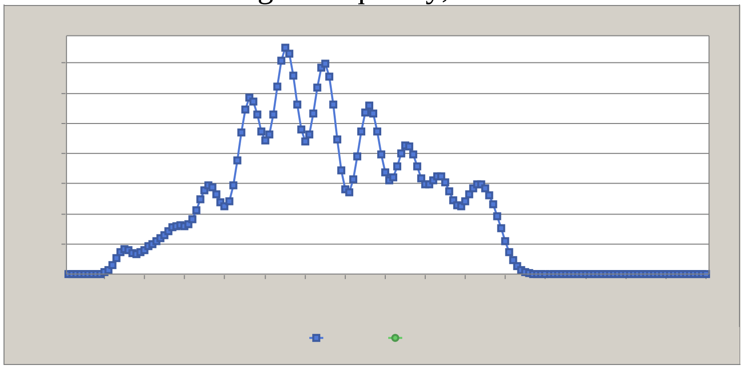
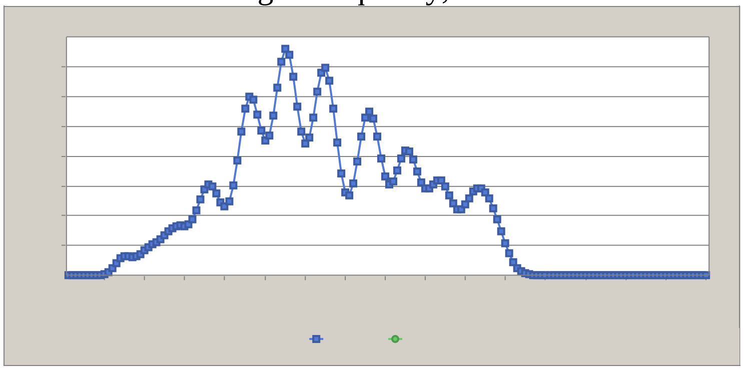


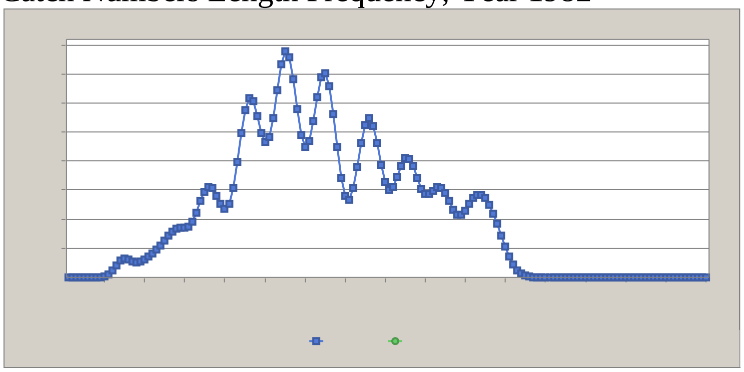
Catch Numbers Length Frequency, Year 1980



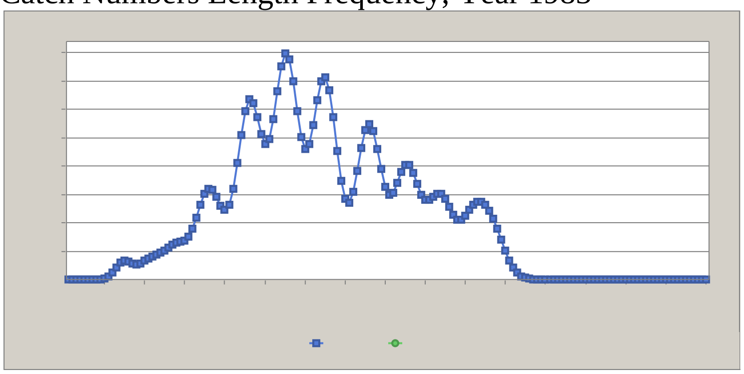
Catch Numbers Length Frequency, Year 1981



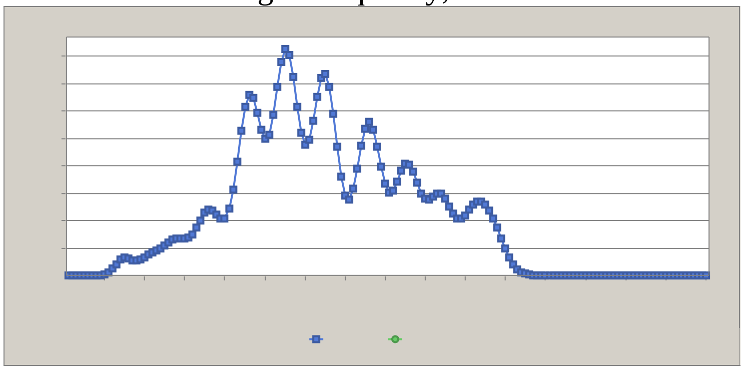
Catch Numbers Length Frequency, Year 1982



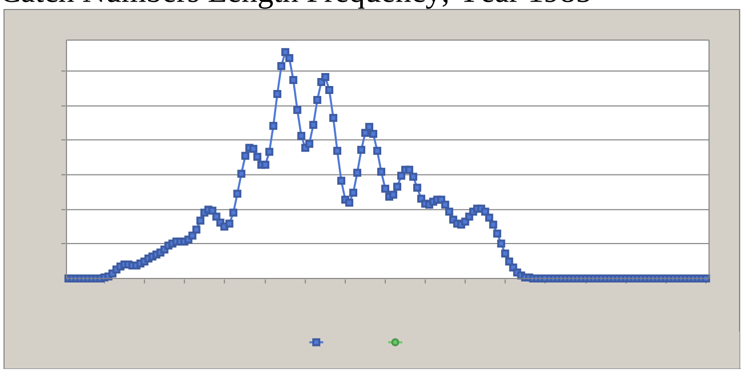
Catch Numbers Length Frequency, Year 1983



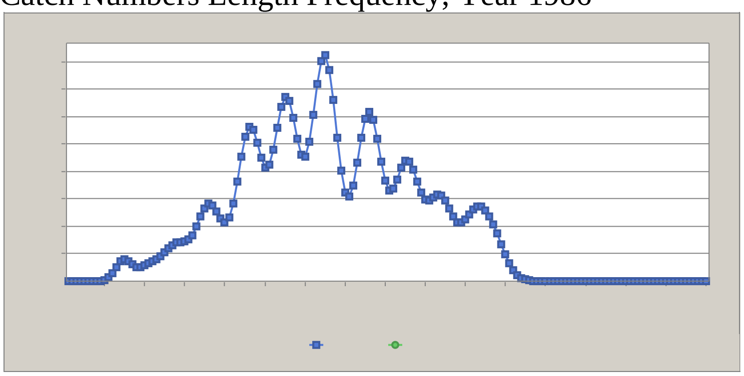
Catch Numbers Length Frequency, Year 1984



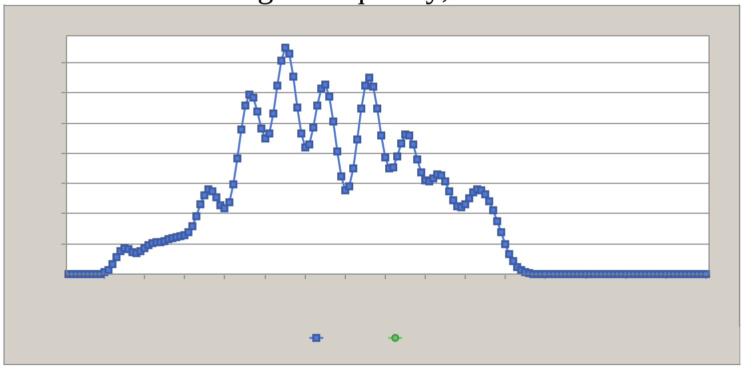
Catch Numbers Length Frequency, Year 1985



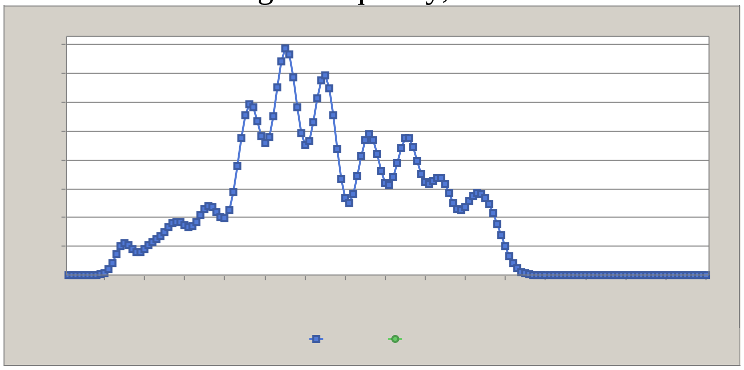
Catch Numbers Length Frequency, Year 1986



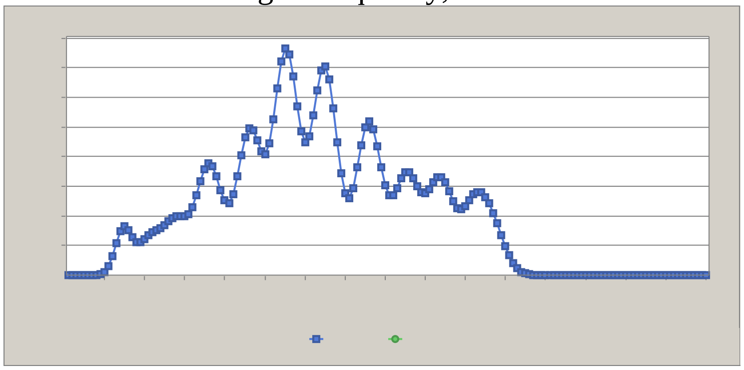
Catch Numbers Length Frequency, Year 1987



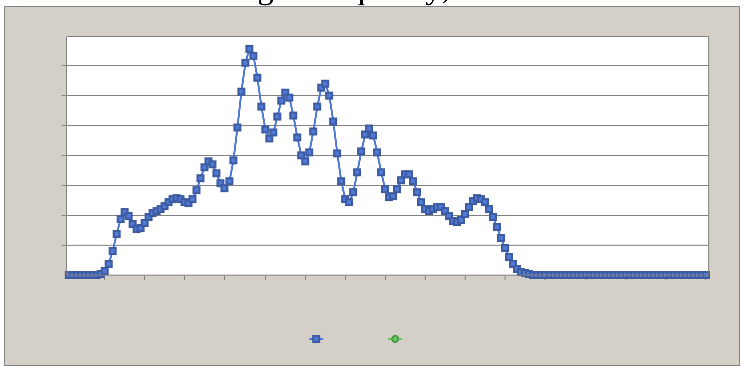
Catch Numbers Length Frequency, Year 1988



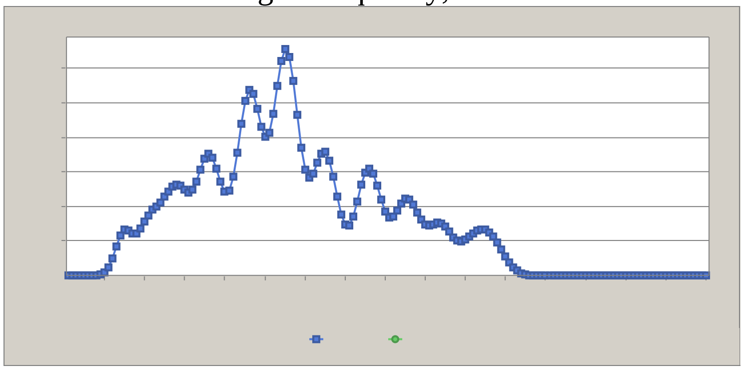
Catch Numbers Length Frequency, Year 1989



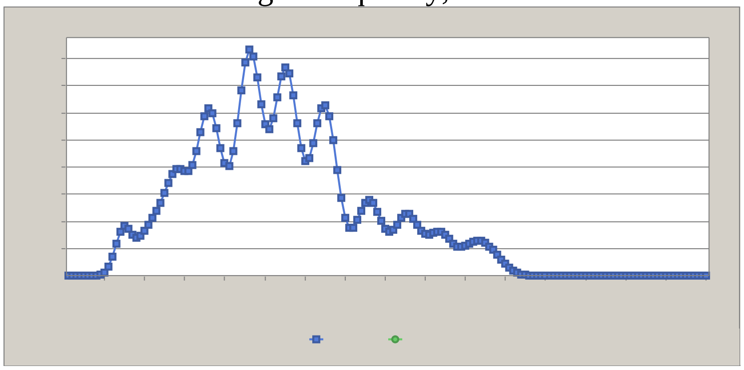
Catch Numbers Length Frequency, Year 1990



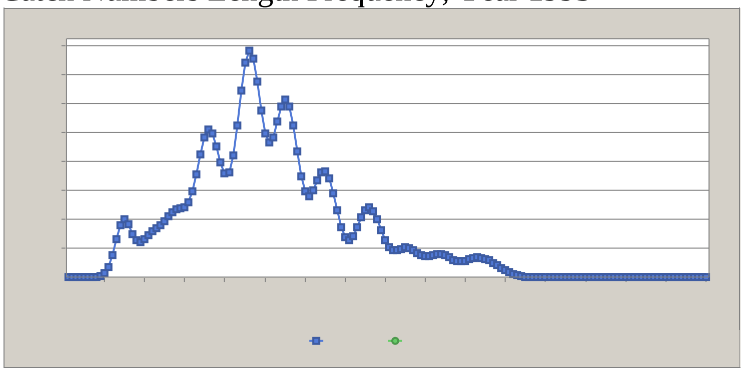
Catch Numbers Length Frequency, Year 1991



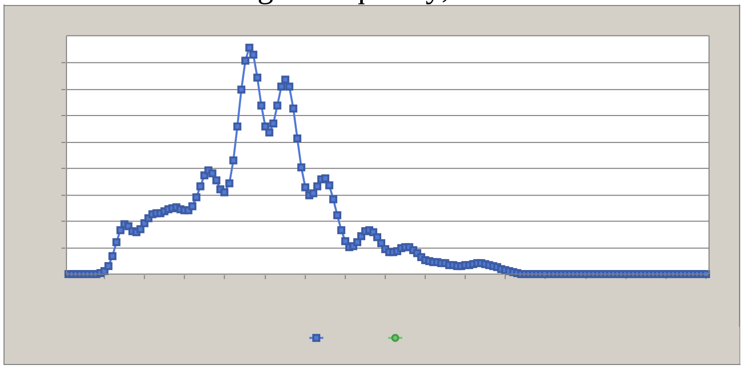
Catch Numbers Length Frequency, Year 1992



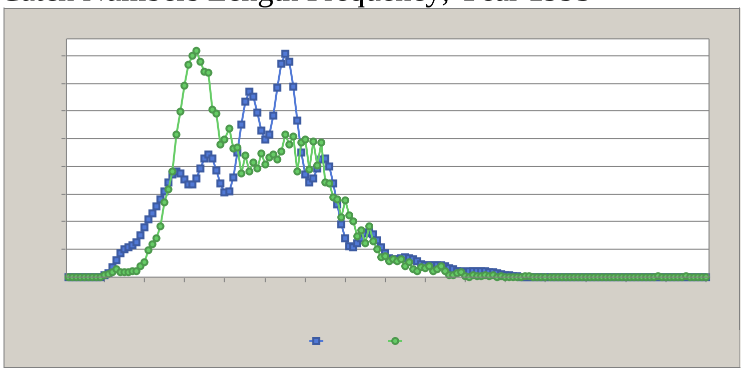
Catch Numbers Length Frequency, Year 1993



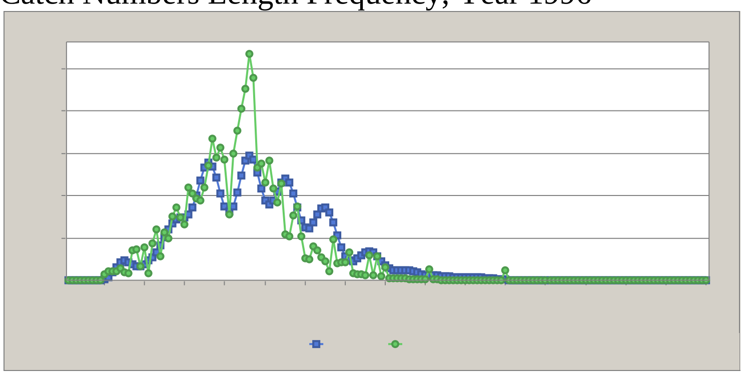
Catch Numbers Length Frequency, Year 1994



Catch Numbers Length Frequency, Year 1995



Catch Numbers Length Frequency, Year 1996



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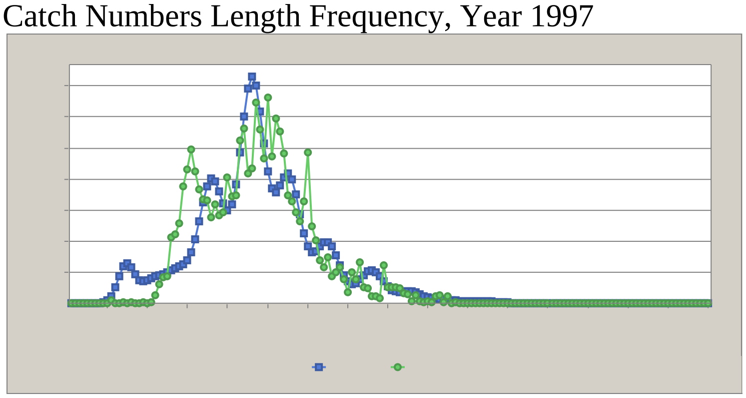
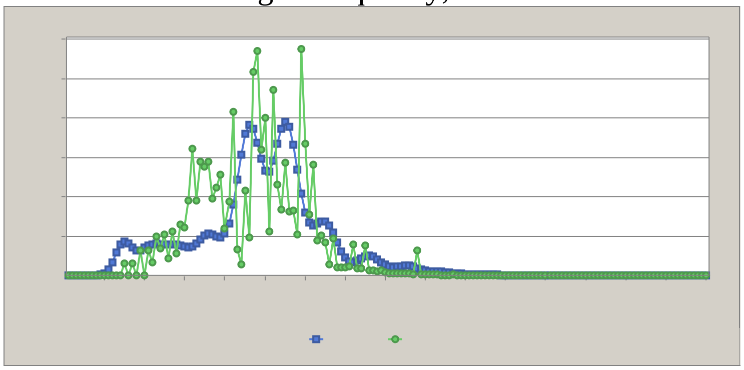
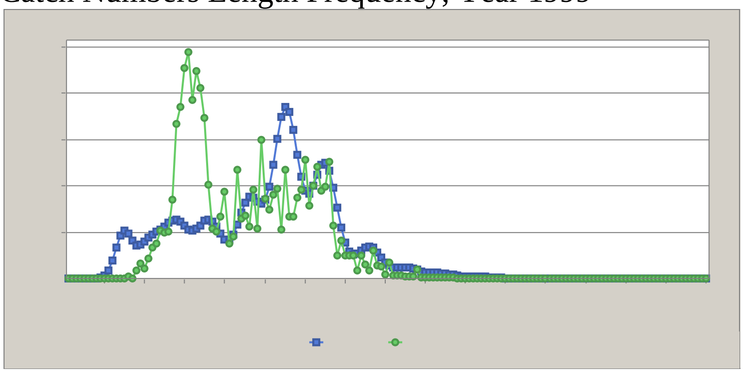


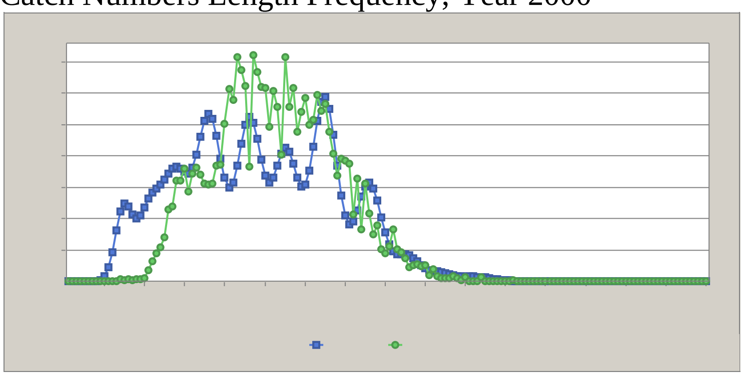
Catch Numbers Length Frequency, Year 1998



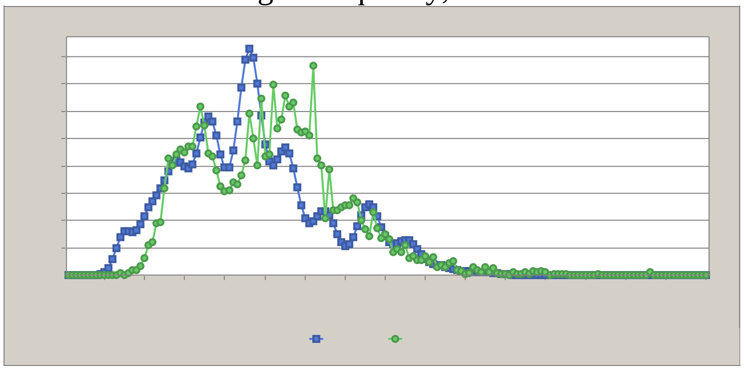
Catch Numbers Length Frequency, Year 1999



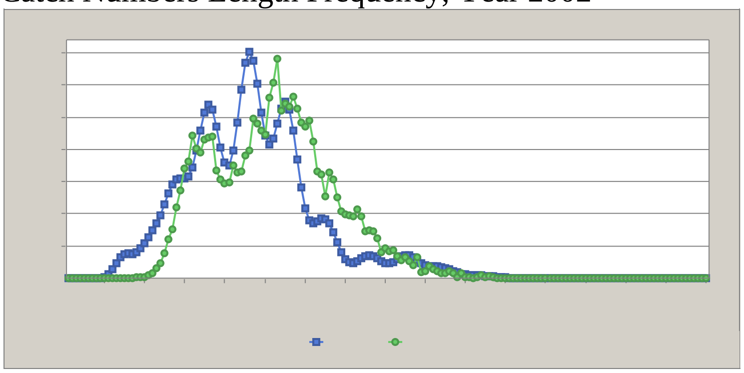
Catch Numbers Length Frequency, Year 2000



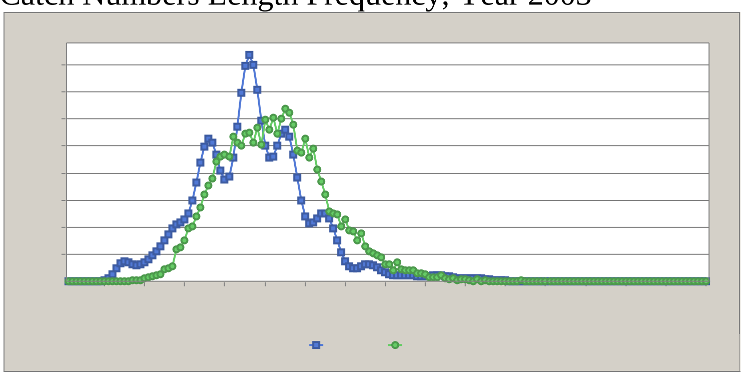
Catch Numbers Length Frequency, Year 2001



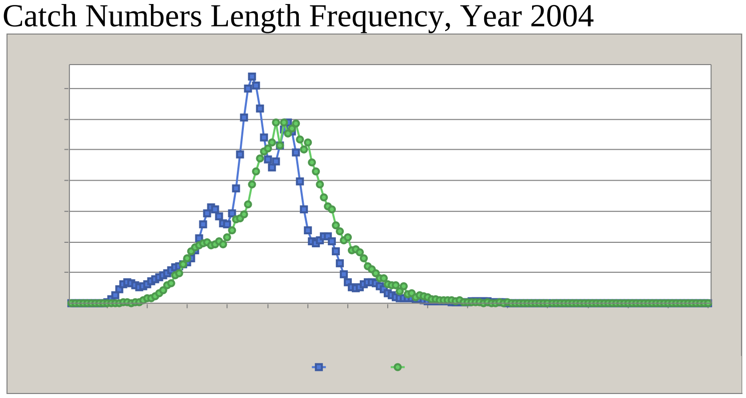
Catch Numbers Length Frequency, Year 2002



Catch Numbers Length Frequency, Year 2003



Catch Numbers Length Frequency, Year 2004



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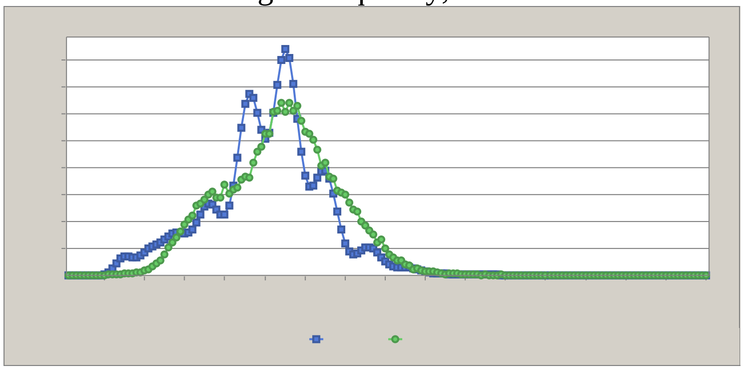
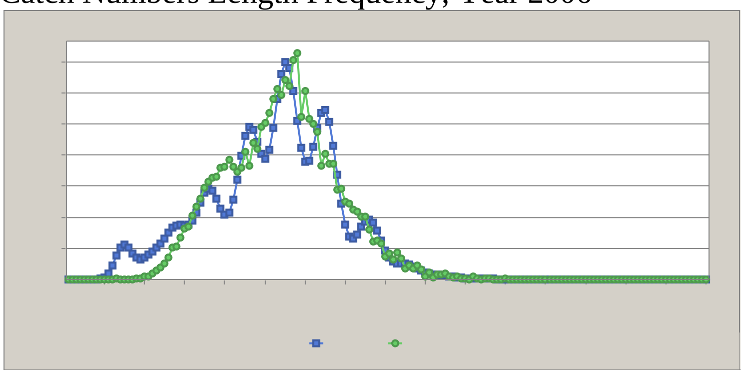
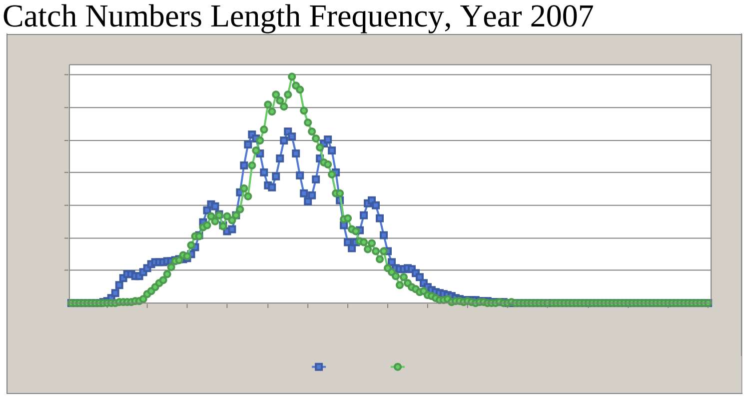


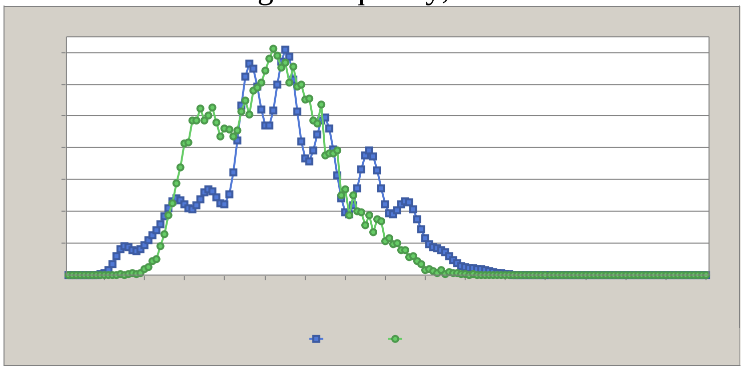
Catch Numbers Length Frequency, Year 2006



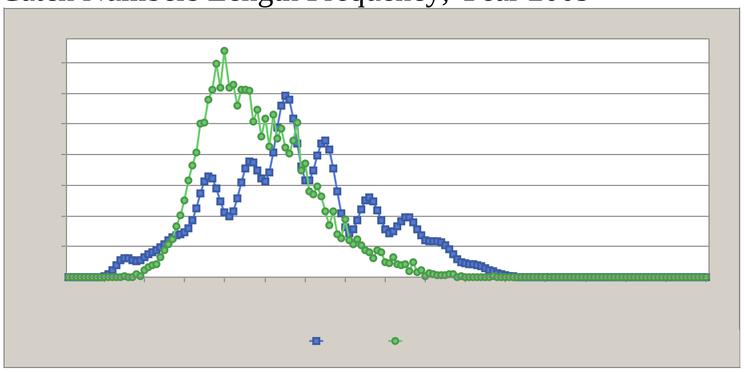
Catch Numbers Length Frequency, Year 2007



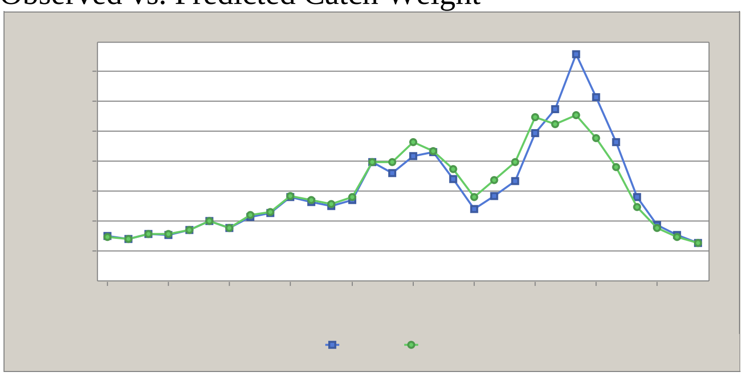
Catch Numbers Length Frequency, Year 2008



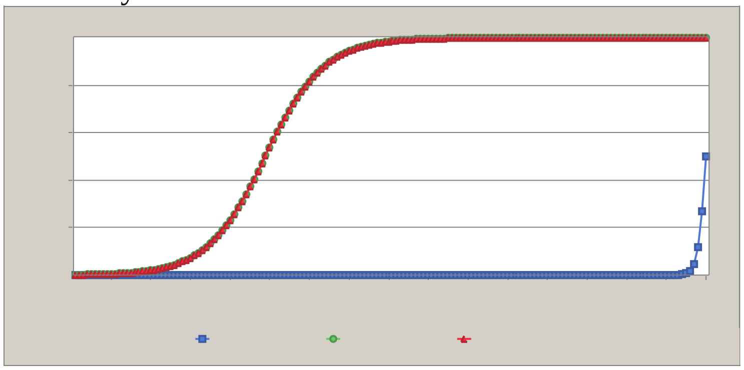
Catch Numbers Length Frequency, Year 2009



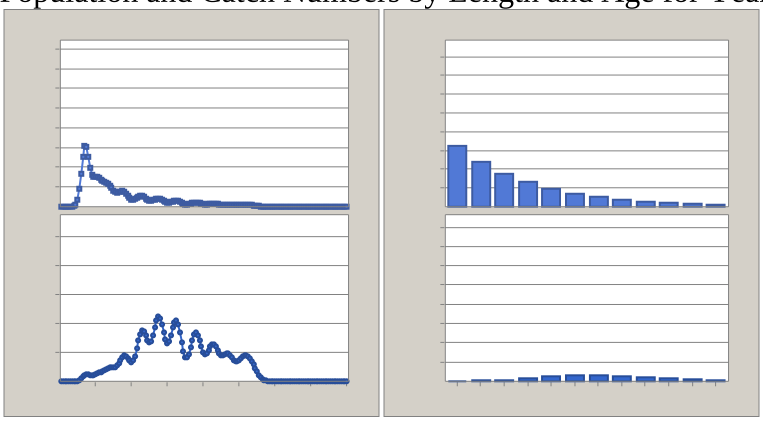
Observed vs. Predicted Catch Weight



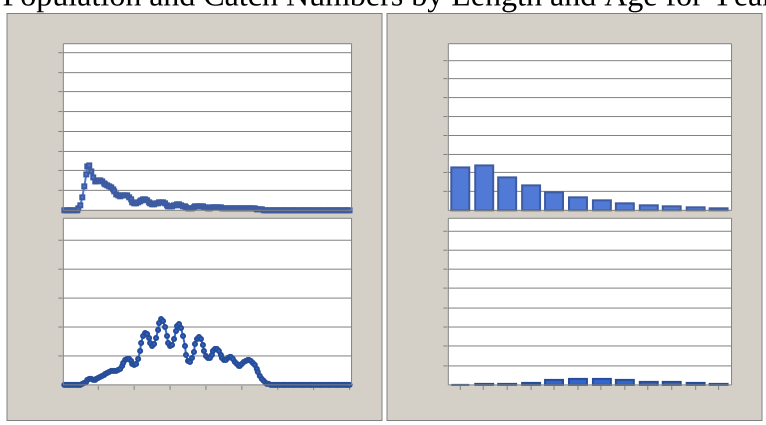
Selectivity for Block 1



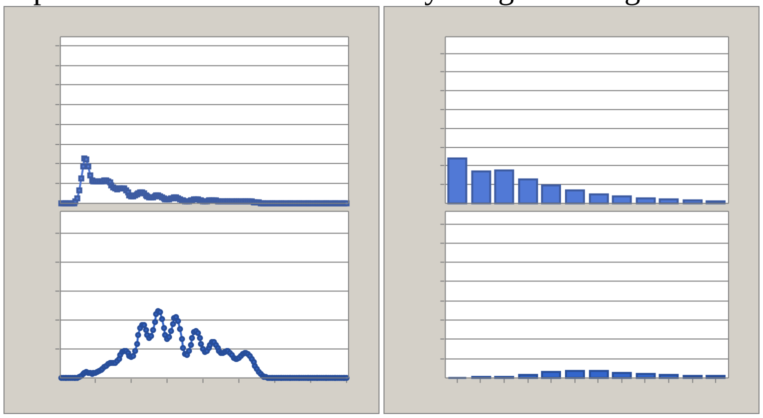
Population and Catch Numbers by Length and Age for Year 1980



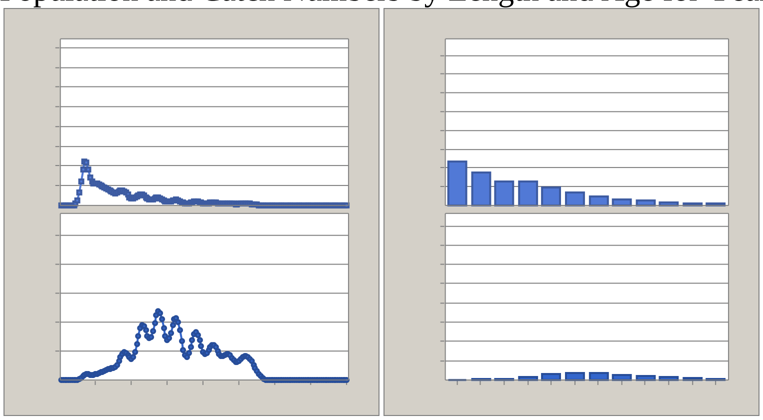
Population and Catch Numbers by Length and Age for Year 1981



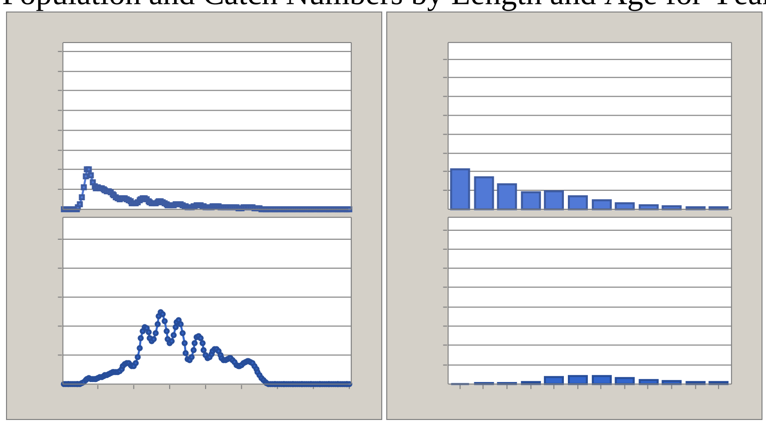
Population and Catch Numbers by Length and Age for Year 1982



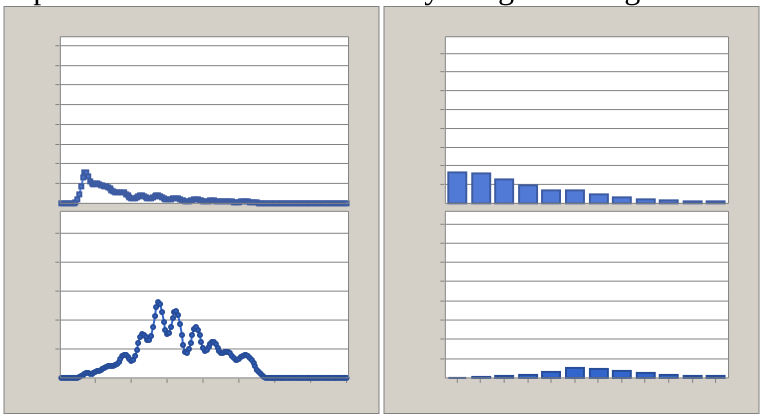
Population and Catch Numbers by Length and Age for Year 1983



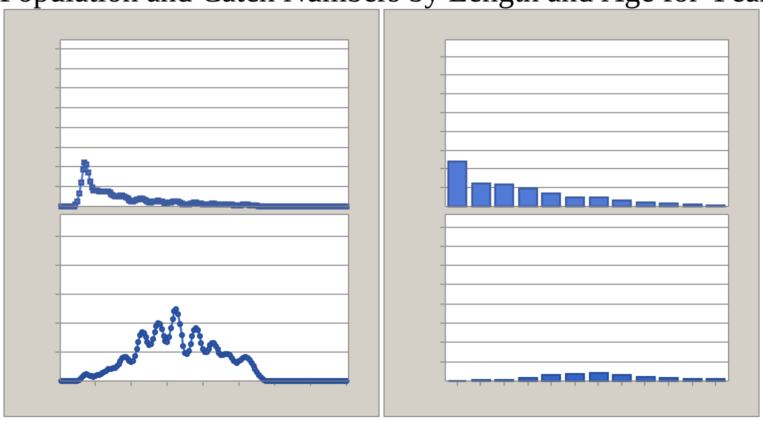
Population and Catch Numbers by Length and Age for Year 1984



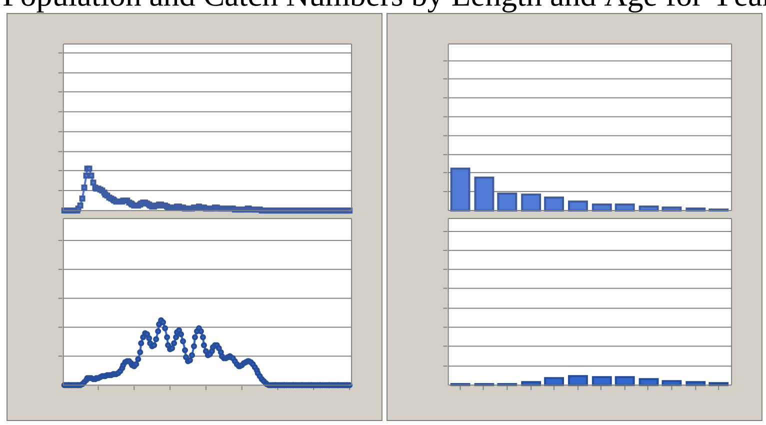
Population and Catch Numbers by Length and Age for Year 1985



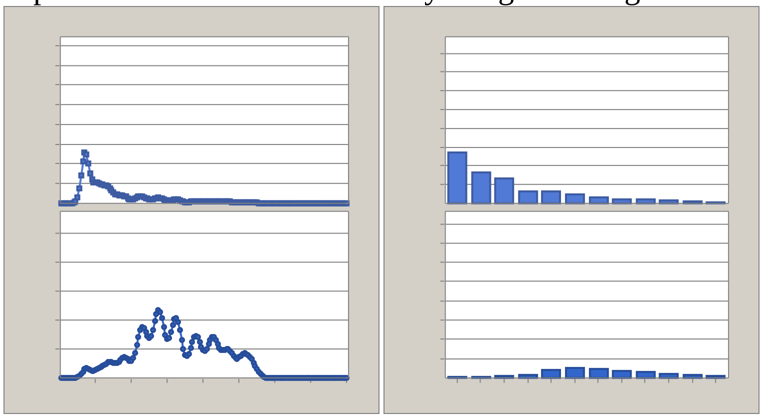
Population and Catch Numbers by Length and Age for Year 1986



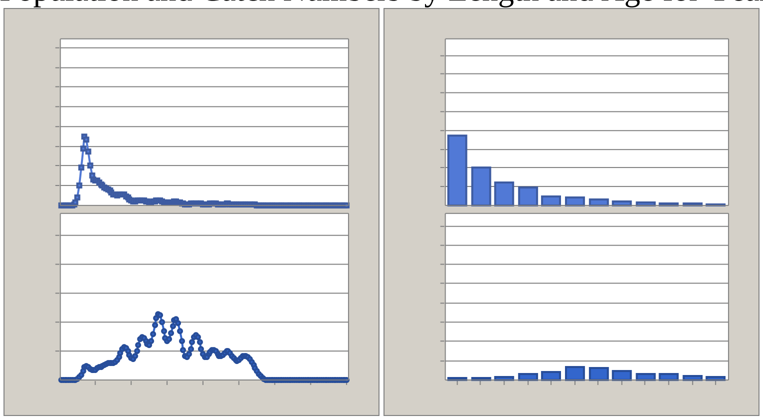
Population and Catch Numbers by Length and Age for Year 1987



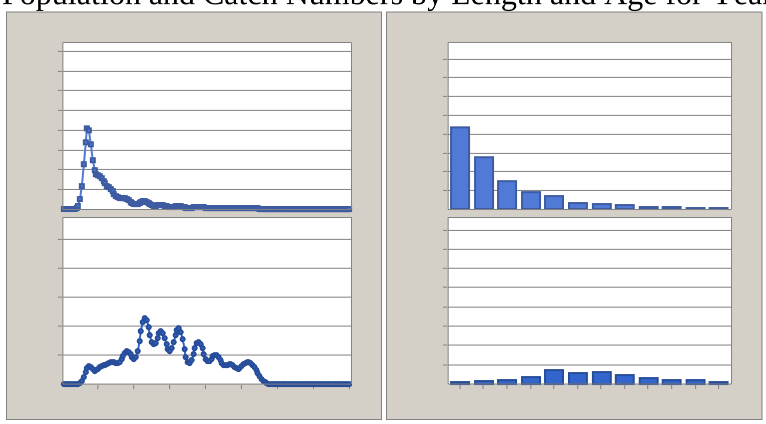
Population and Catch Numbers by Length and Age for Year 1988



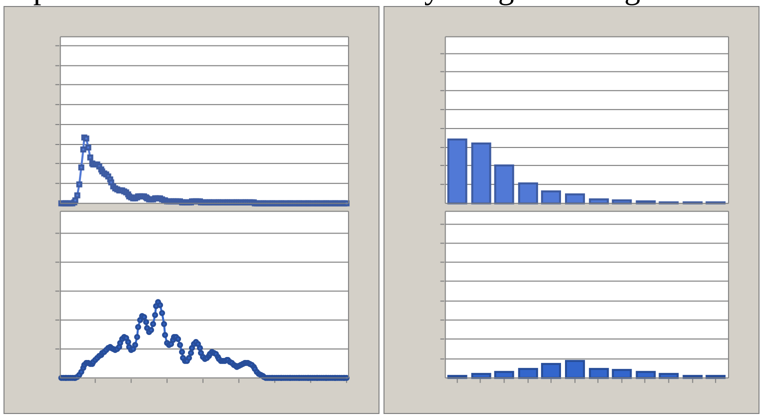
Population and Catch Numbers by Length and Age for Year 1989



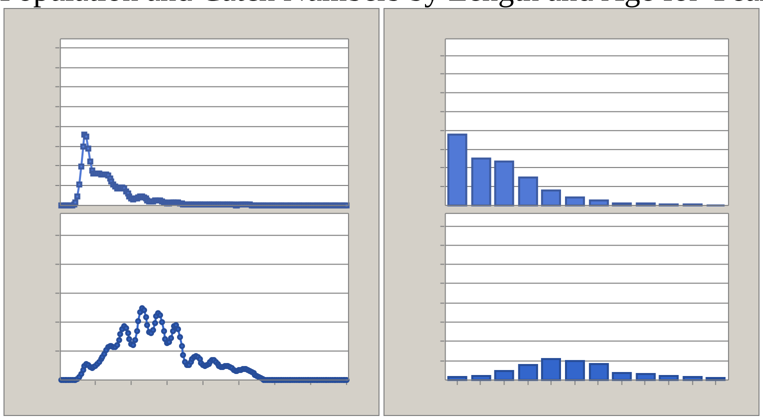
Population and Catch Numbers by Length and Age for Year 1990



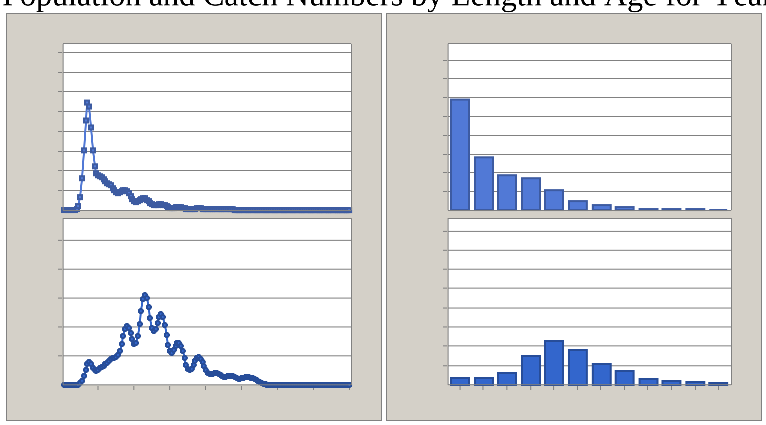
Population and Catch Numbers by Length and Age for Year 1991



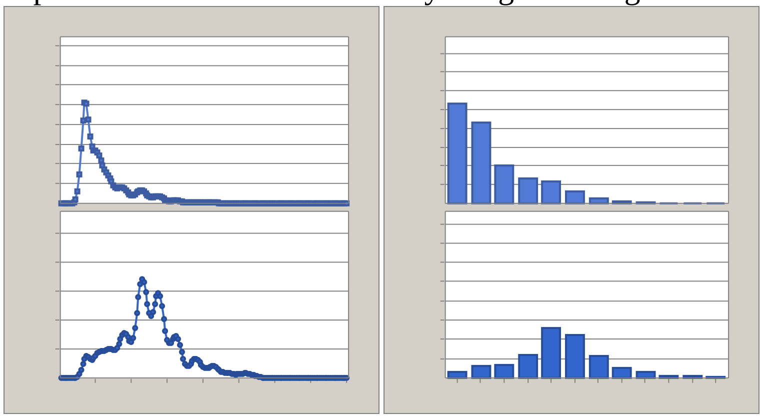
Population and Catch Numbers by Length and Age for Year 1992



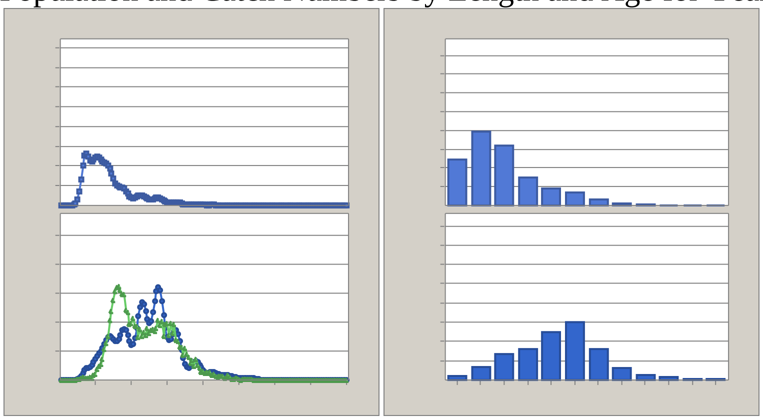
Population and Catch Numbers by Length and Age for Year 1993



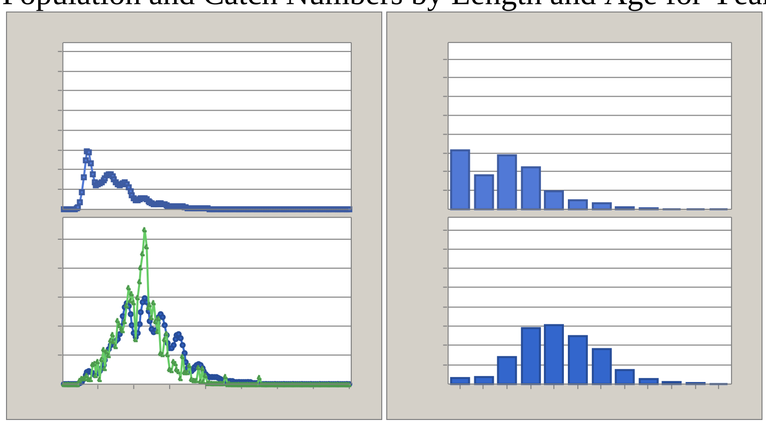
Population and Catch Numbers by Length and Age for Year 1994



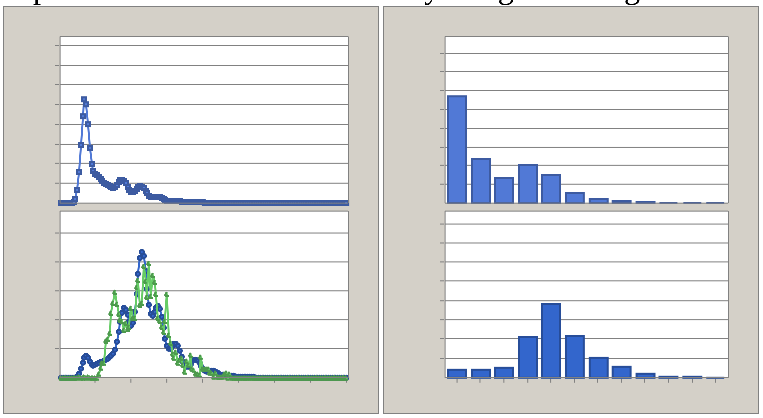
Population and Catch Numbers by Length and Age for Year 1995



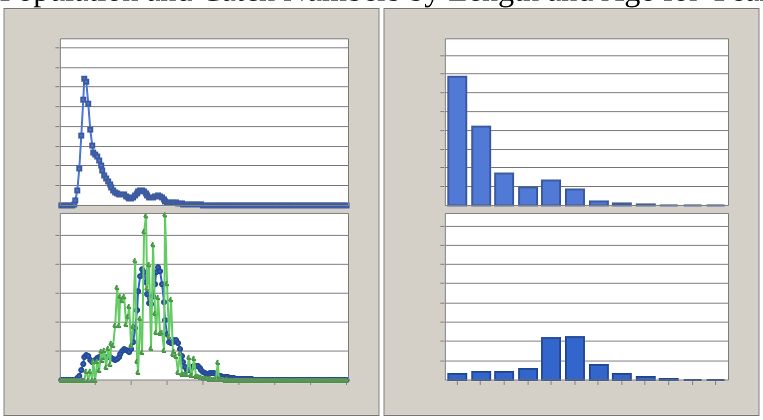
Population and Catch Numbers by Length and Age for Year 1996



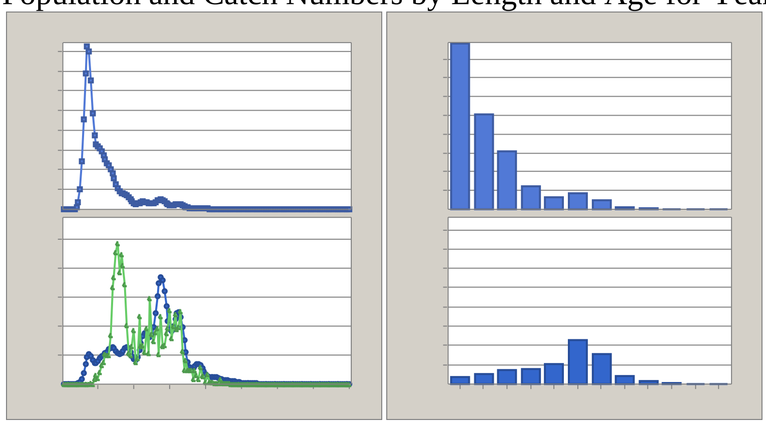
Population and Catch Numbers by Length and Age for Year 1997



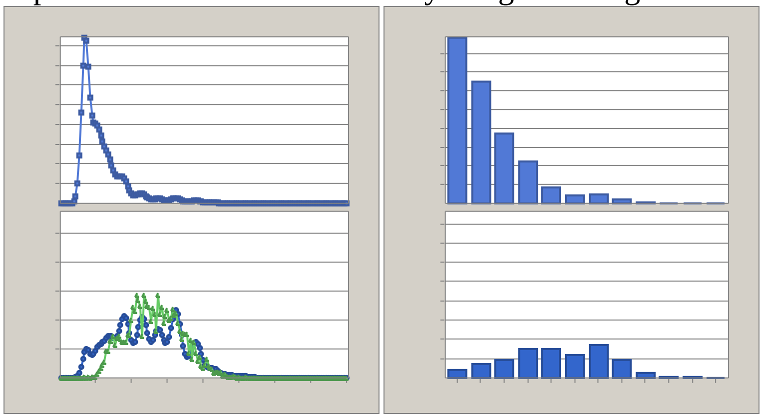
Population and Catch Numbers by Length and Age for Year 1998



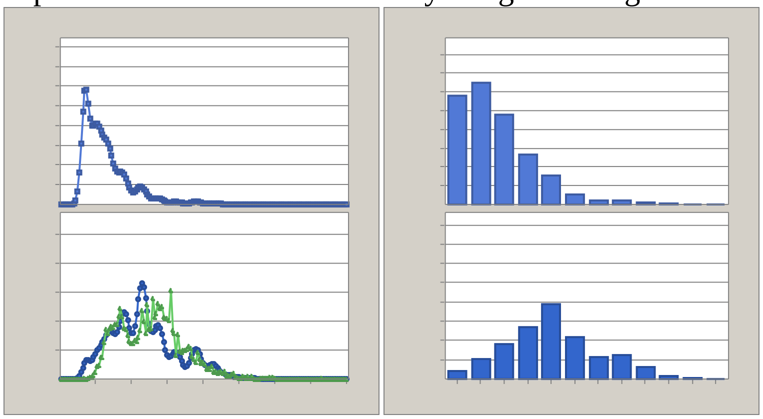
Population and Catch Numbers by Length and Age for Year 1999



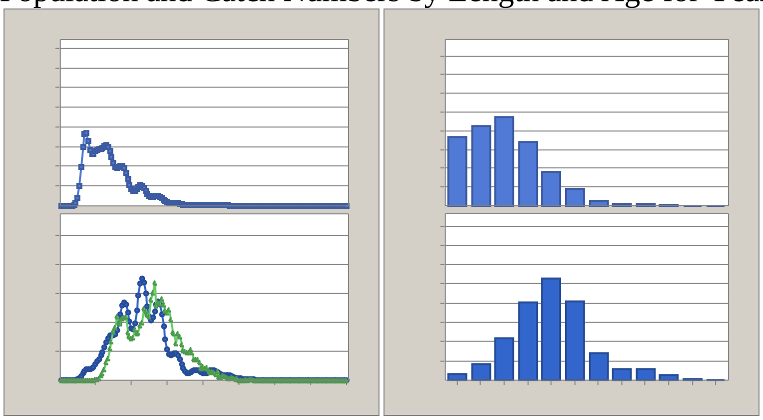
Population and Catch Numbers by Length and Age for Year 2000



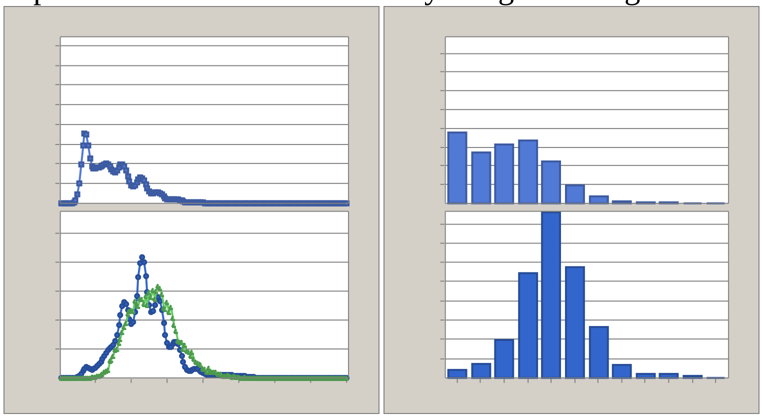
Population and Catch Numbers by Length and Age for Year 2001



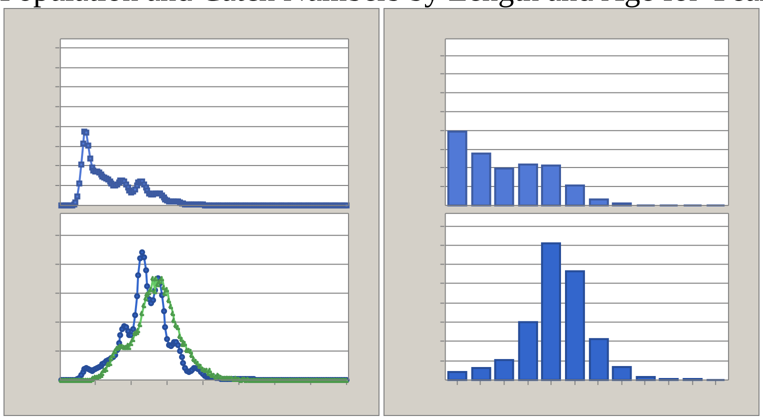
Population and Catch Numbers by Length and Age for Year 2002



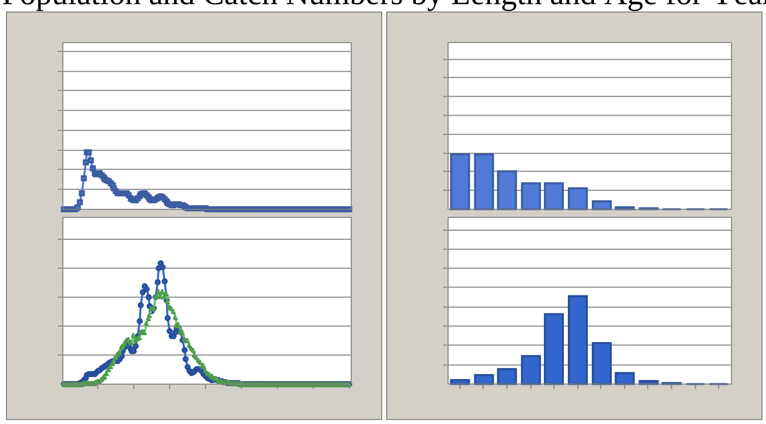
Population and Catch Numbers by Length and Age for Year 2003



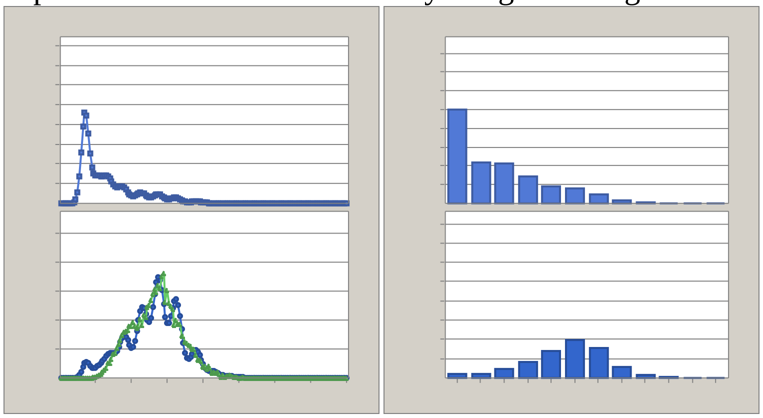
Population and Catch Numbers by Length and Age for Year 2004



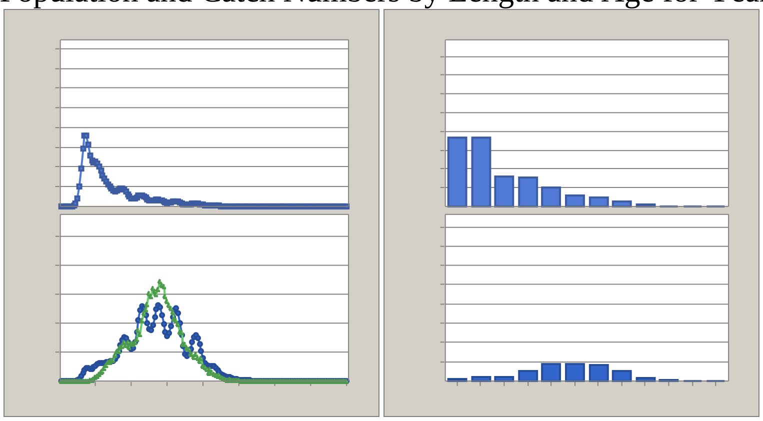
Population and Catch Numbers by Length and Age for Year 2005



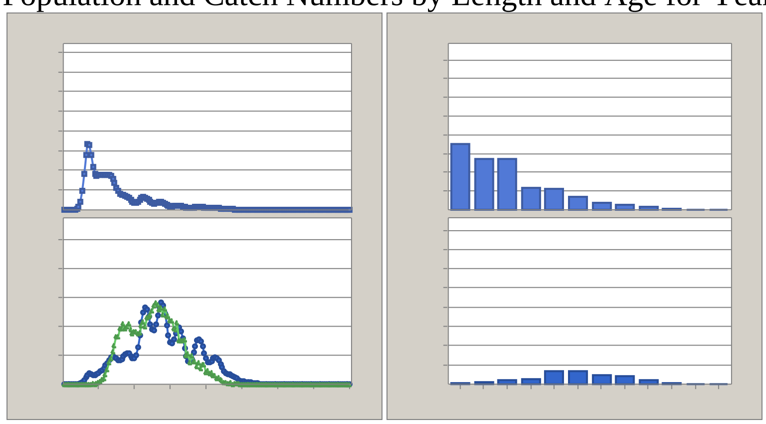
Population and Catch Numbers by Length and Age for Year 2006



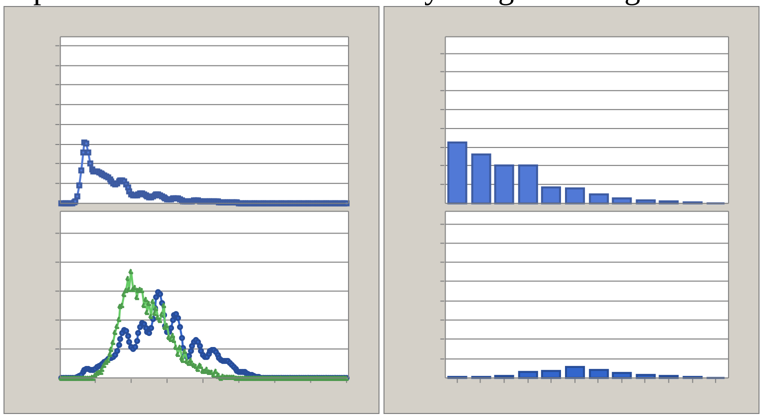
Population and Catch Numbers by Length and Age for Year 2007



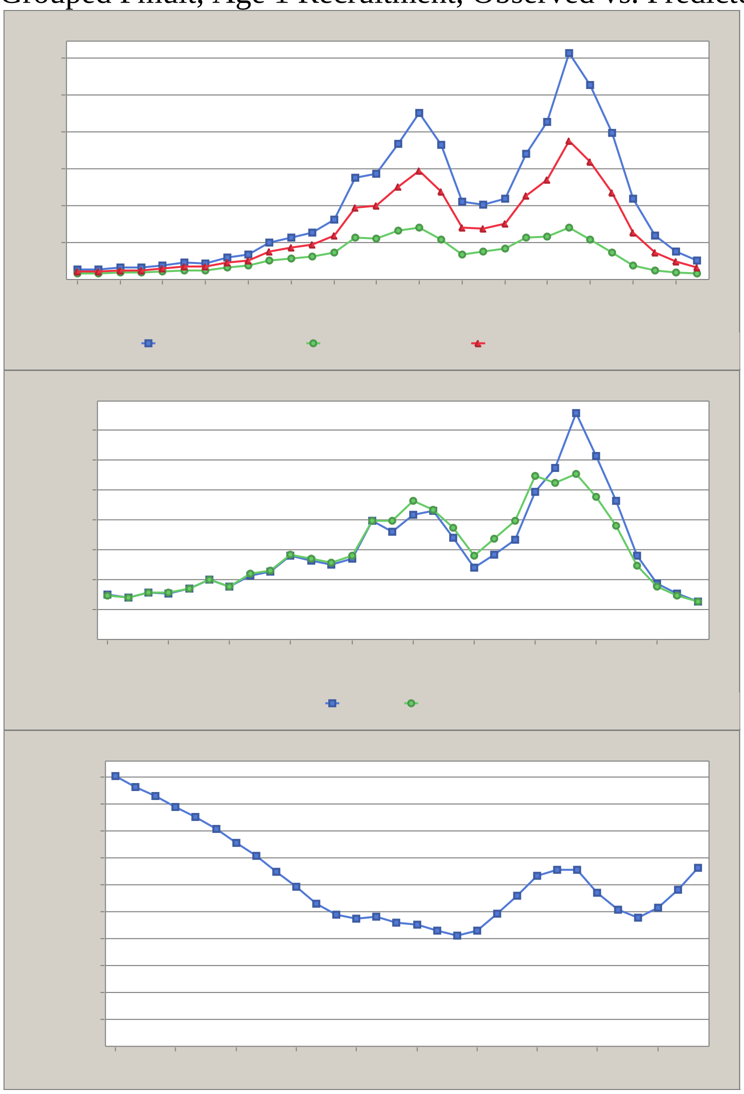
Population and Catch Numbers by Length and Age for Year 2008



Population and Catch Numbers by Length and Age for Year 2009



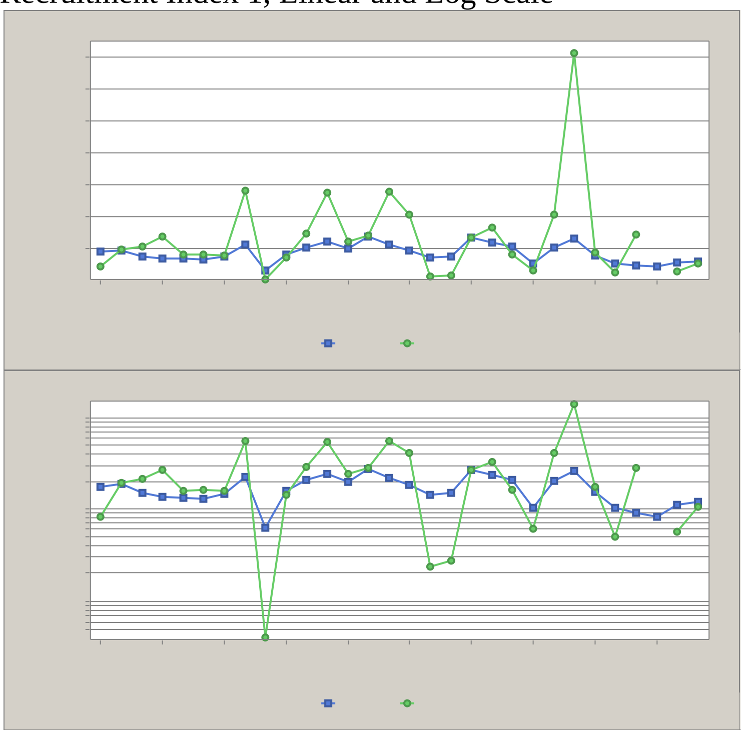
Grouped Fmult, Age 1 Recruitment, Observed vs. Predicted Catch Weight, and Total Biomass



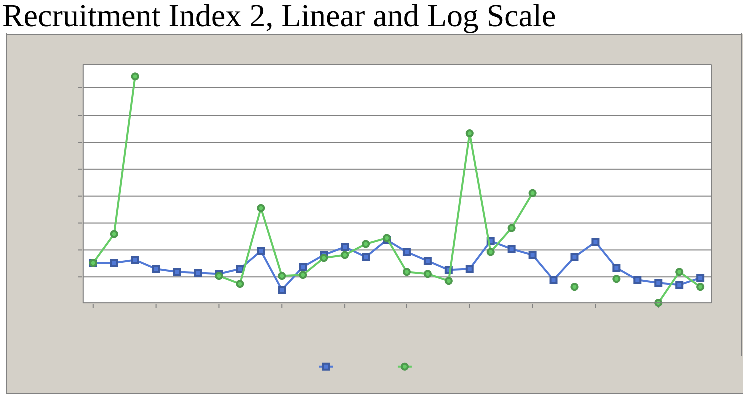
Southern Management Area Final Run 8

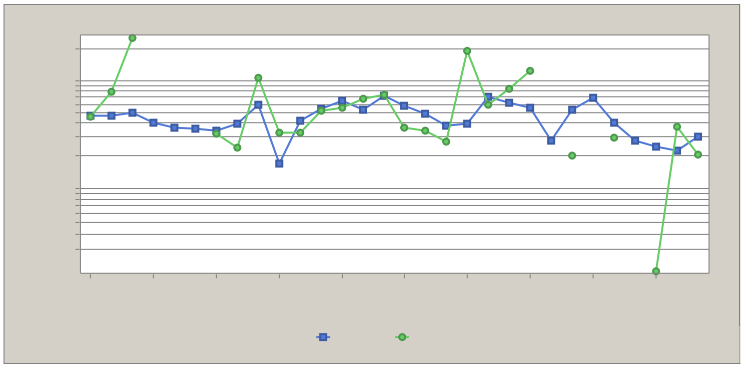
Recruitment Indices, Group Linear and Log Scale, 1 Index per Line (14 Plots)
Adult Indices, Group Linear and Log Scale, 1 Index per Line (8 Plots)
Survey Length Frequencies (210 Plots)
Catch Numbers, Catch Length Frequency (30 Plots)
Observed vs. Predicted Catch Weight (1 Plot)
Selectivity (2 Plots)
4-Plot: Population and Catch Numbers (60 Plots)
Fmult, Age 1 Recruitment, Observed vs. Predicted Catch Weight, and Total Biomass: Group 2 per Line (4 Plots)

Recruitment Index 1, Linear and Log Scale

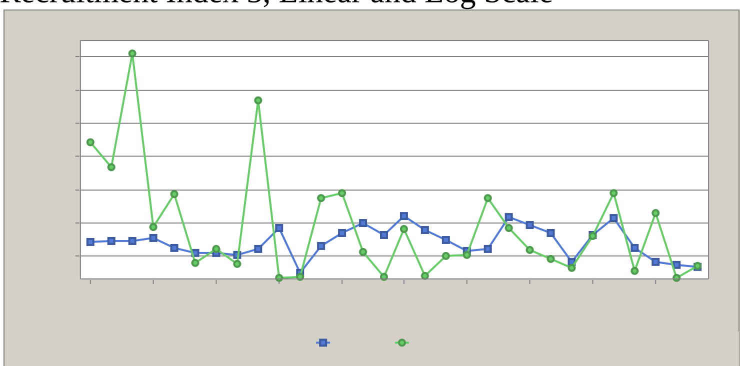


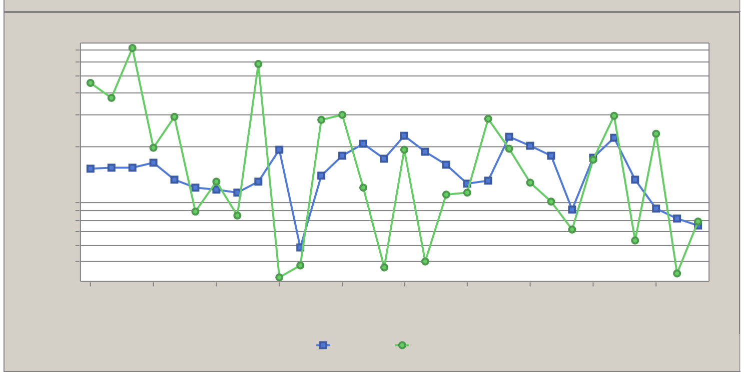
Recruitment Index 2, Linear and Log Scale



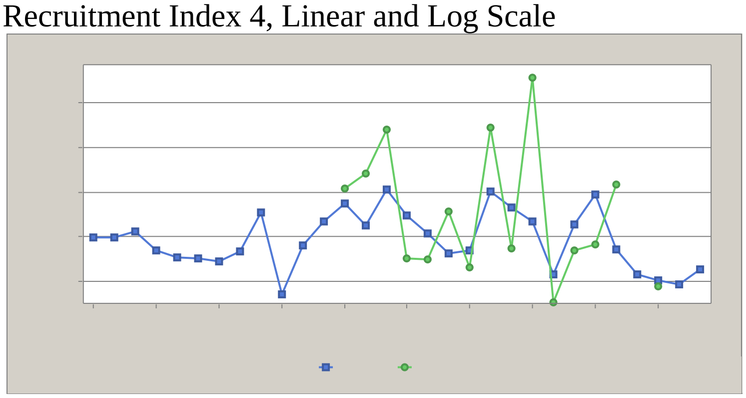


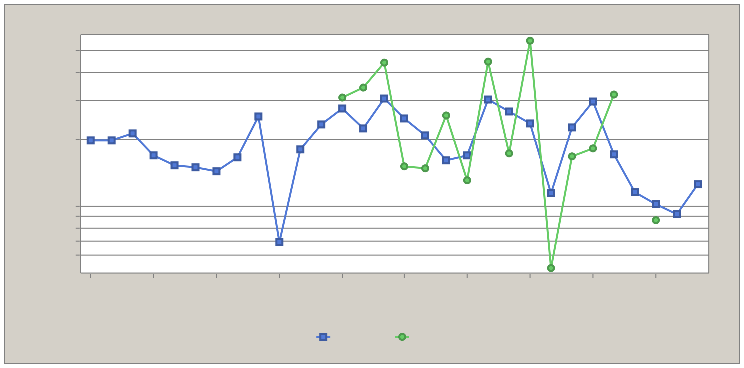
Recruitment Index 3, Linear and Log Scale



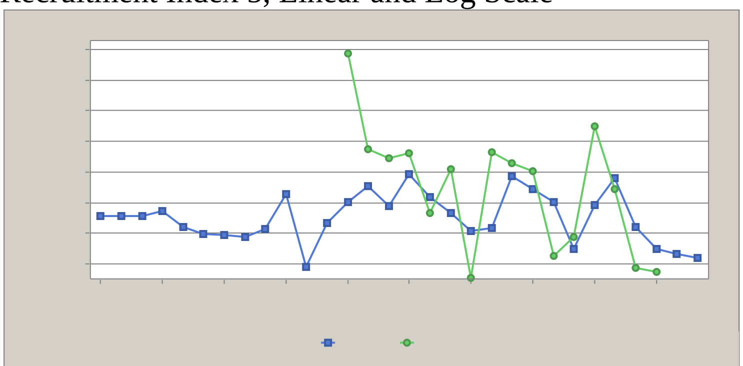


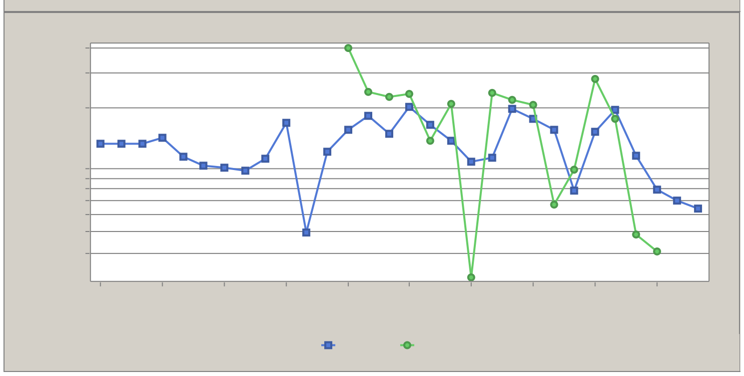
Recruitment Index 4, Linear and Log Scale



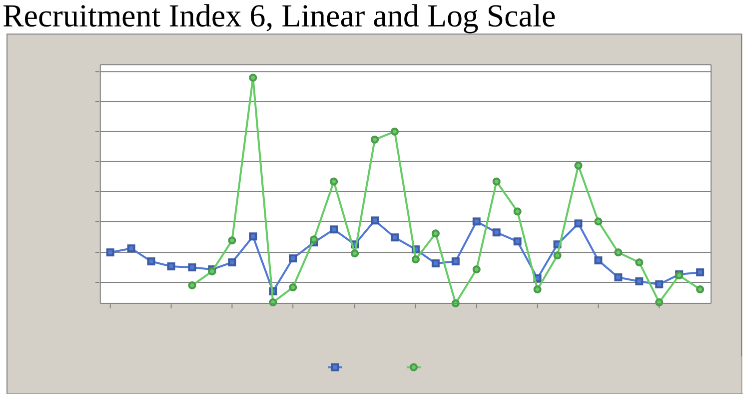


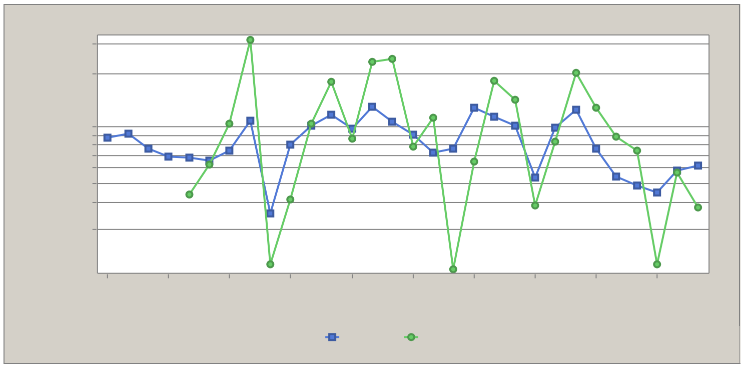
Recruitment Index 5, Linear and Log Scale



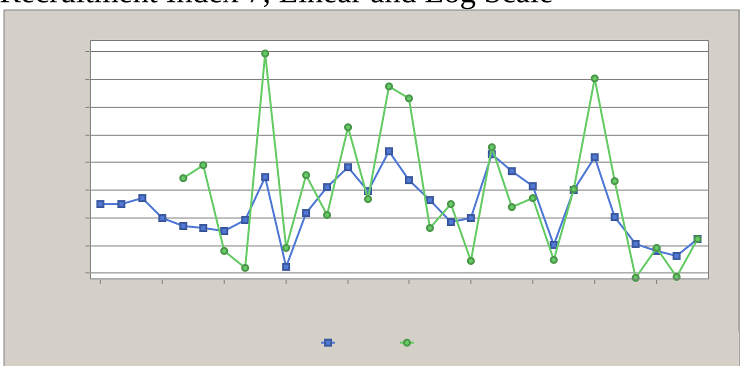


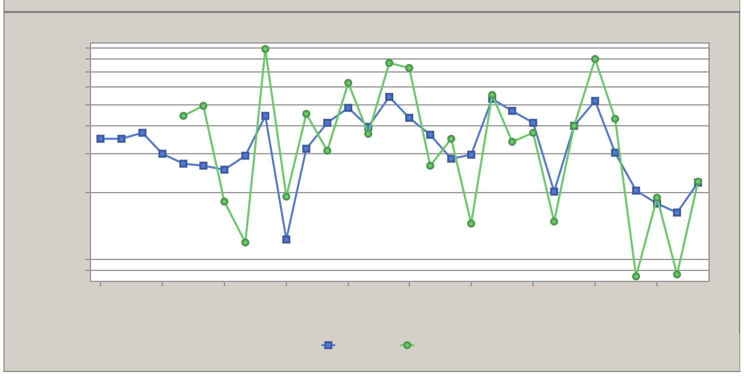
Recruitment Index 6, Linear and Log Scale



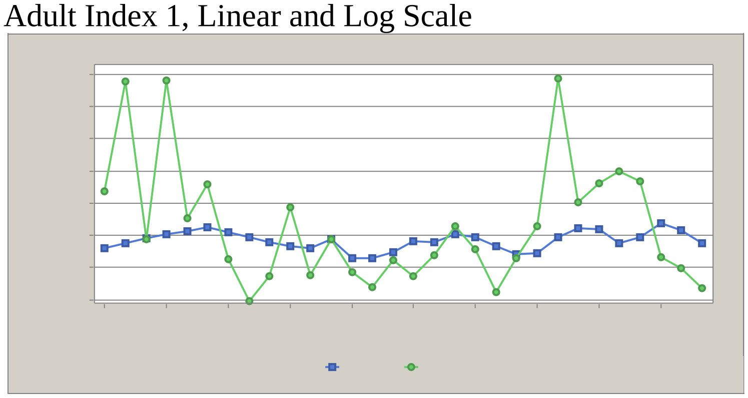


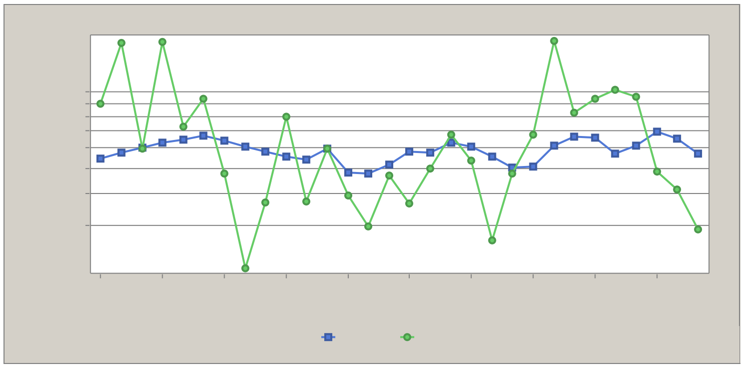
Recruitment Index 7, Linear and Log Scale



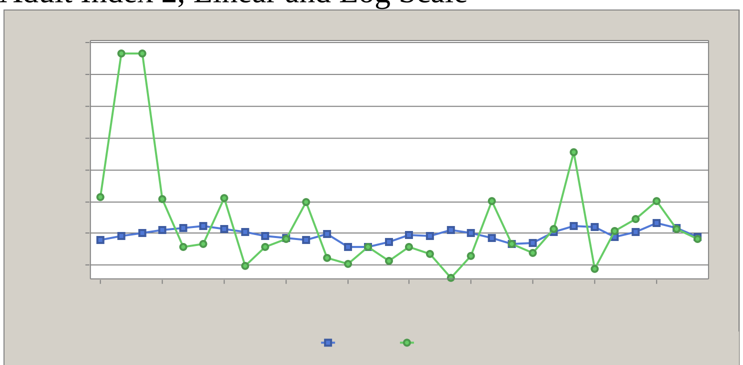


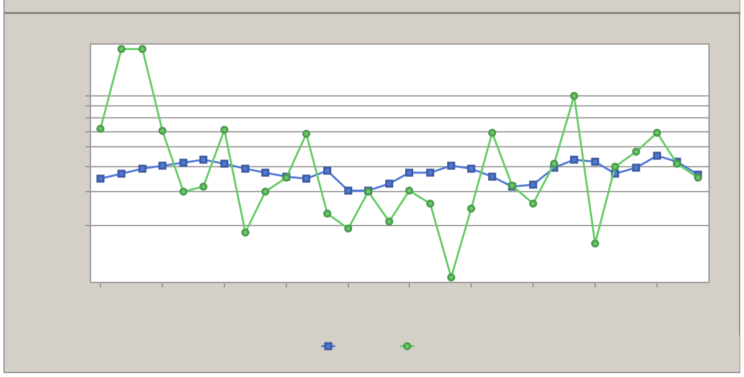
Adult Index 1, Linear and Log Scale



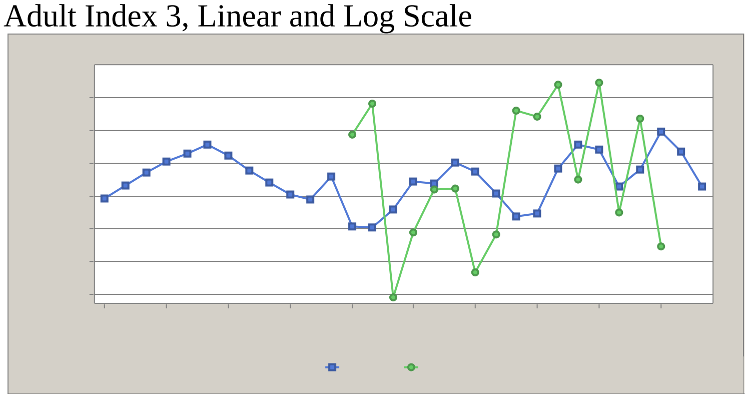


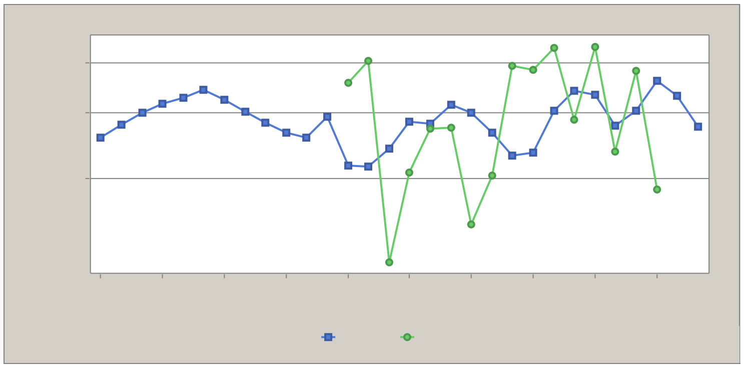
Adult Index 2, Linear and Log Scale



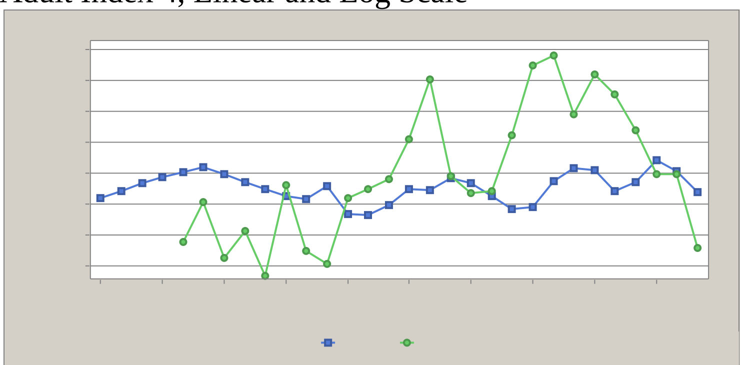


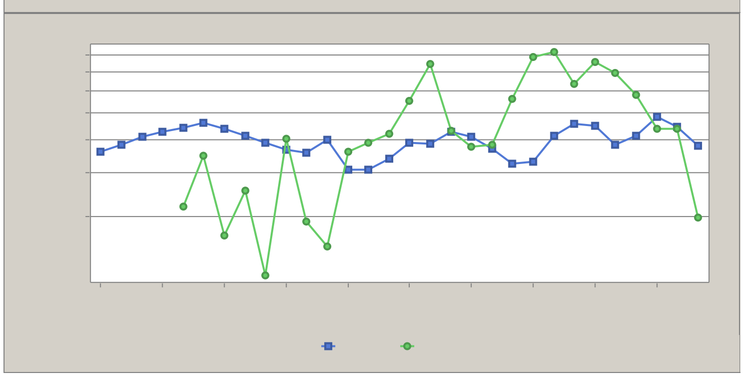
Adult Index 3, Linear and Log Scale



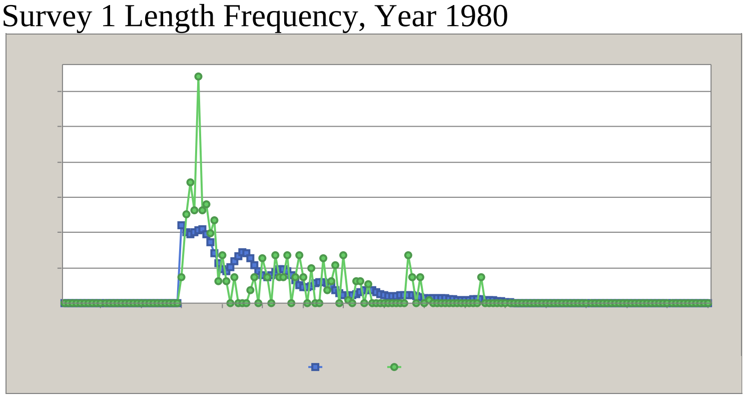


Adult Index 4, Linear and Log Scale

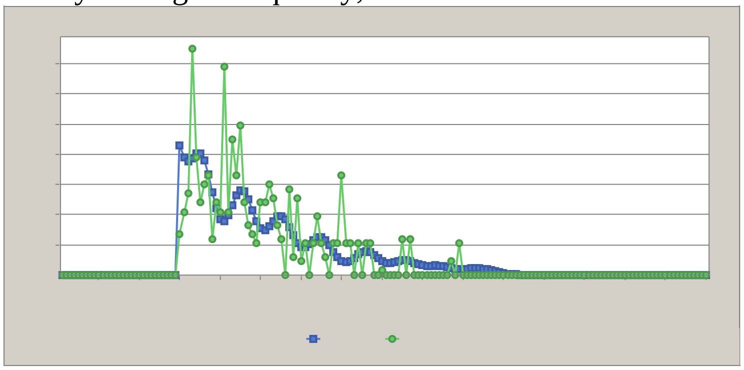




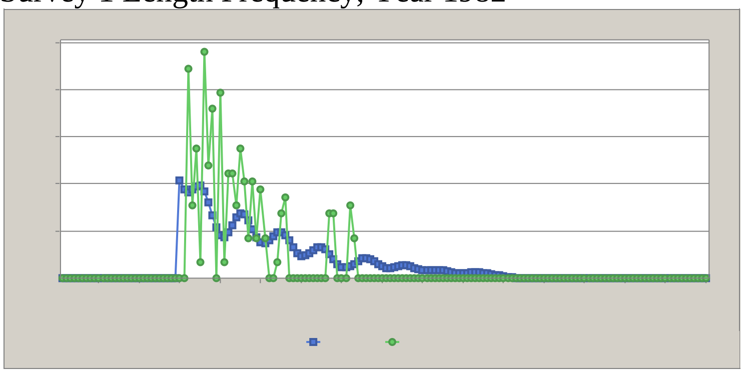
Survey 1 Length Frequency, Year 1980



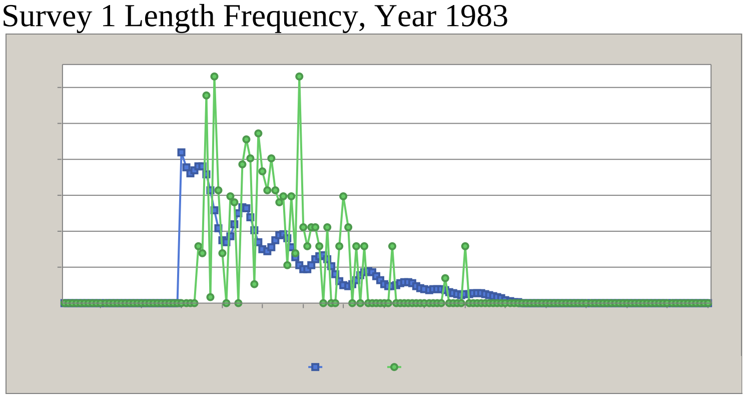
Survey 1 Length Frequency, Year 1981



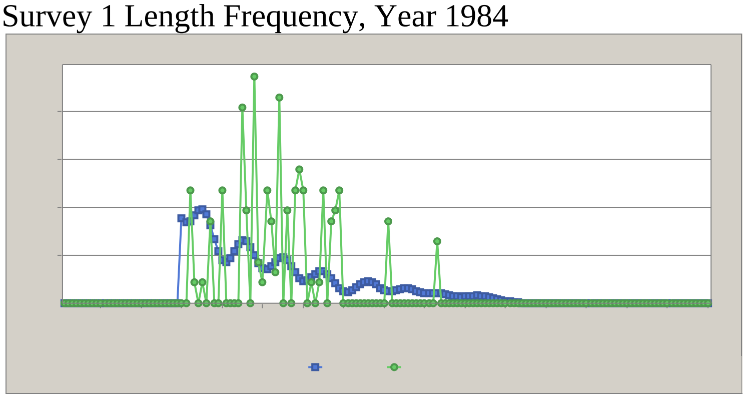
Survey 1 Length Frequency, Year 1982



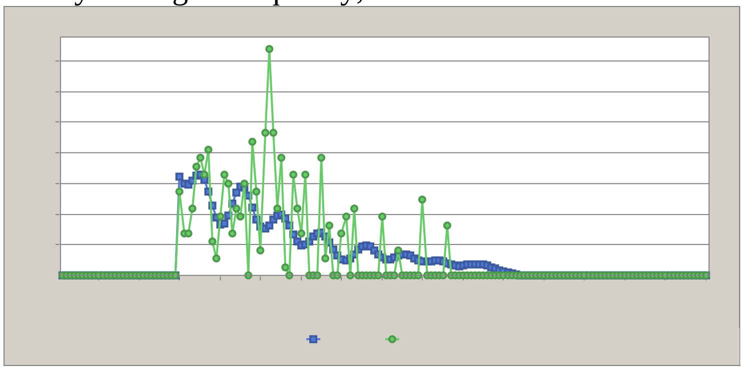
Survey 1 Length Frequency, Year 1983



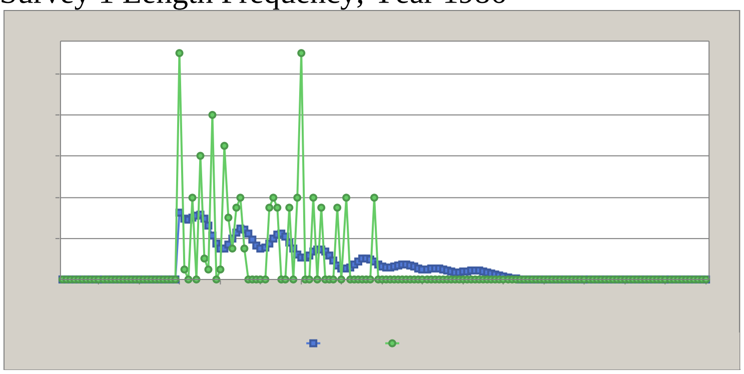
Survey 1 Length Frequency, Year 1984



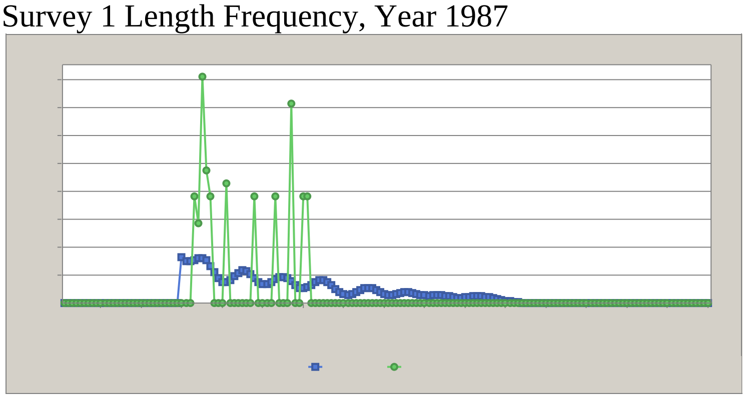
Survey 1 Length Frequency, Year 1985



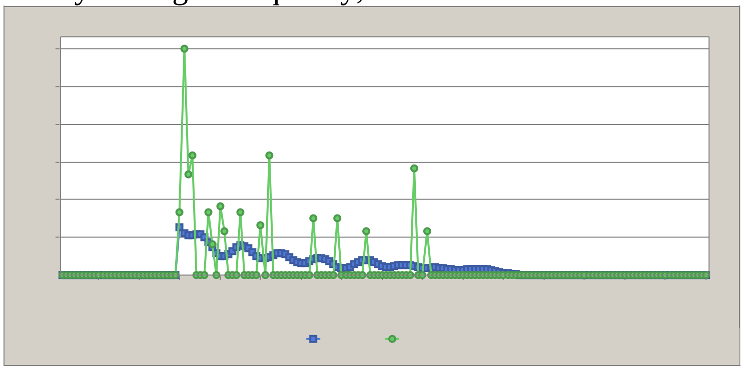
Survey 1 Length Frequency, Year 1986



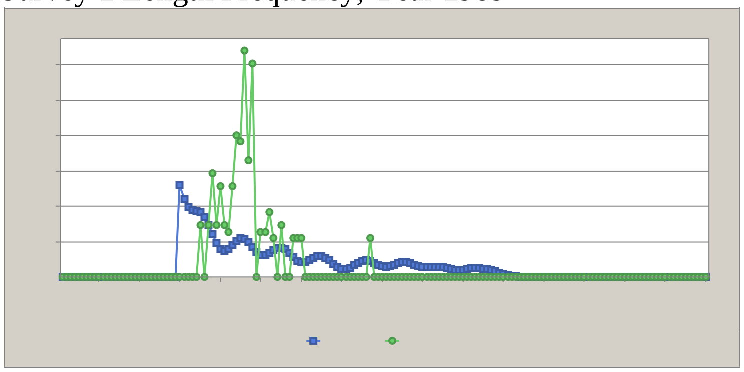
Survey 1 Length Frequency, Year 1987



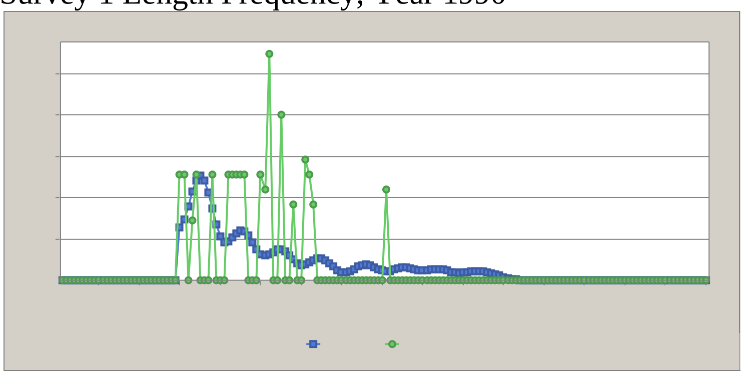
Survey 1 Length Frequency, Year 1988



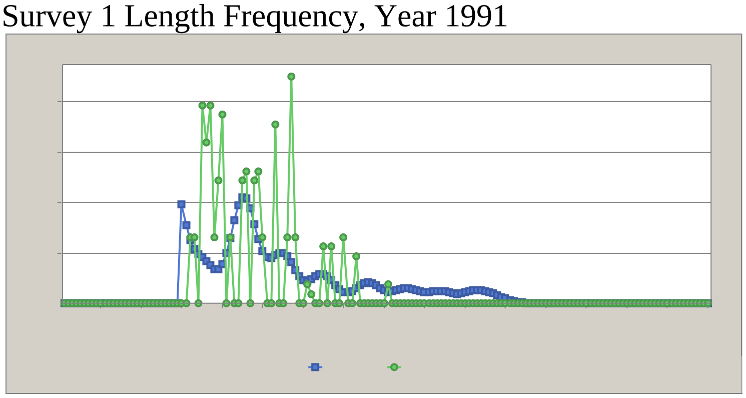
Survey 1 Length Frequency, Year 1989



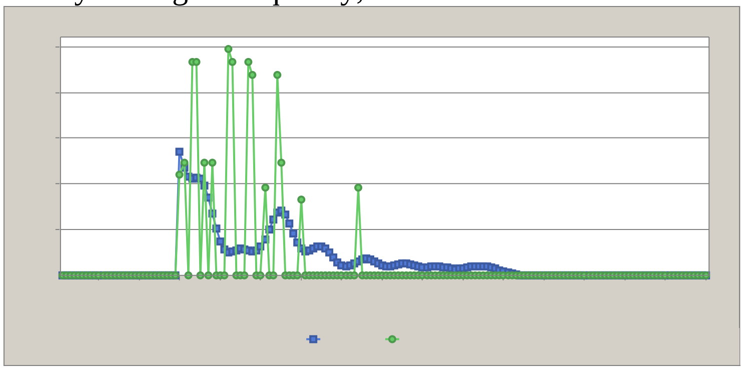
Survey 1 Length Frequency, Year 1990



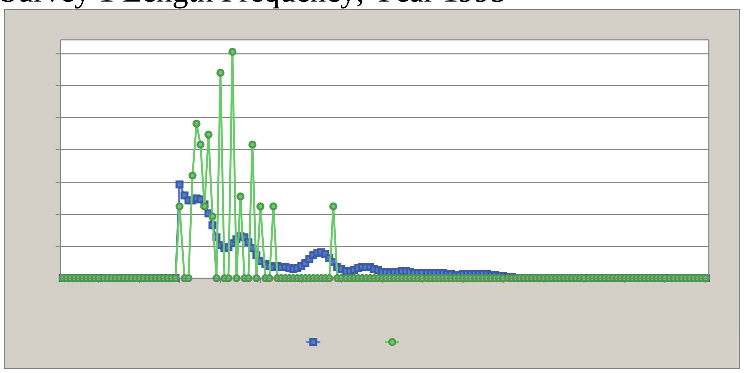
Survey 1 Length Frequency, Year 1991



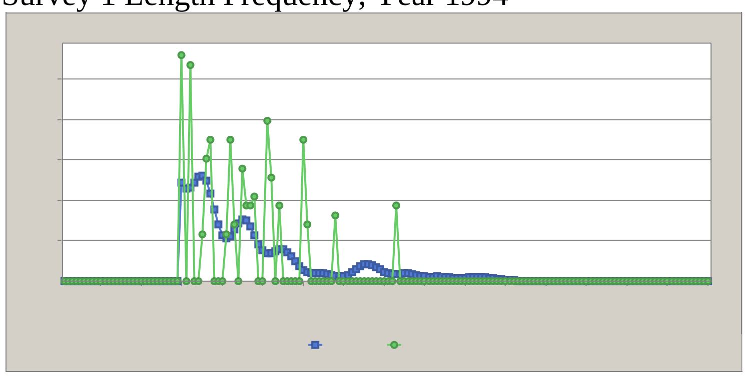
Survey 1 Length Frequency, Year 1992



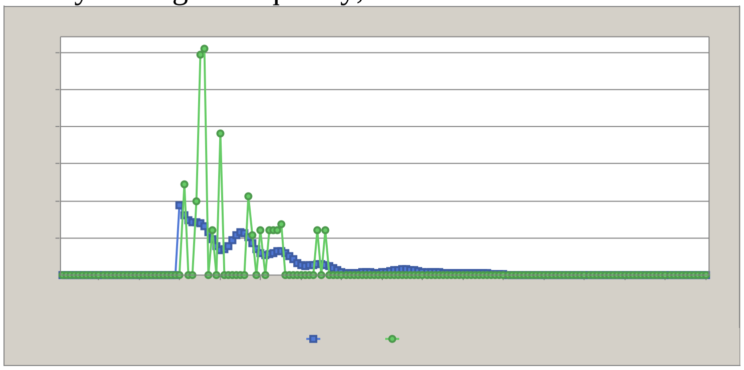
Survey 1 Length Frequency, Year 1993



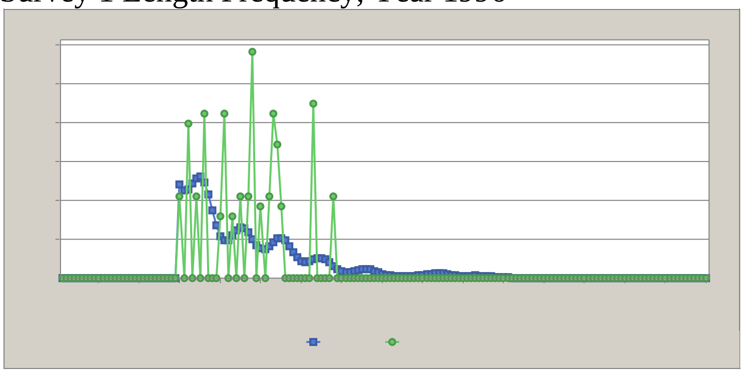
Survey 1 Length Frequency, Year 1994



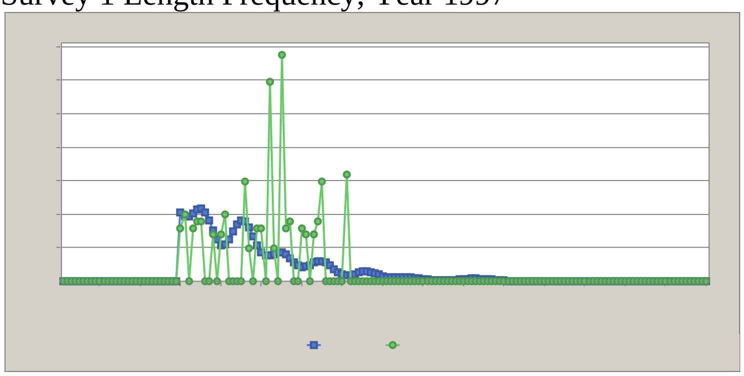
Survey 1 Length Frequency, Year 1995



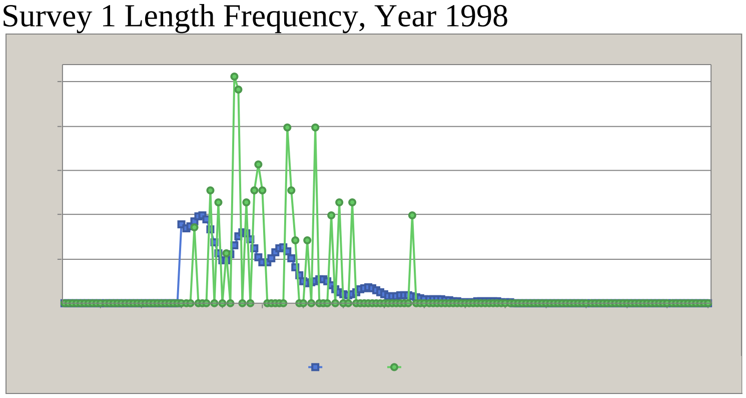
Survey 1 Length Frequency, Year 1996



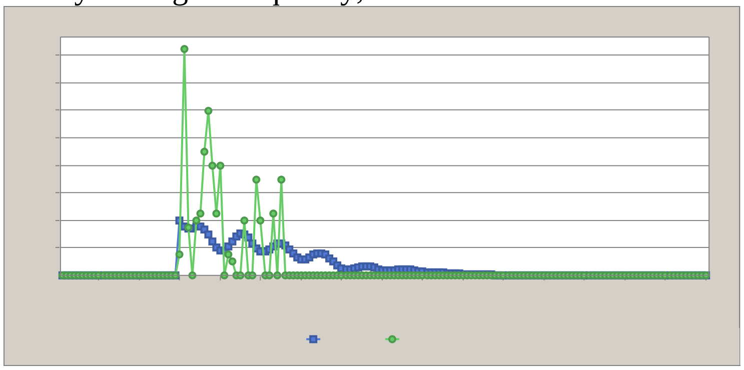
Survey 1 Length Frequency, Year 1997



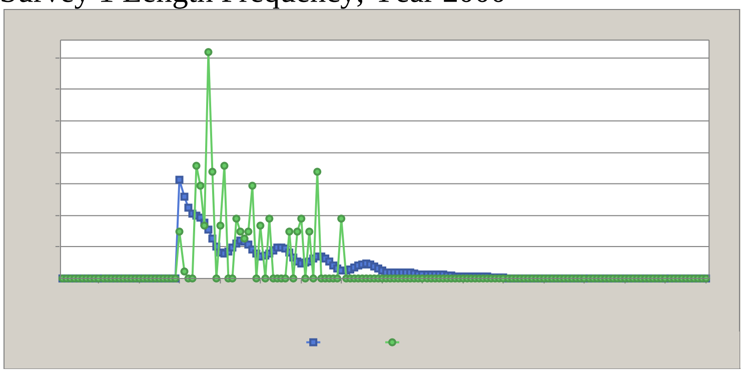
Survey 1 Length Frequency, Year 1998



Survey 1 Length Frequency, Year 1999



Survey 1 Length Frequency, Year 2000



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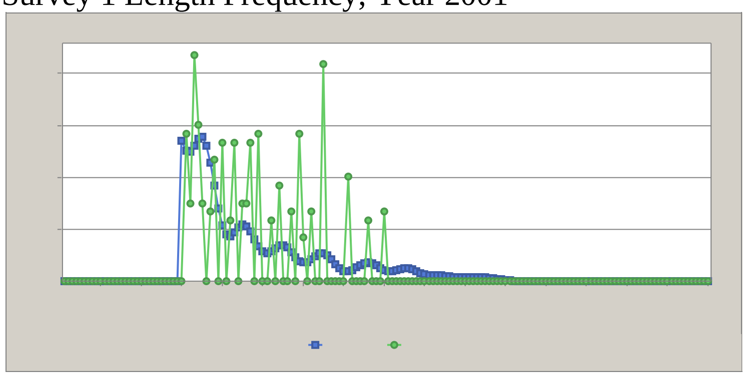

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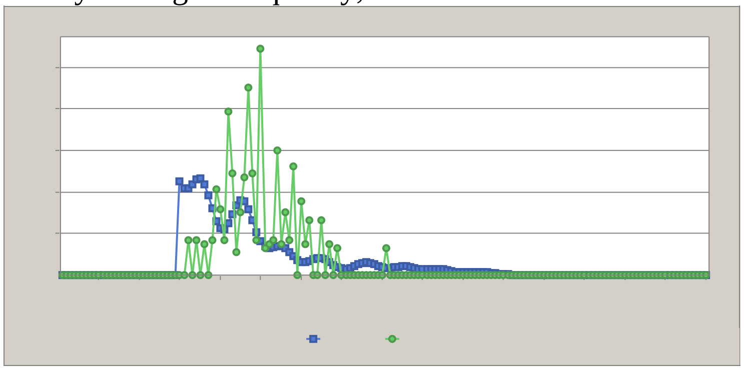
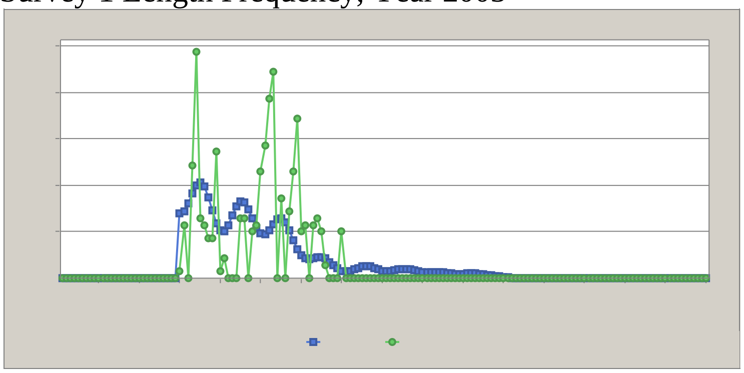
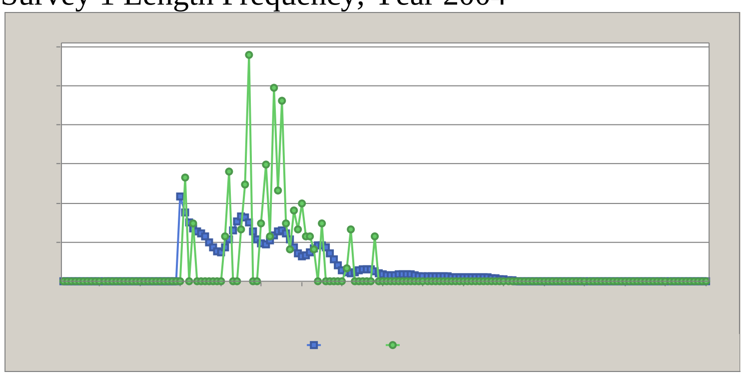


Survey 1 Length Frequency, Year 2003



Survey 1 Length Frequency, Year 2004



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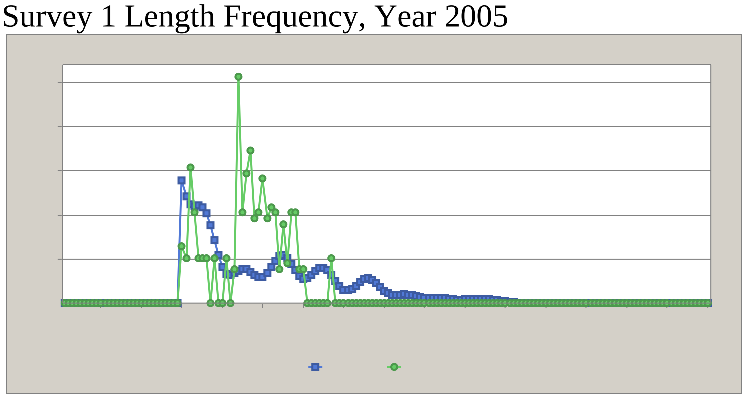

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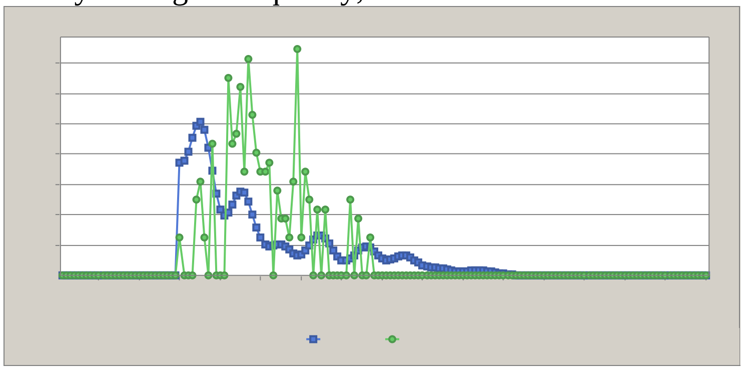

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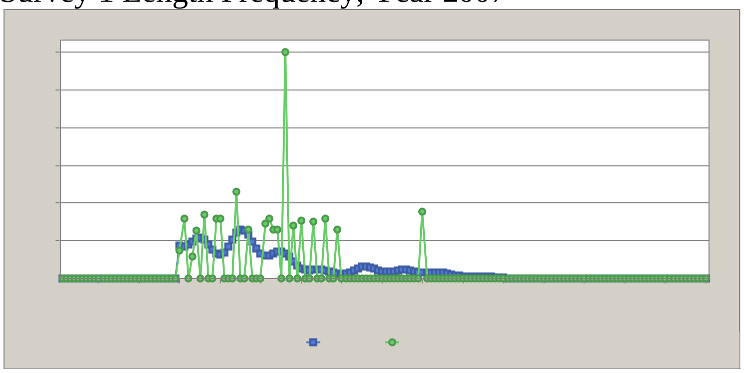
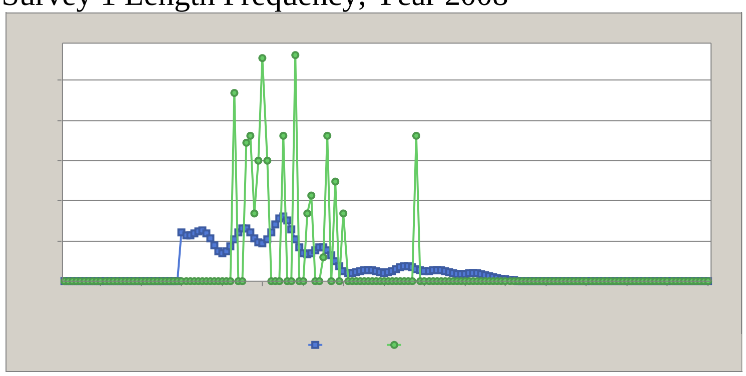


Survey 1 Length Frequency, Year 2008



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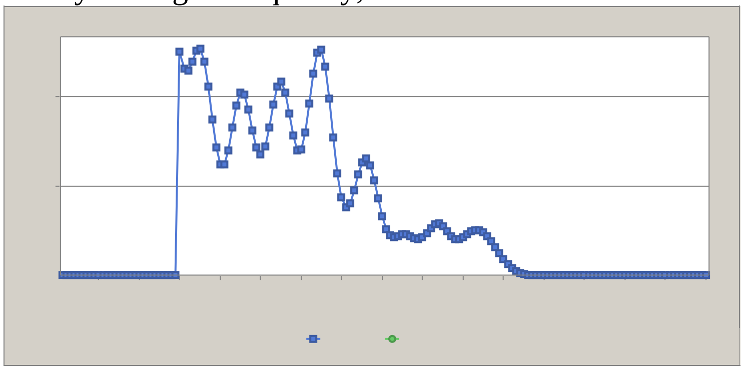
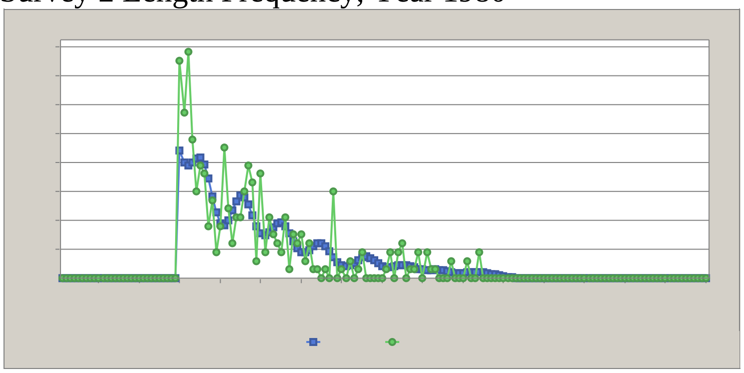
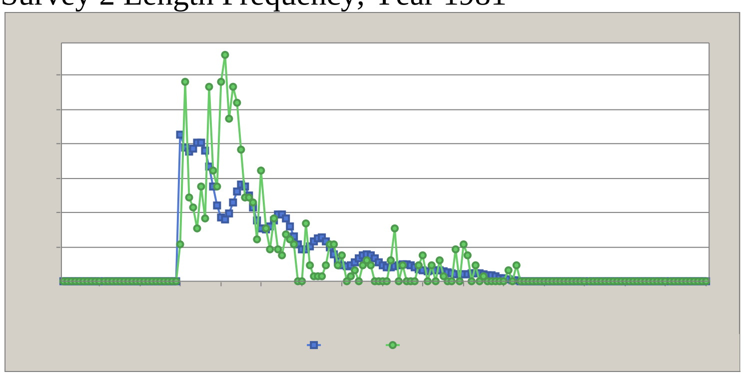


Survey 2 Length Frequency, Year 1980



Survey 2 Length Frequency, Year 1981



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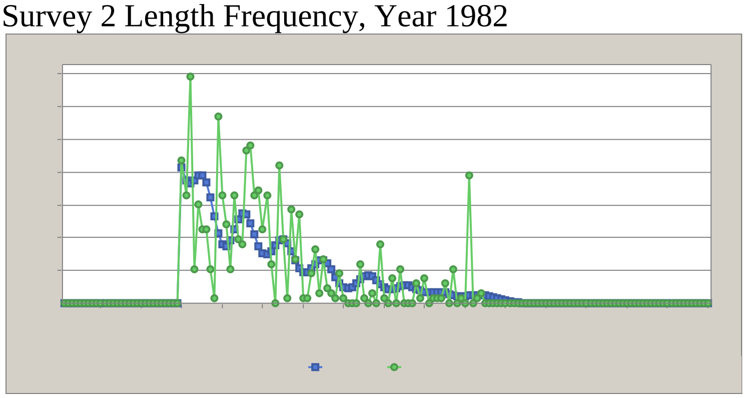

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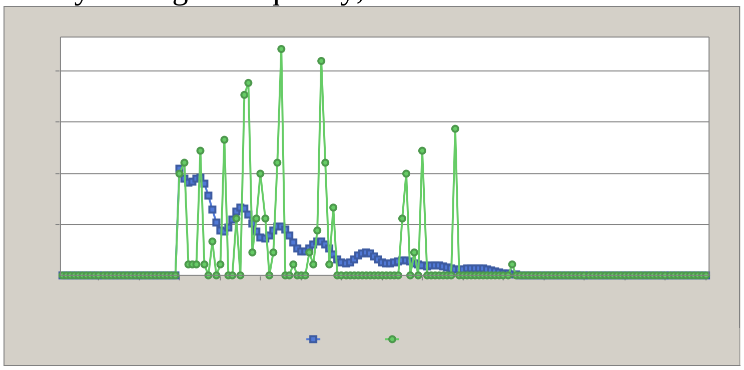

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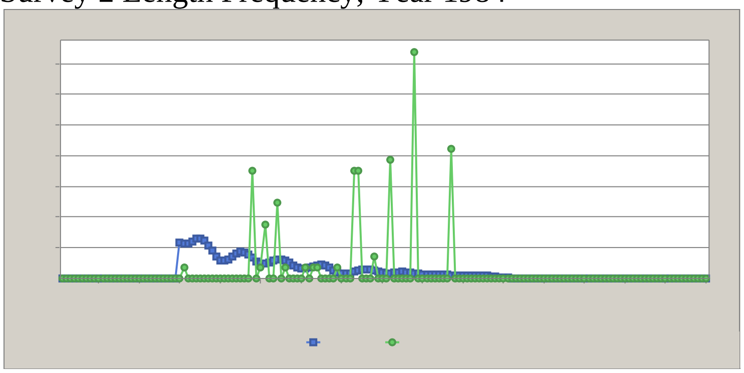

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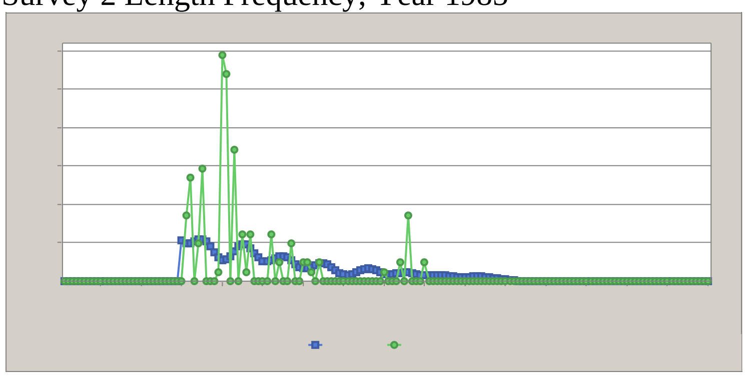

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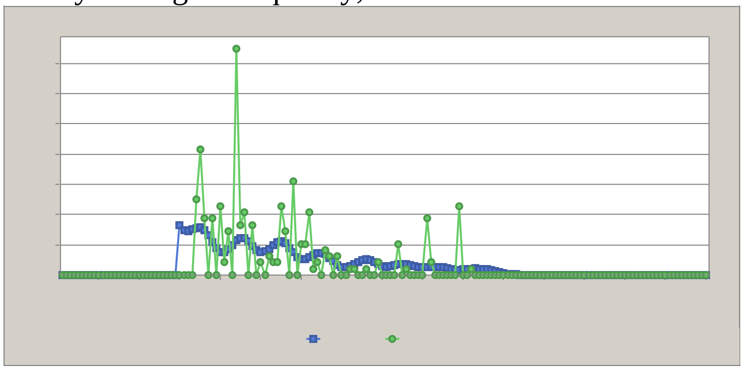

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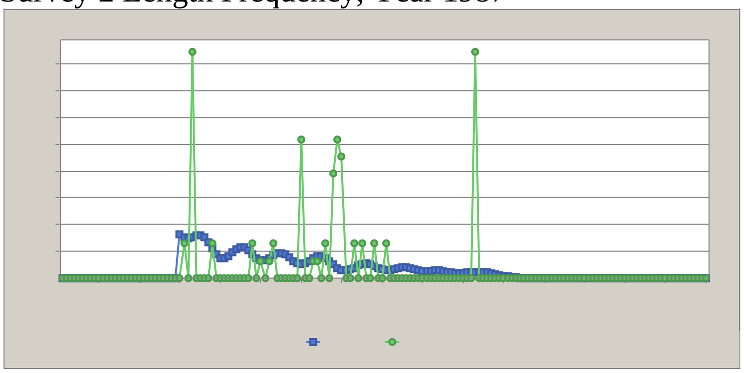

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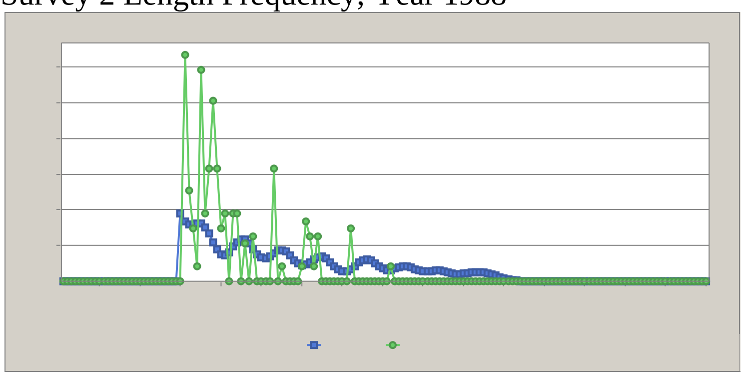

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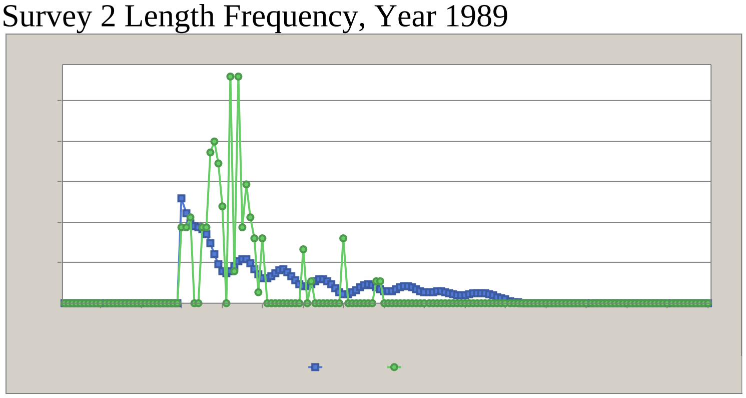

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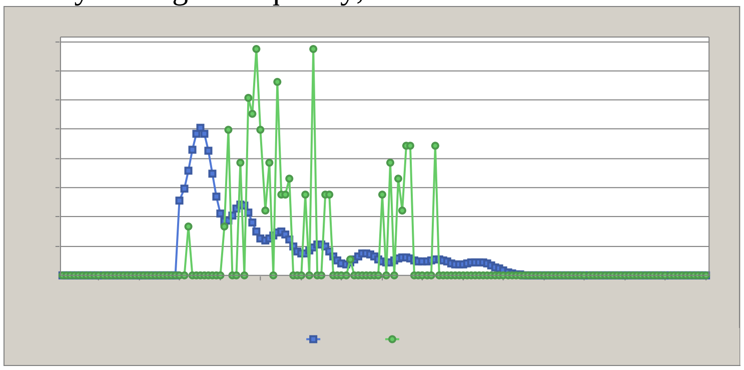

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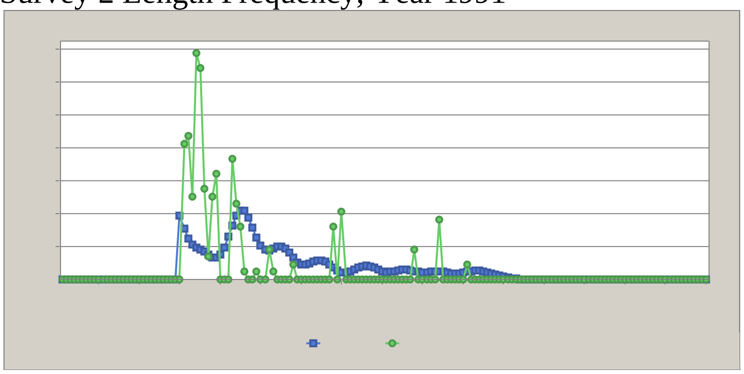

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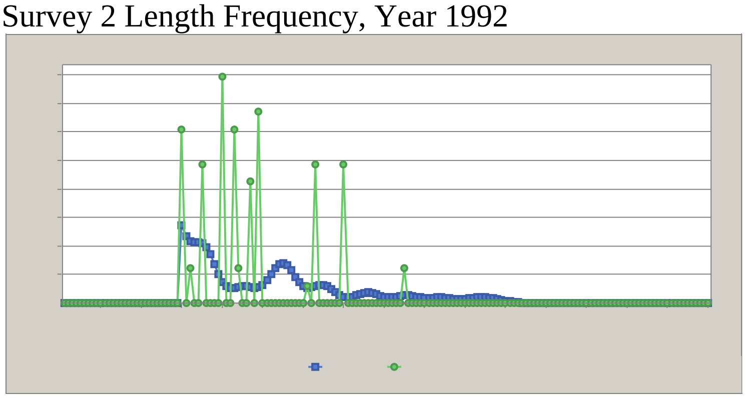

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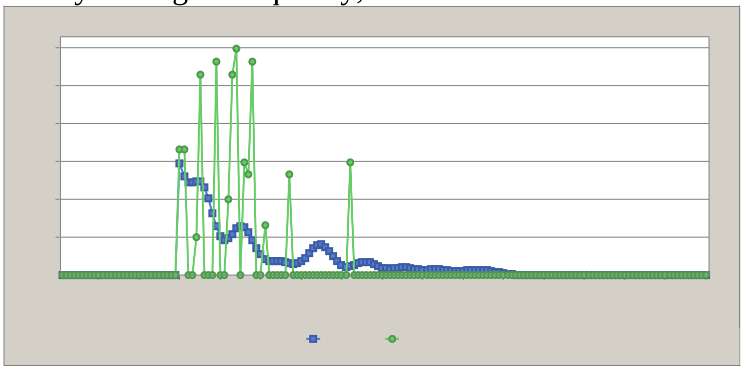

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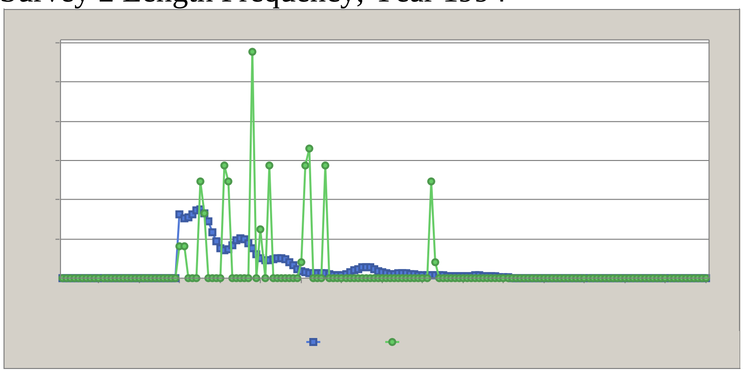

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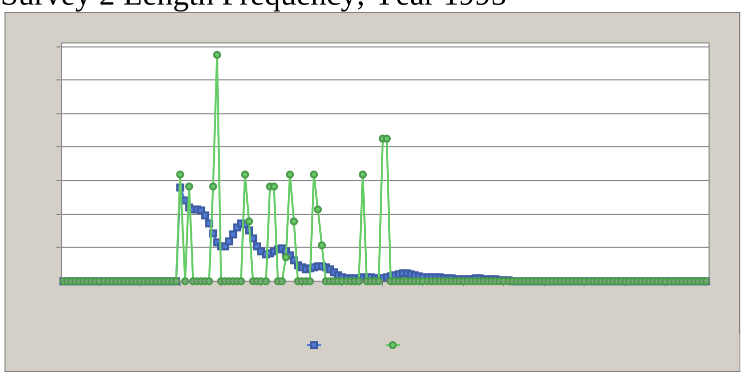

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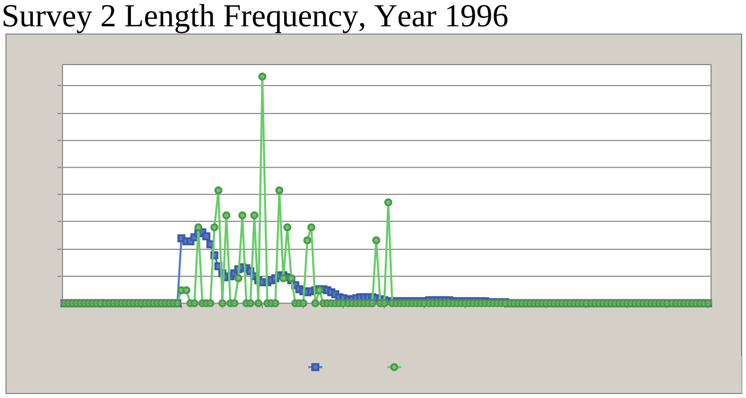

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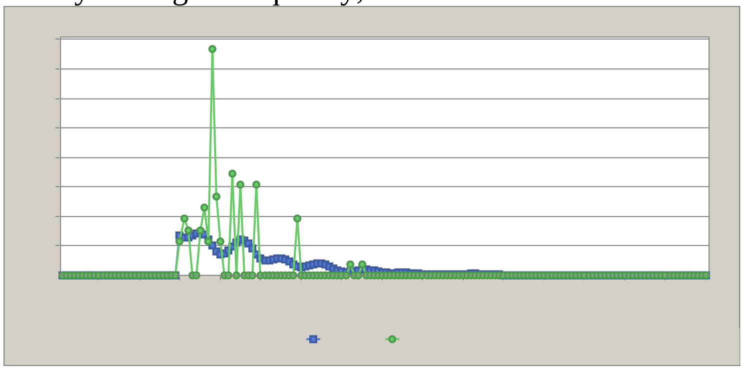

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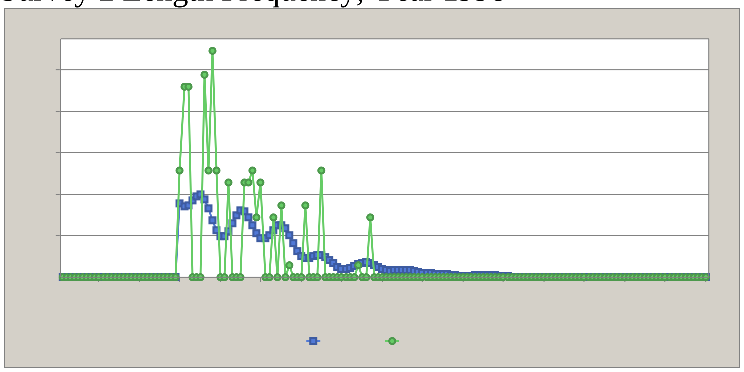

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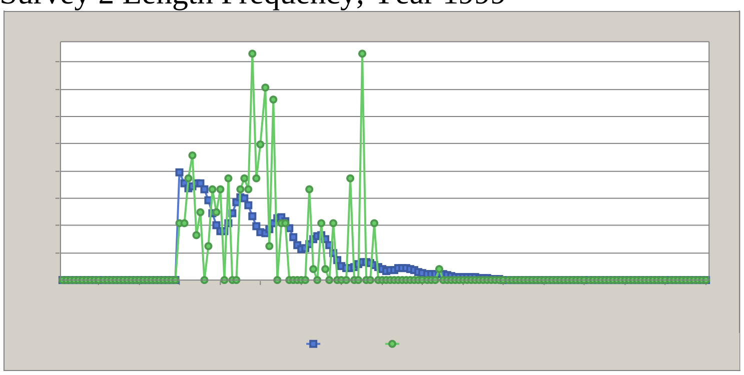

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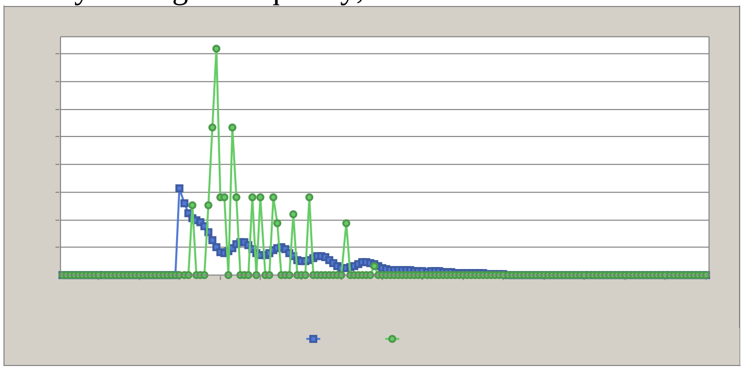

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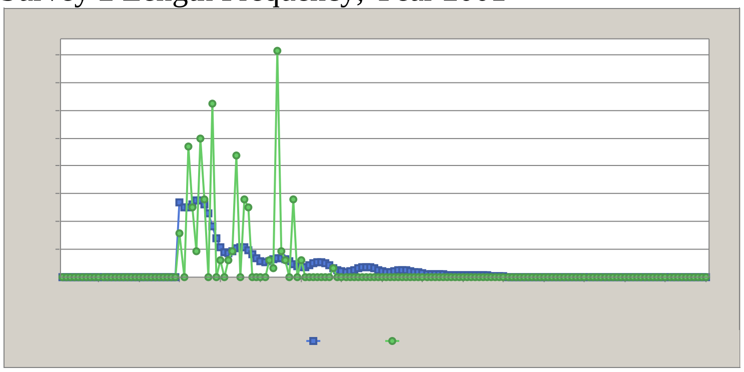

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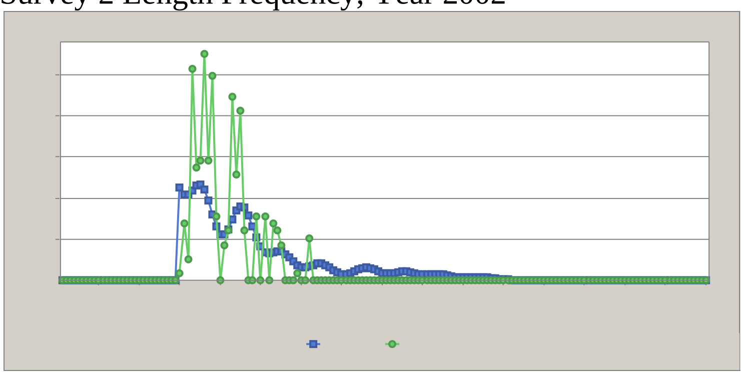

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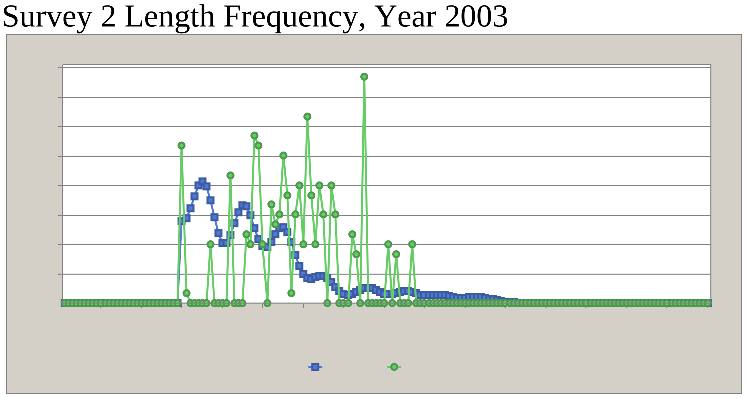

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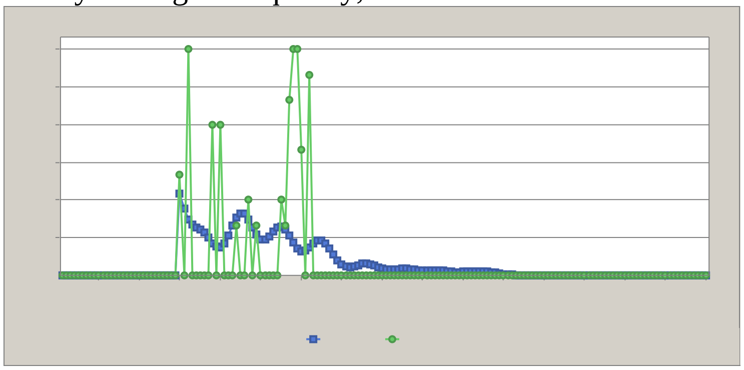

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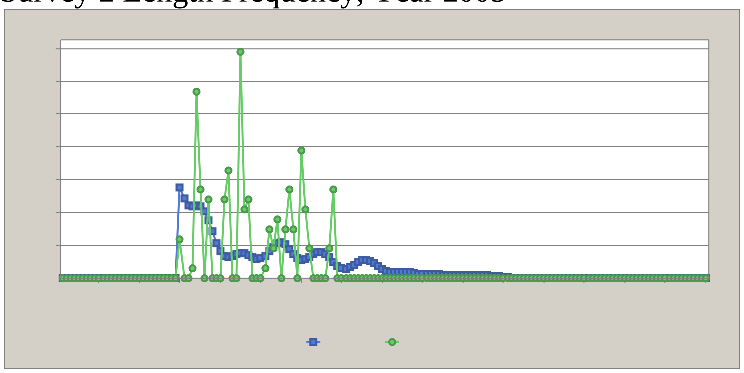

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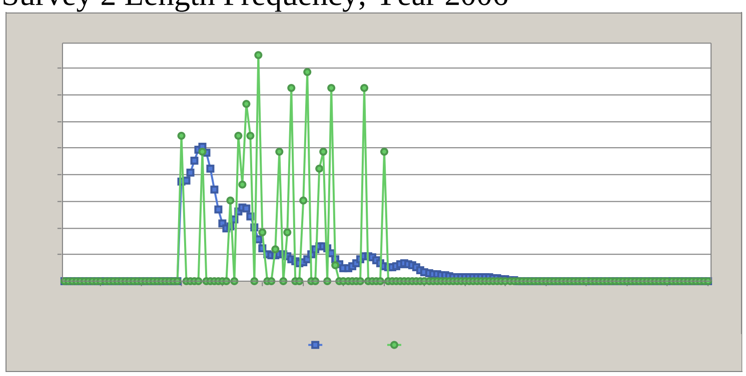

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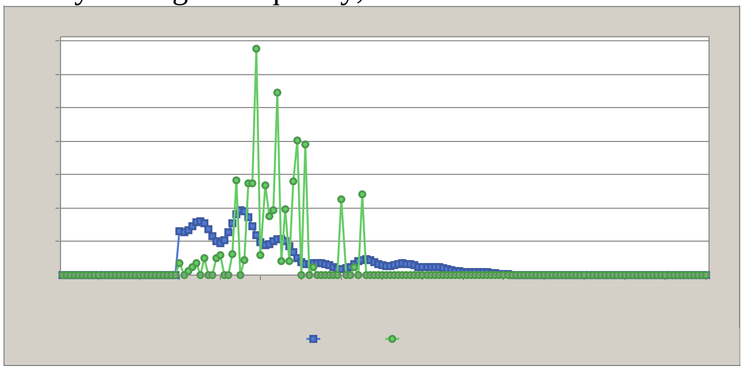
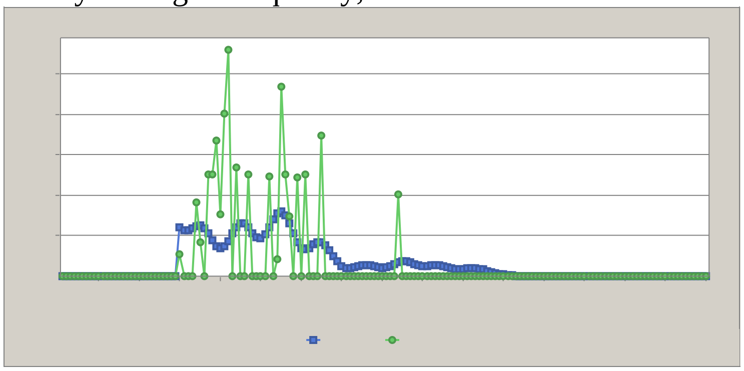
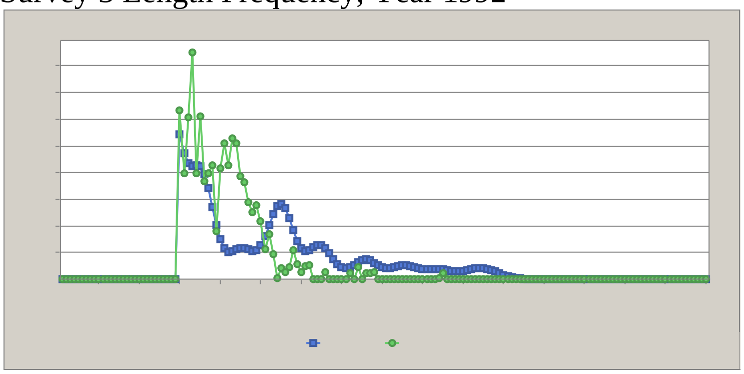


Survey 2 Length Frequency, Year 2008



Survey 3 Length Frequency, Year 1992



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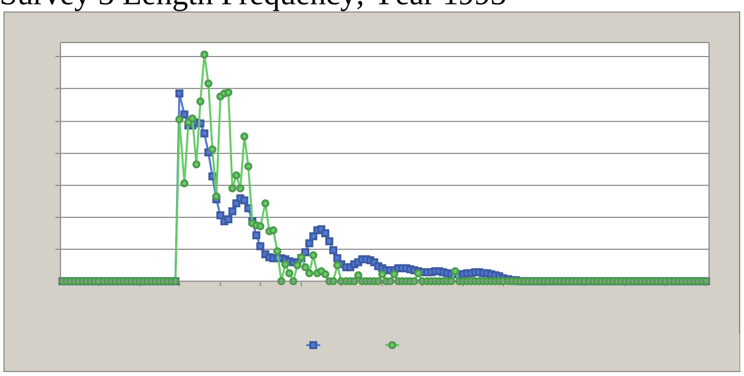

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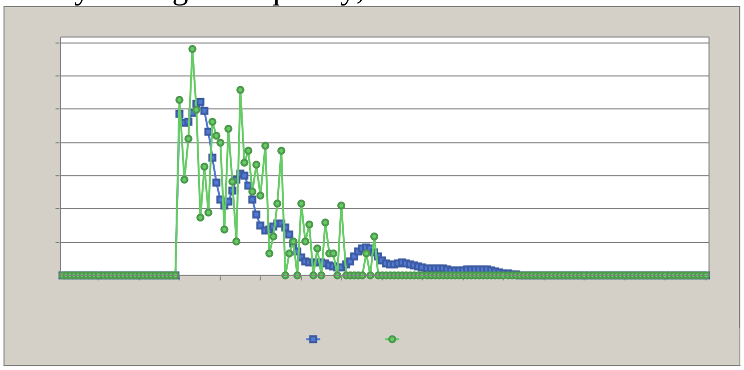

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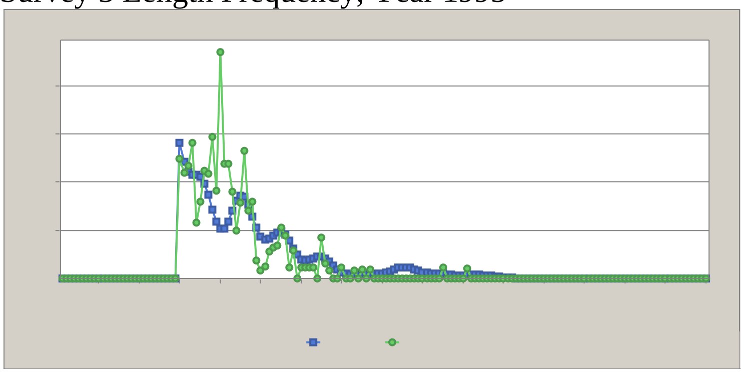

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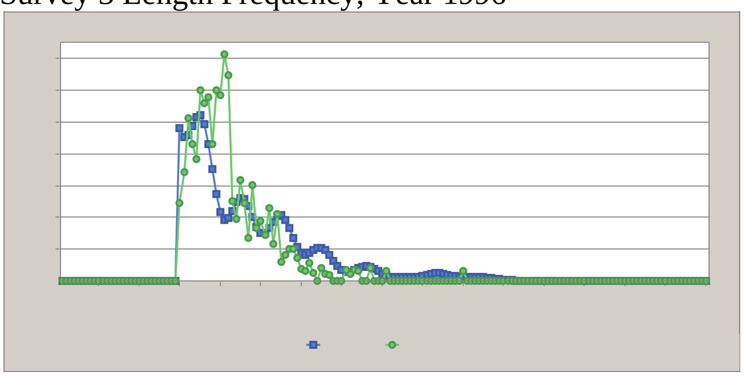

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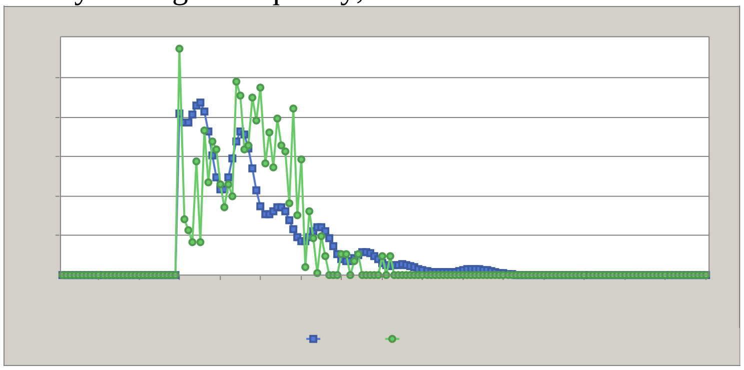

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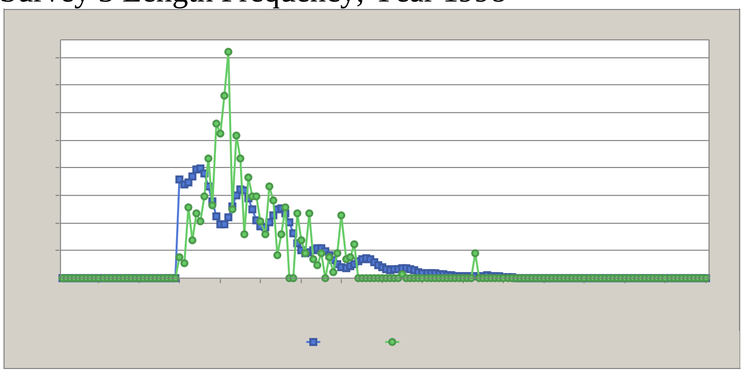

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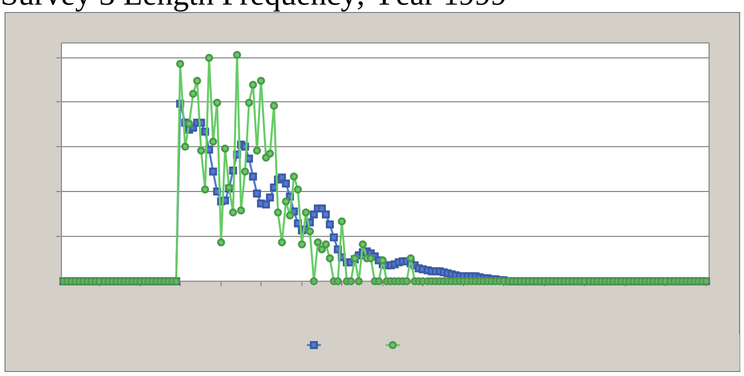

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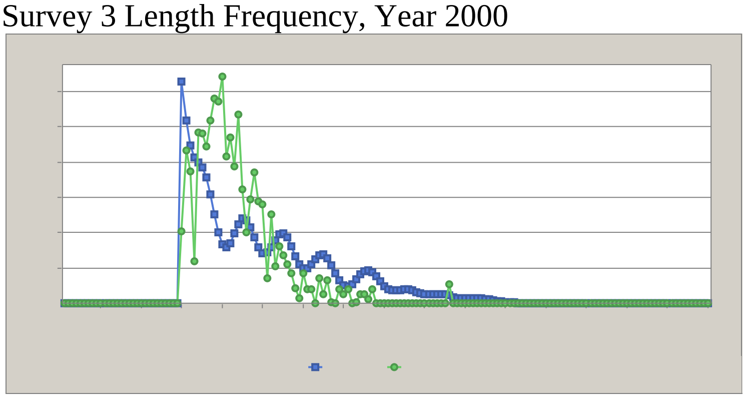

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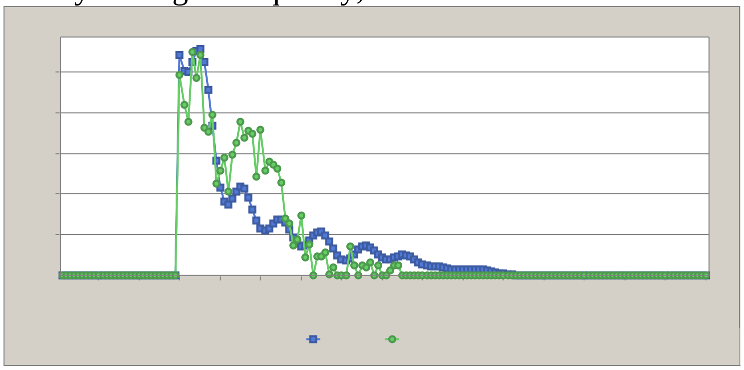

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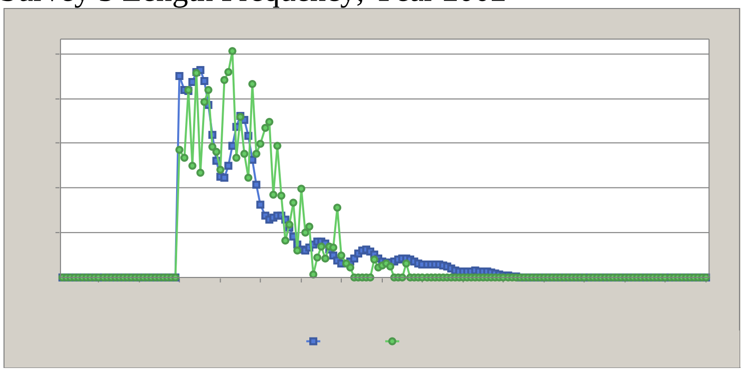

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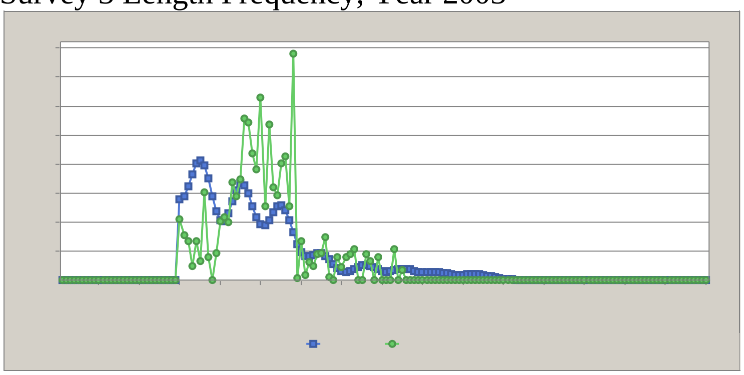

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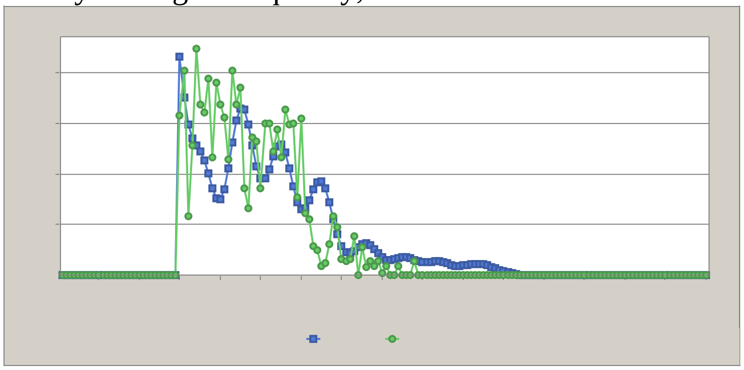

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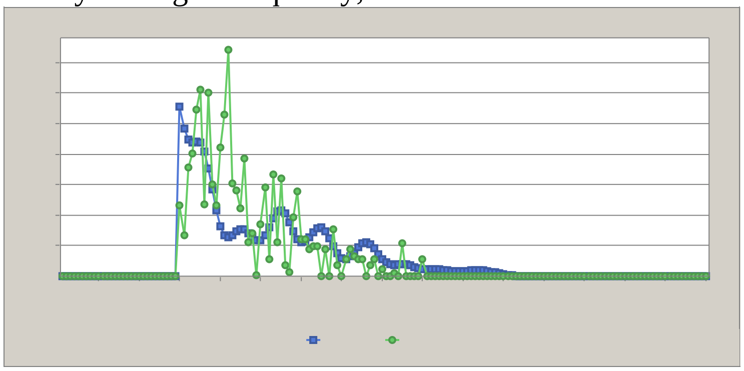

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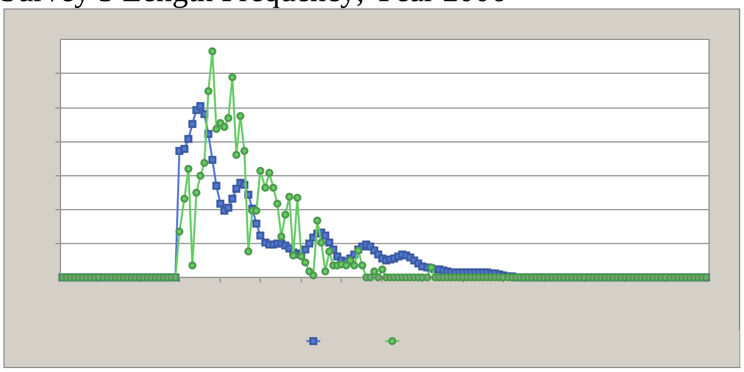

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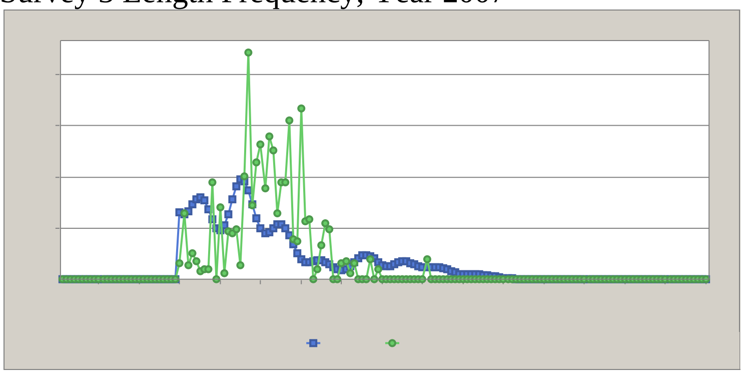

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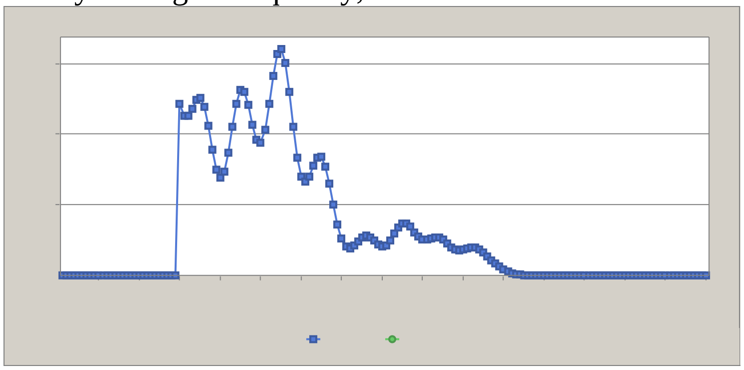

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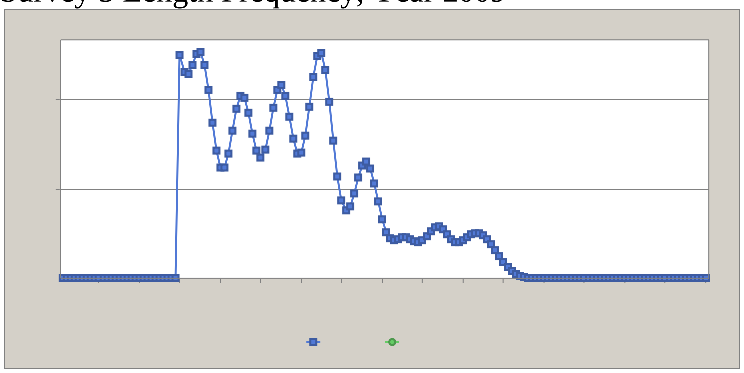

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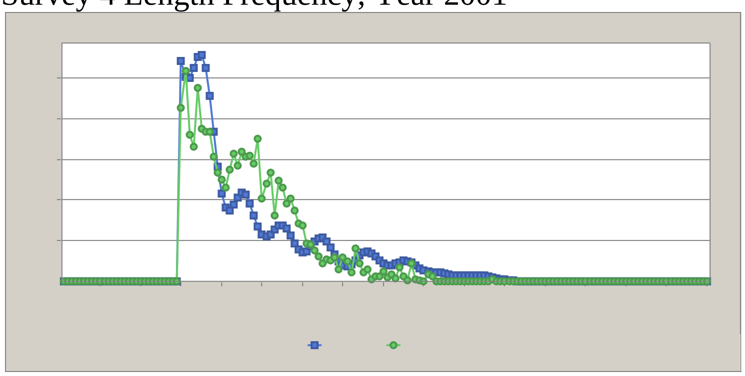

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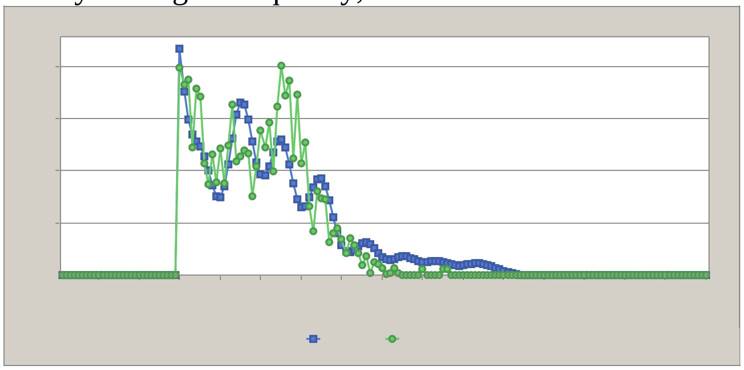

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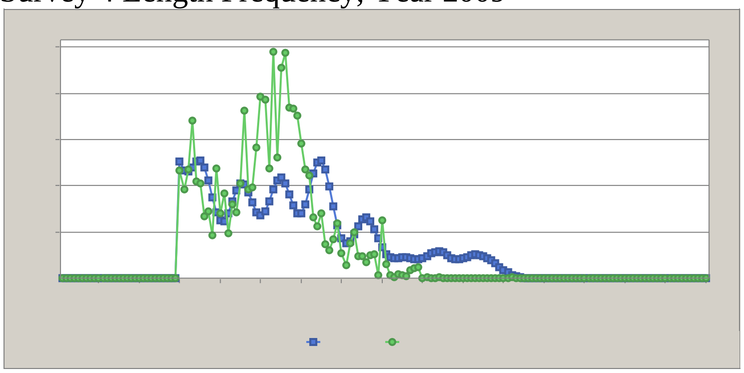
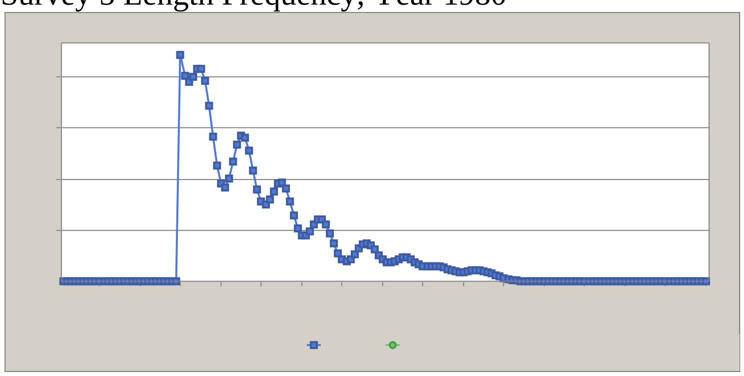
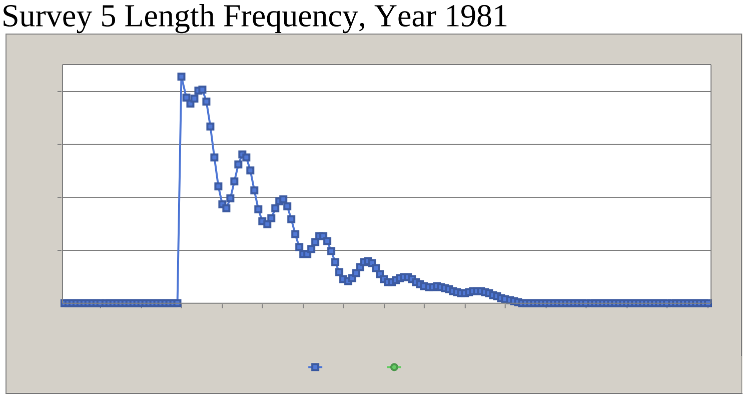


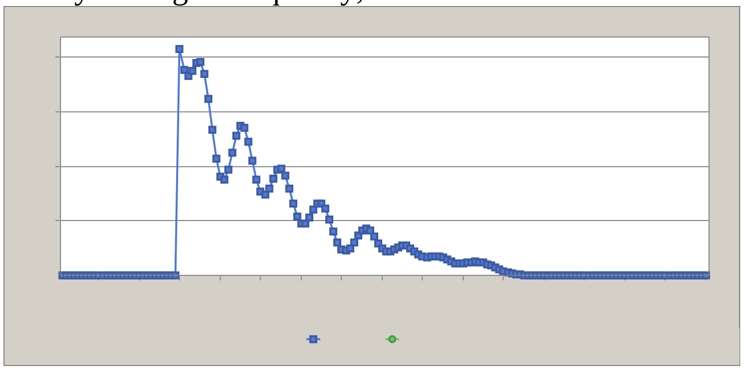
Survey 5 Length Frequency, Year 1980



Survey 5 Length Frequency, Year 1981



Survey 5 Length Frequency, Year 1982



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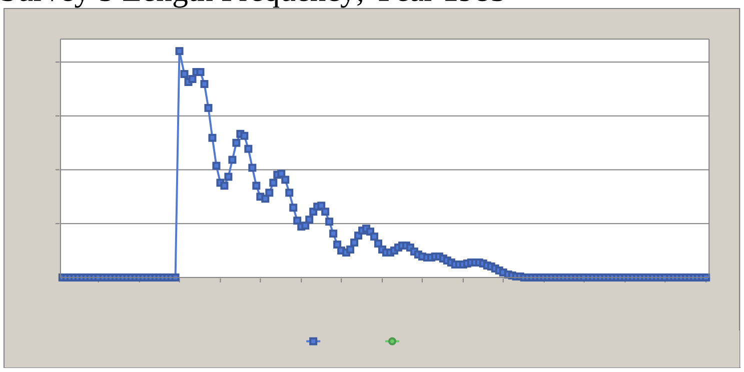

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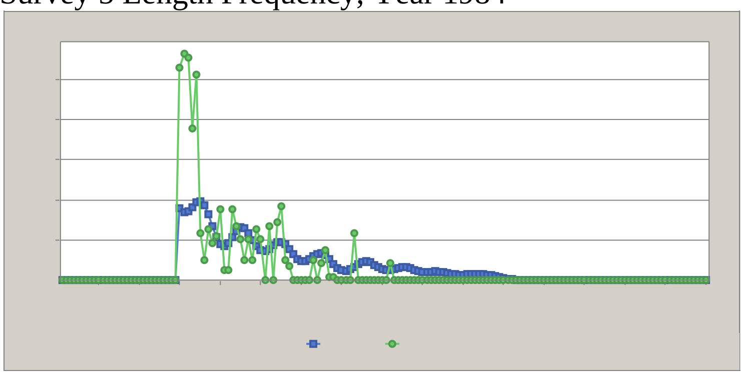

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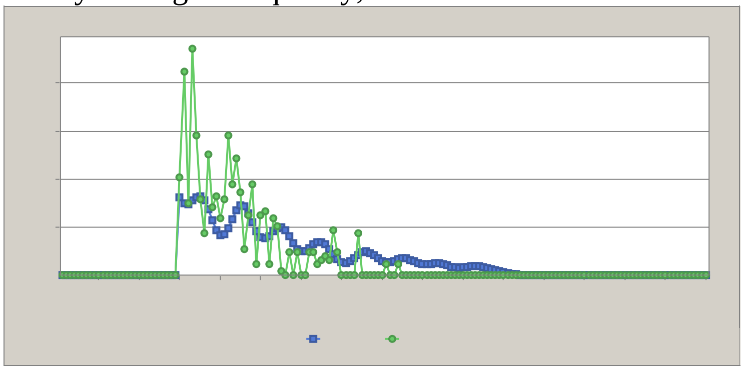

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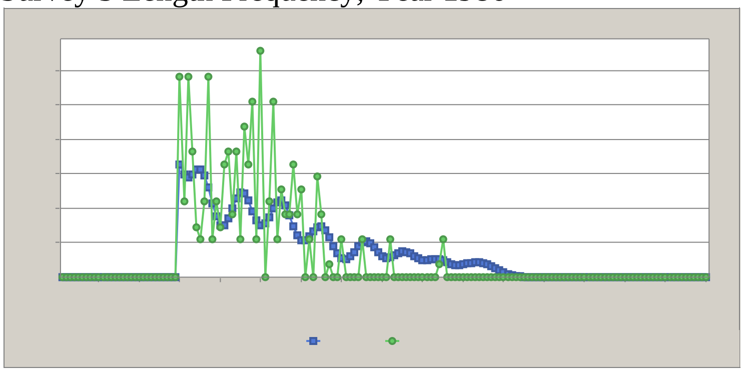

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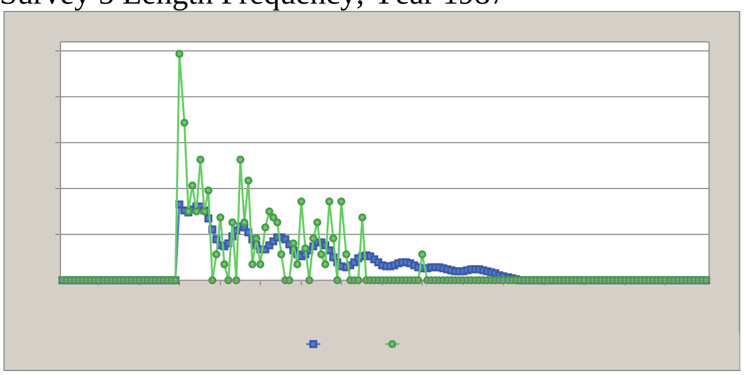

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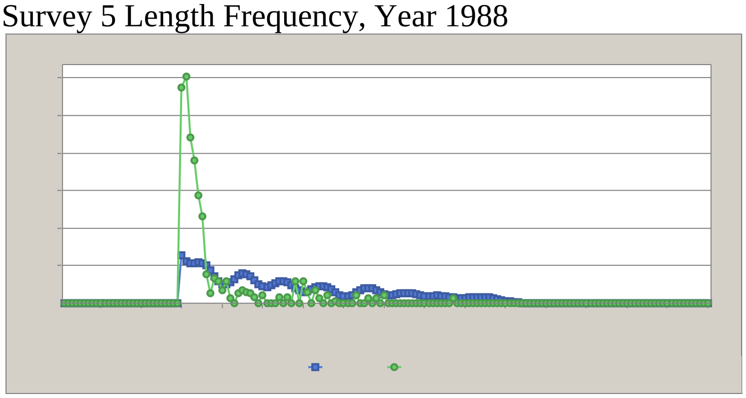
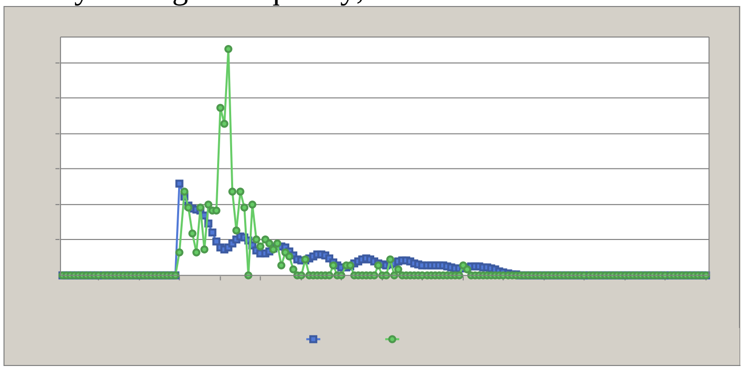
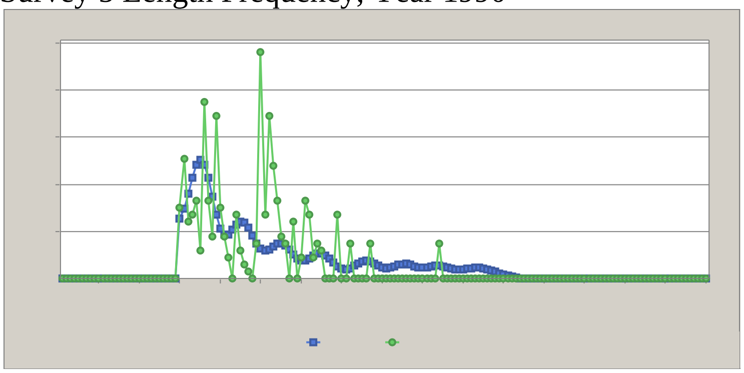


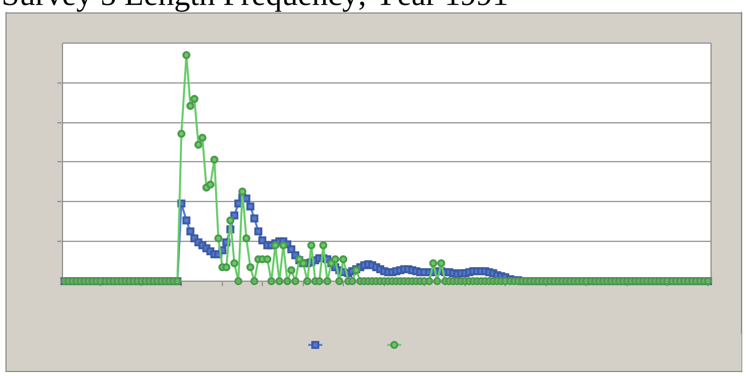
Survey 5 Length Frequency, Year 1989



Survey 5 Length Frequency, Year 1990



Survey 5 Length Frequency, Year 1991



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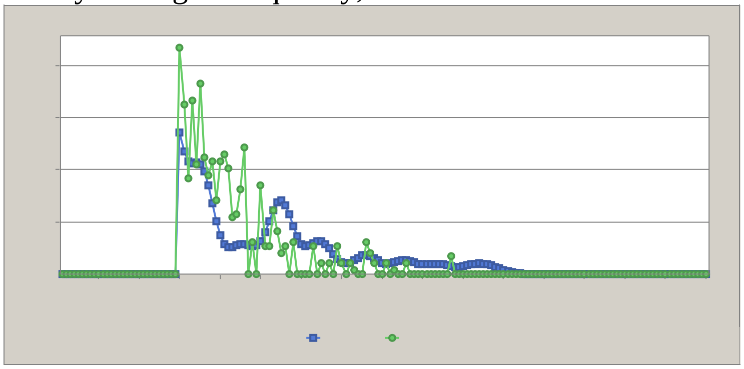

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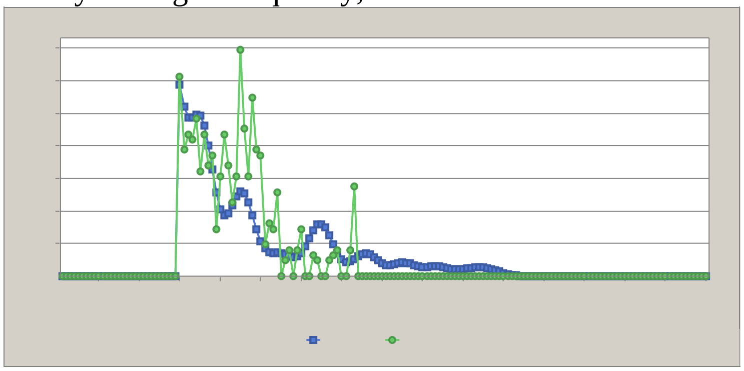
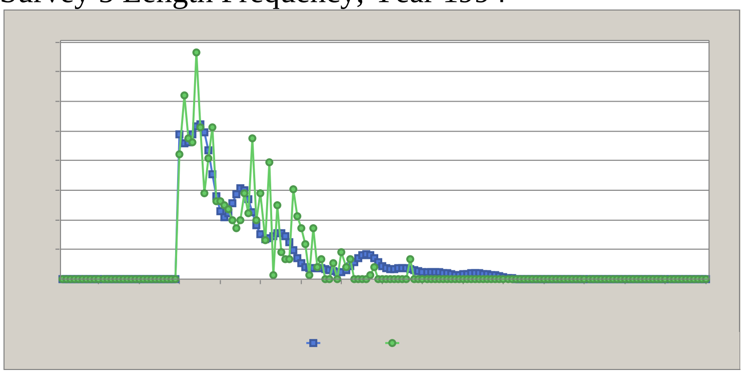
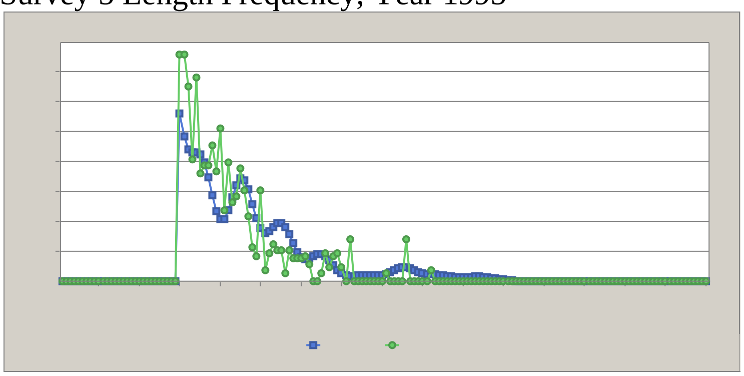


Survey 5 Length Frequency, Year 1994



Survey 5 Length Frequency, Year 1995



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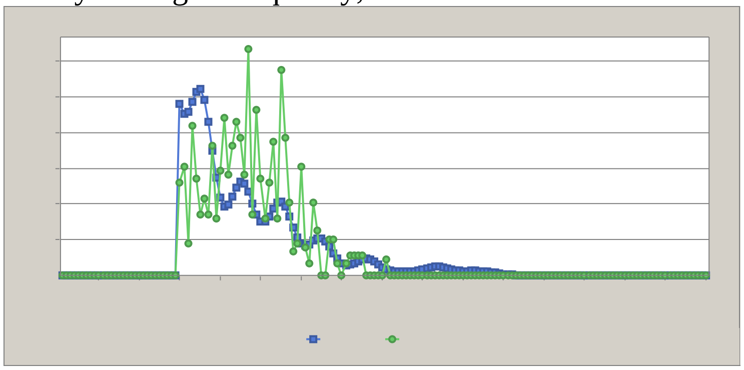

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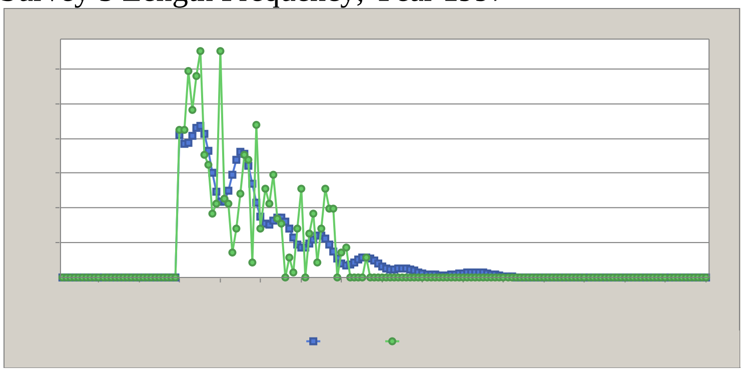

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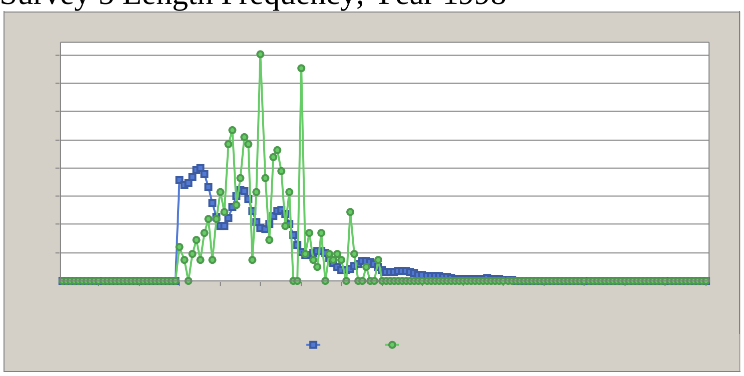
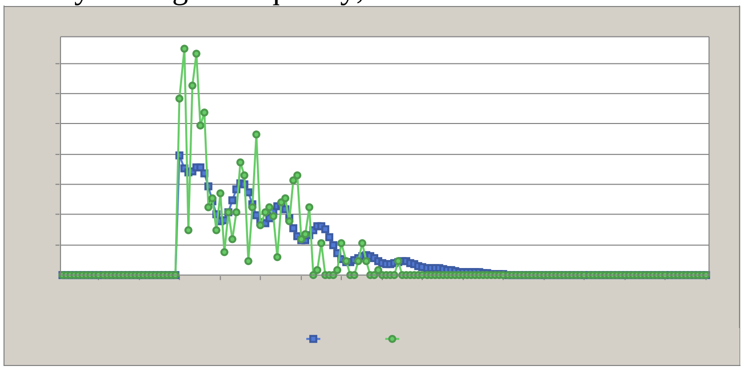
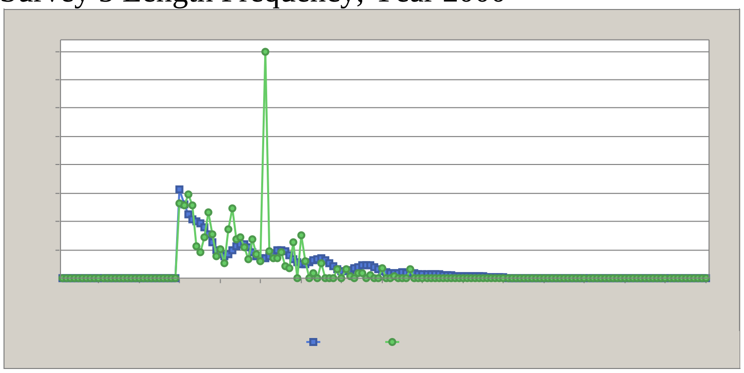


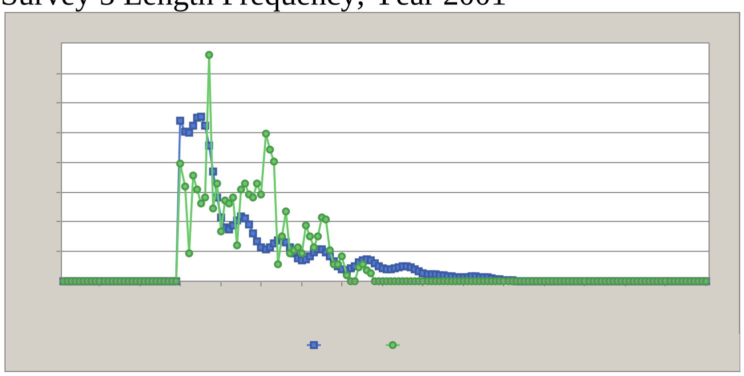
Survey 5 Length Frequency, Year 1999



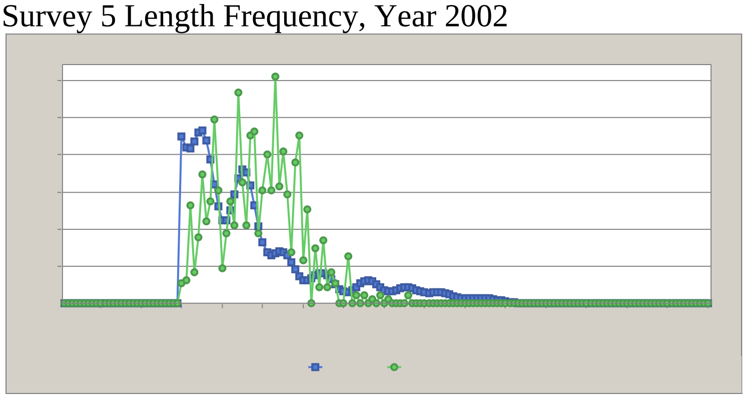
Survey 5 Length Frequency, Year 2000



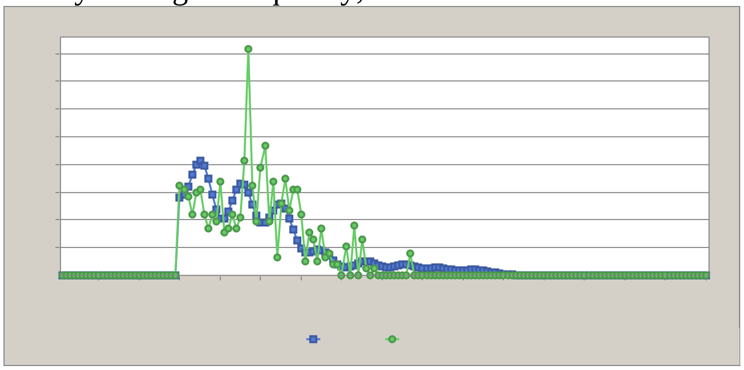
Survey 5 Length Frequency, Year 2001



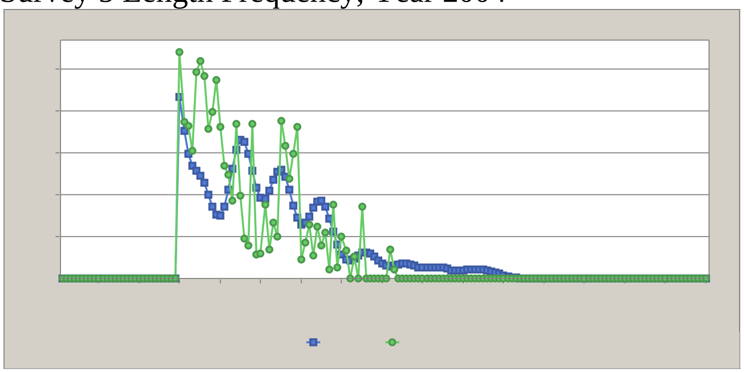
Survey 5 Length Frequency, Year 2002



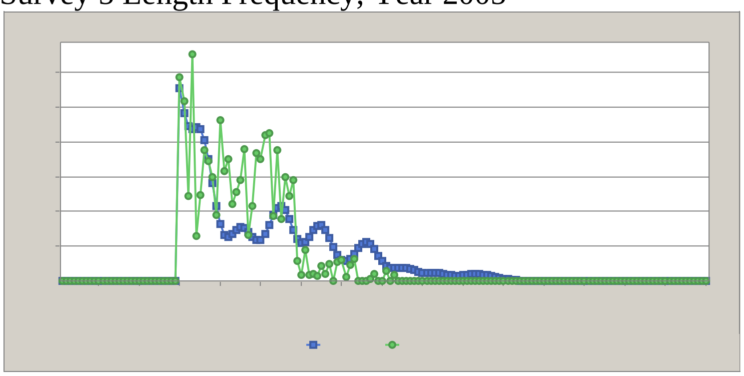
Survey 5 Length Frequency, Year 2003



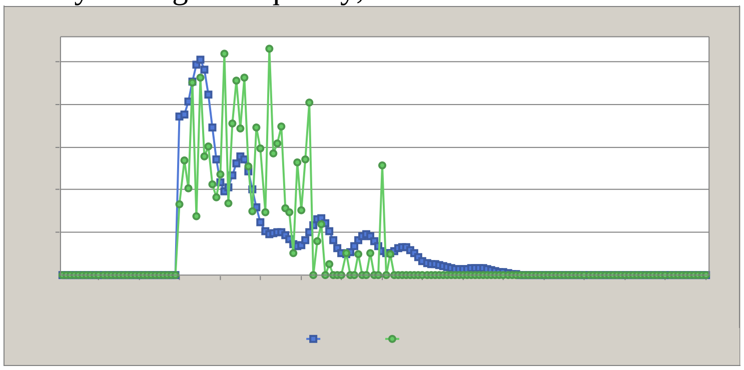
Survey 5 Length Frequency, Year 2004



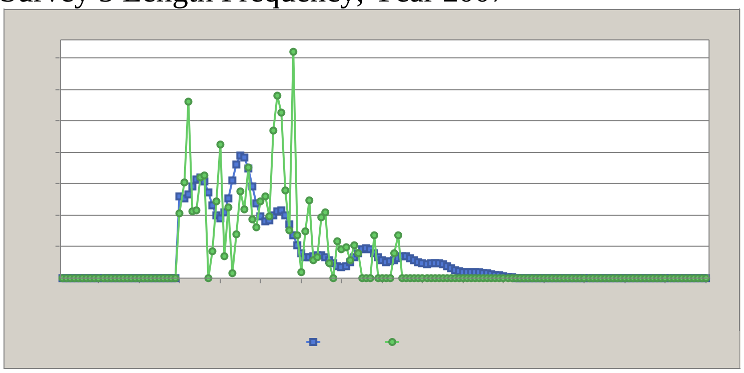
Survey 5 Length Frequency, Year 2005



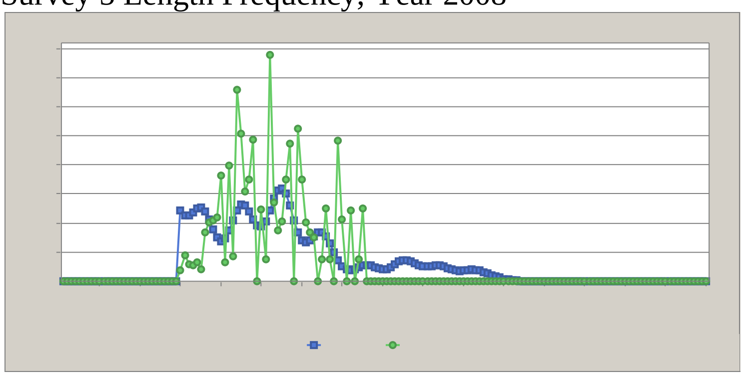
Survey 5 Length Frequency, Year 2006



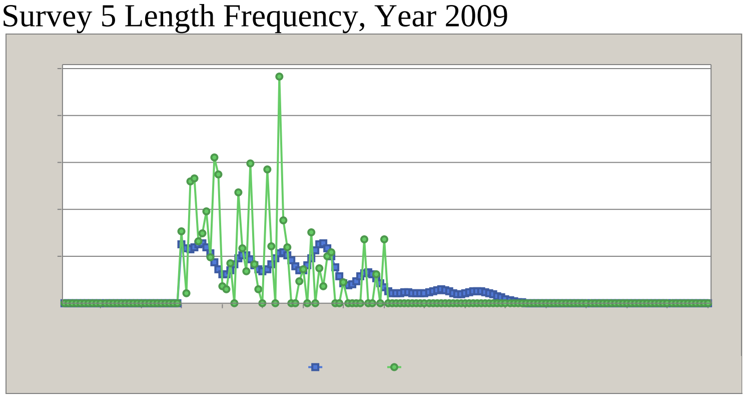
Survey 5 Length Frequency, Year 2007



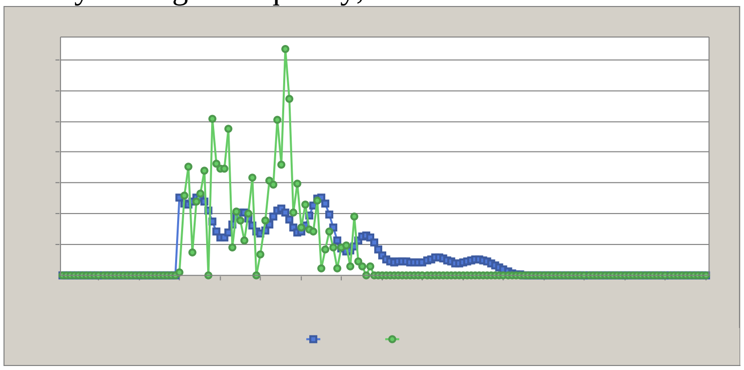
Survey 5 Length Frequency, Year 2008



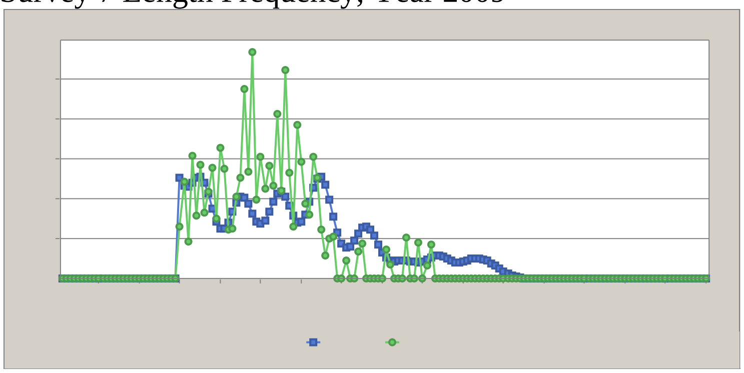
Survey 5 Length Frequency, Year 2009



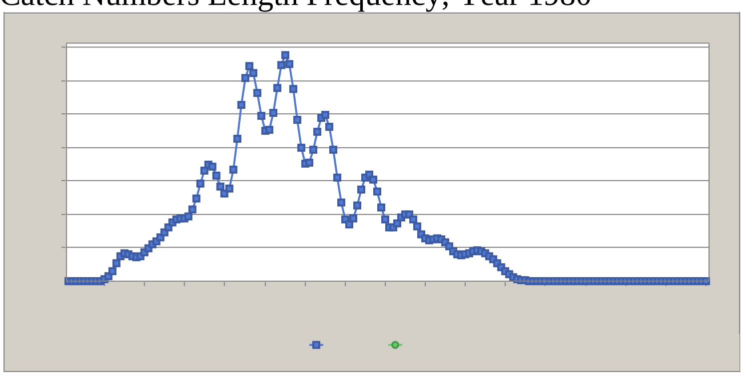
Survey 6 Length Frequency, Year 2009



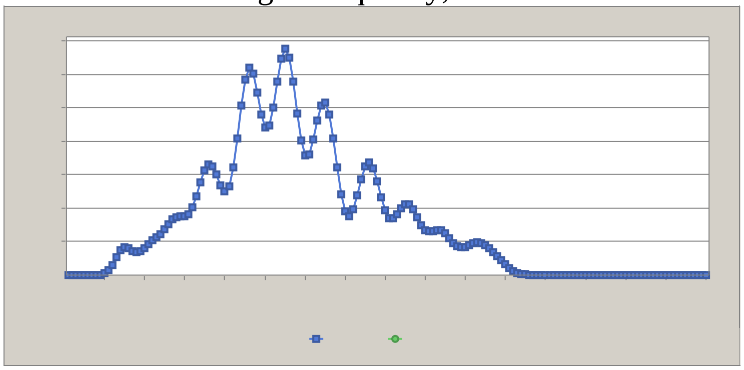
Survey 7 Length Frequency, Year 2009



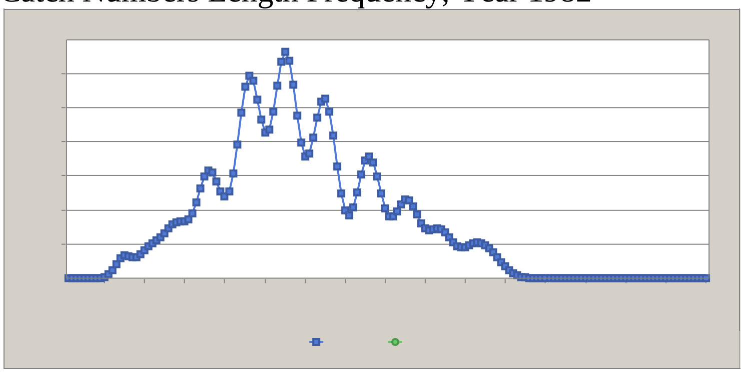
Catch Numbers Length Frequency, Year 1980



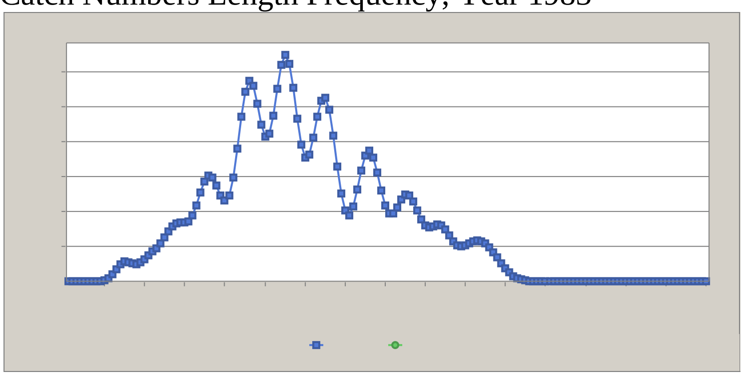
Catch Numbers Length Frequency, Year 1981



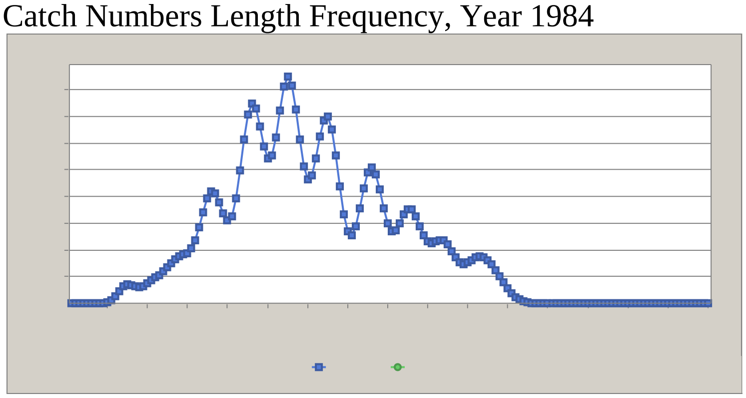
Catch Numbers Length Frequency, Year 1982



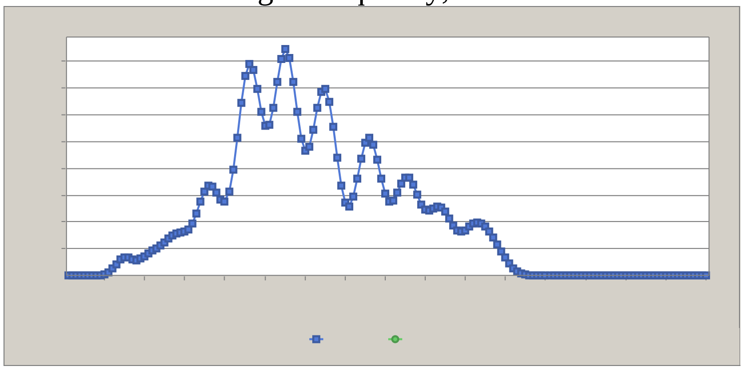
Catch Numbers Length Frequency, Year 1983



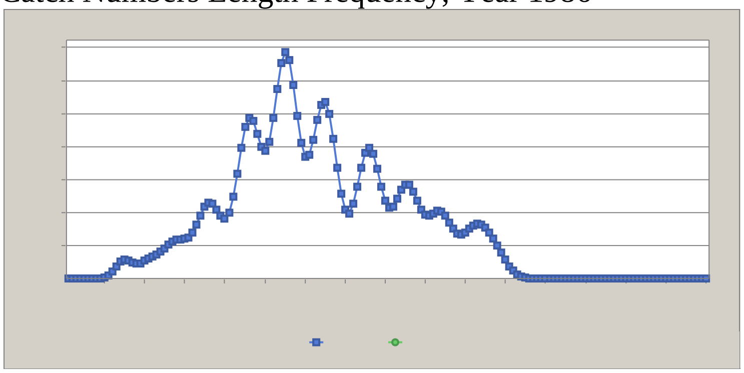
Catch Numbers Length Frequency, Year 1984



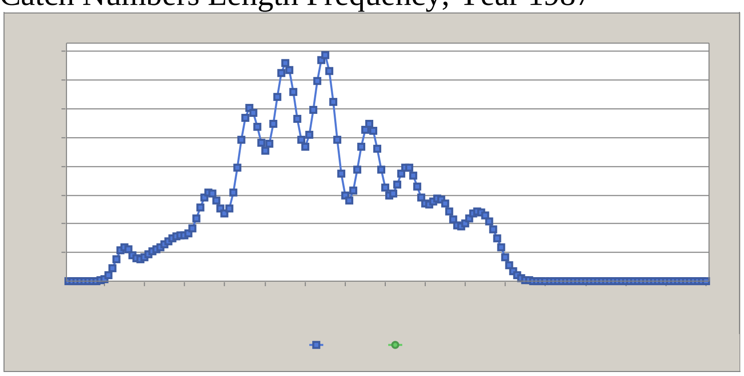
Catch Numbers Length Frequency, Year 1985



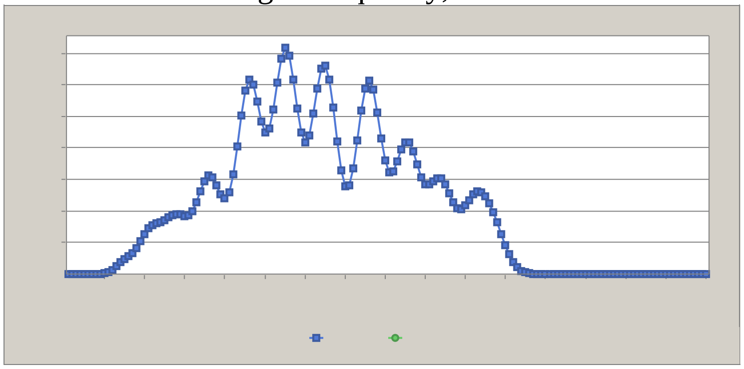
Catch Numbers Length Frequency, Year 1986



Catch Numbers Length Frequency, Year 1987



Catch Numbers Length Frequency, Year 1988



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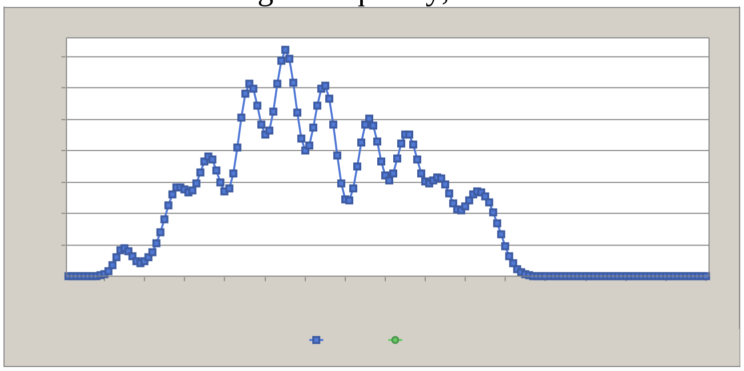

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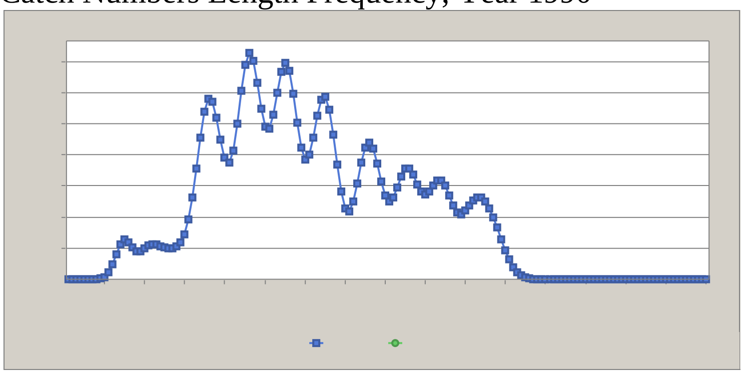

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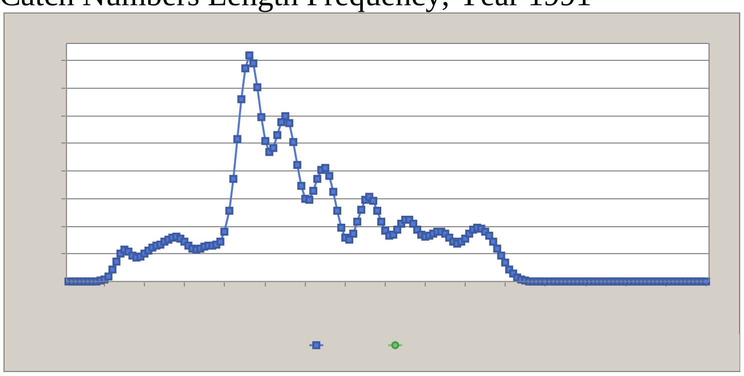

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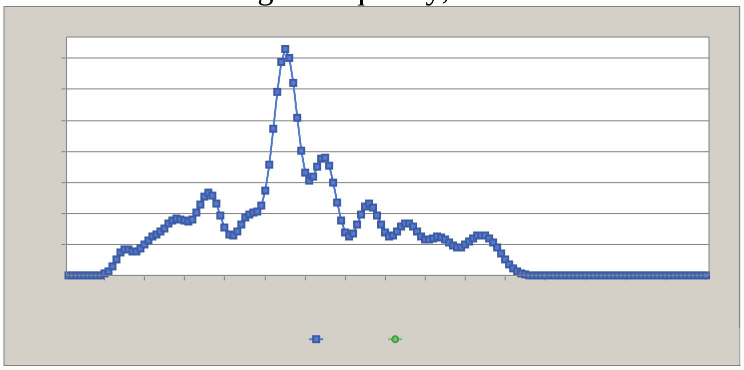

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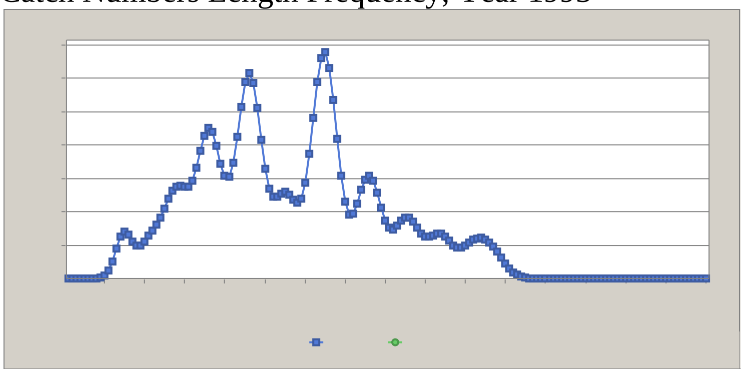

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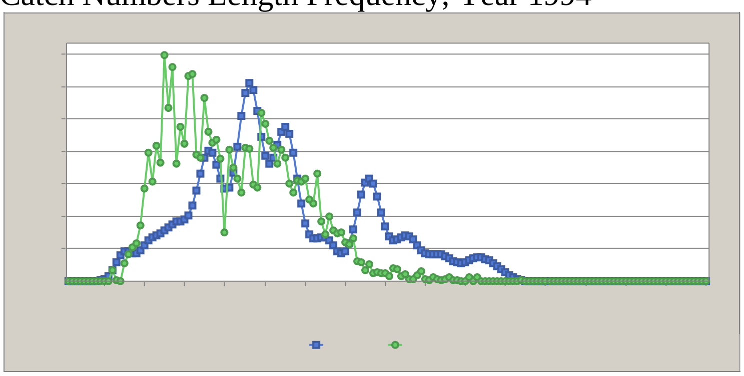
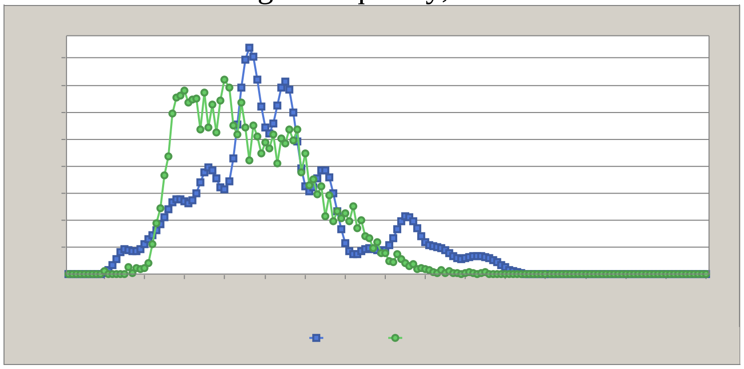
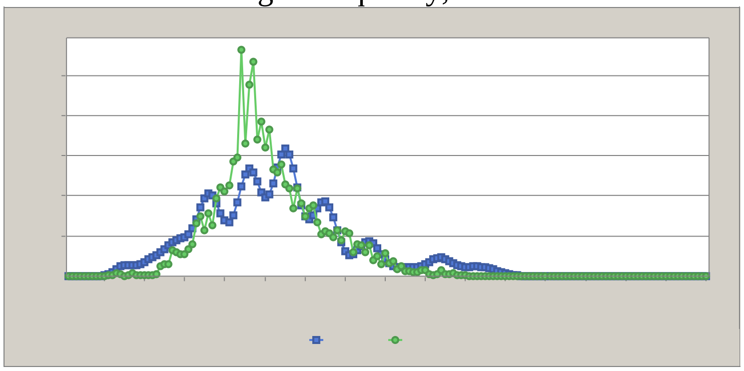


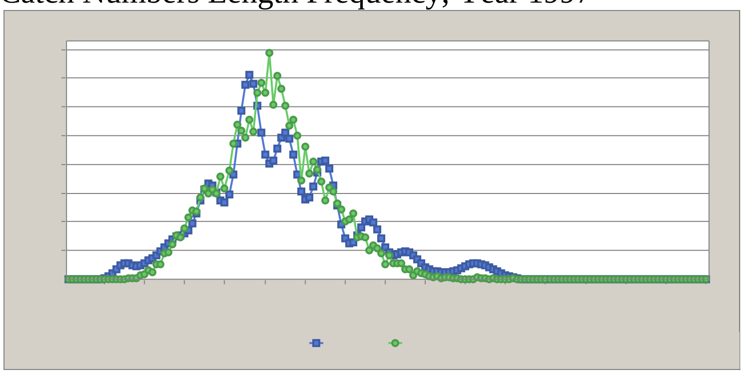
Catch Numbers Length Frequency, Year 1995



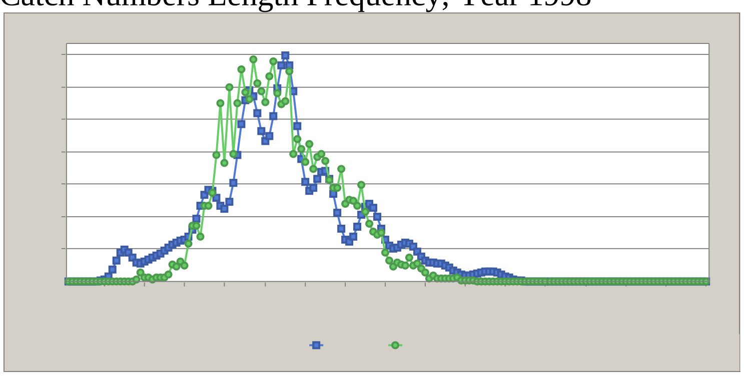
Catch Numbers Length Frequency, Year 1996



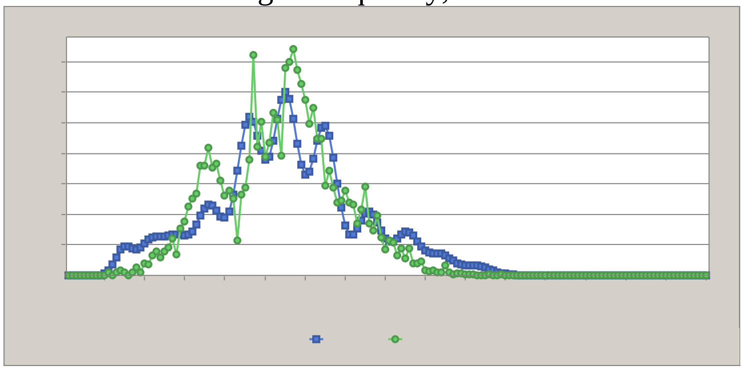
Catch Numbers Length Frequency, Year 1997



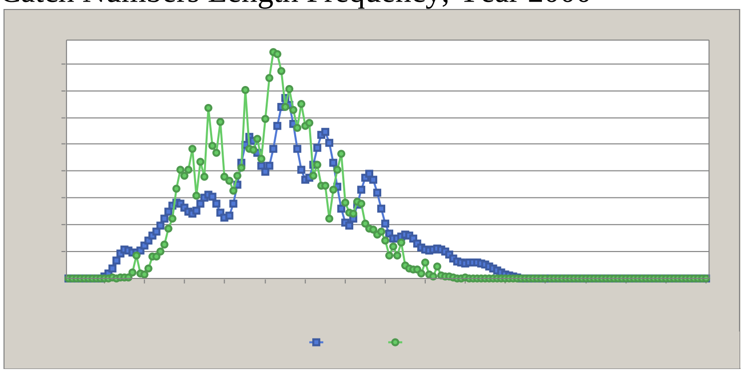
Catch Numbers Length Frequency, Year 1998



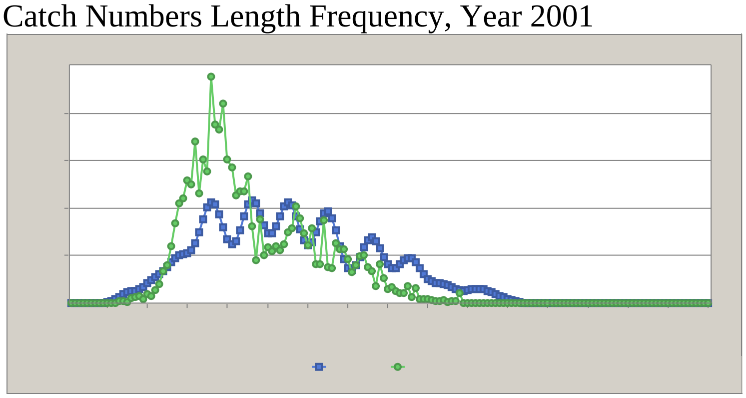
Catch Numbers Length Frequency, Year 1999



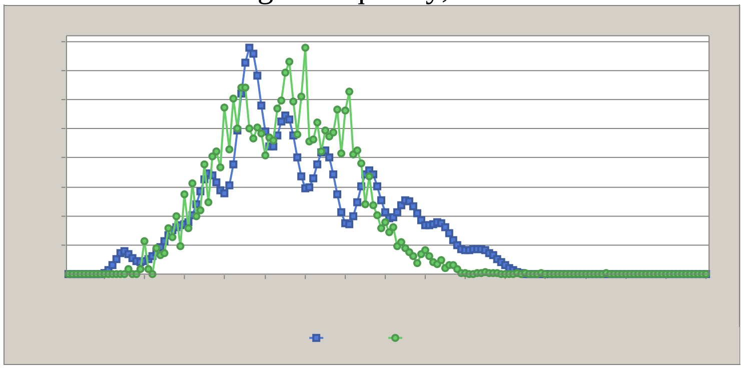
Catch Numbers Length Frequency, Year 2000



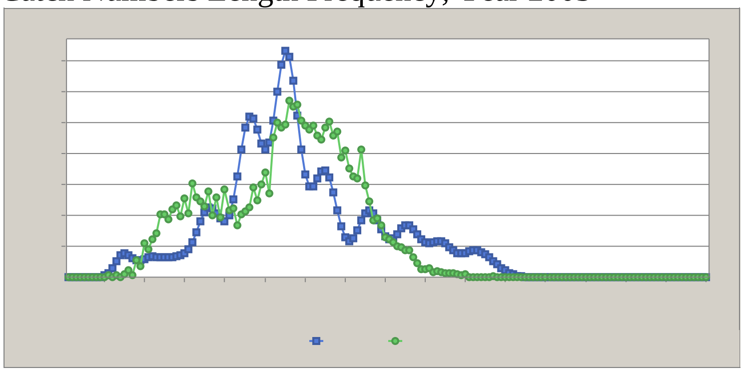
Catch Numbers Length Frequency, Year 2001



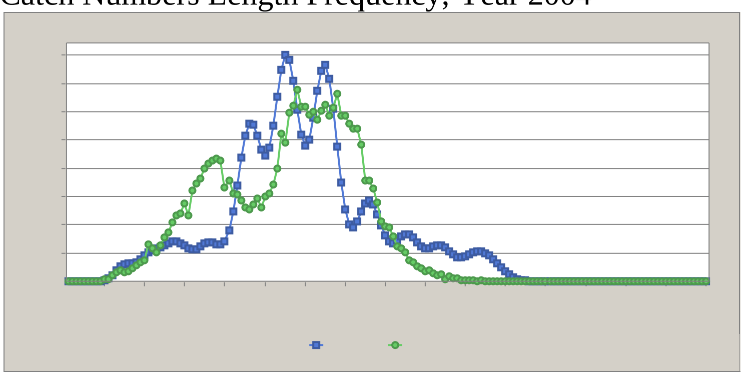
Catch Numbers Length Frequency, Year 2002



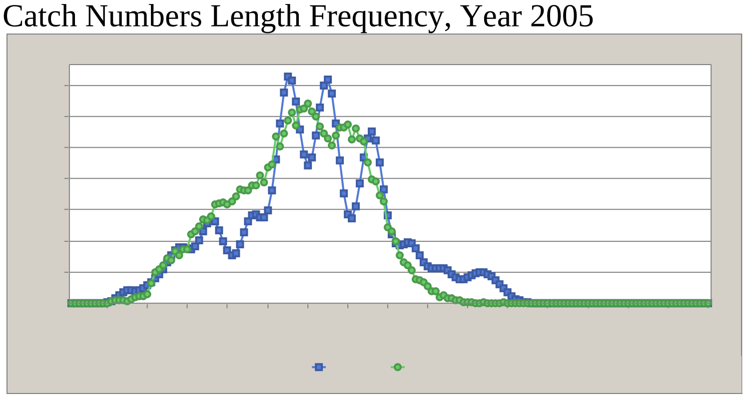
Catch Numbers Length Frequency, Year 2003



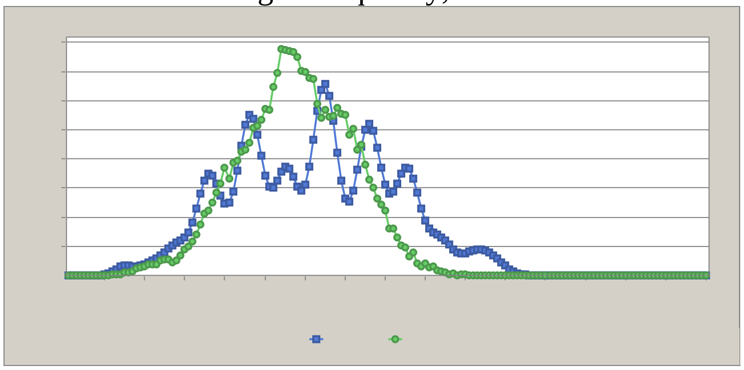
Catch Numbers Length Frequency, Year 2004



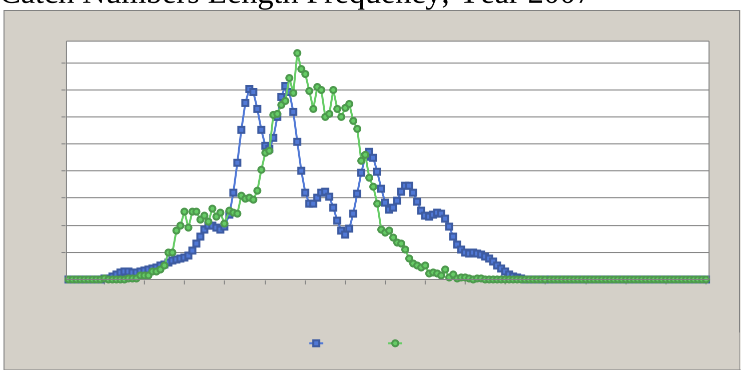
Catch Numbers Length Frequency, Year 2005



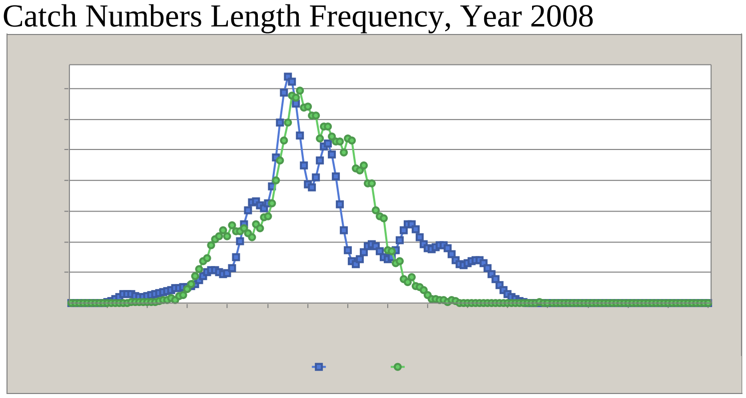
Catch Numbers Length Frequency, Year 2006



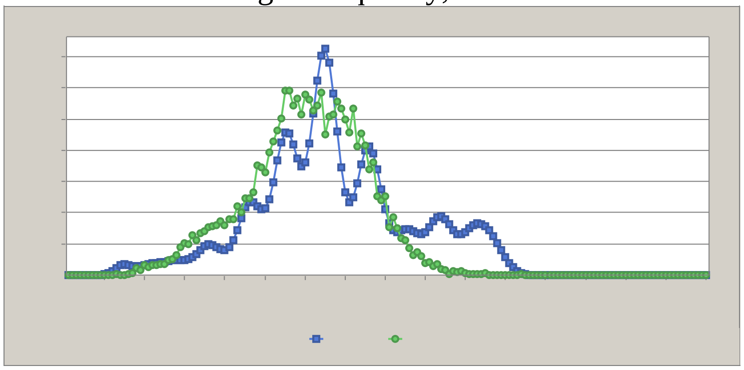
Catch Numbers Length Frequency, Year 2007



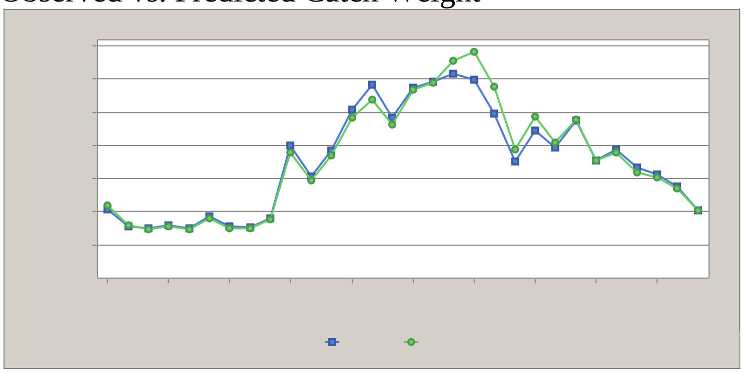
Catch Numbers Length Frequency, Year 2008



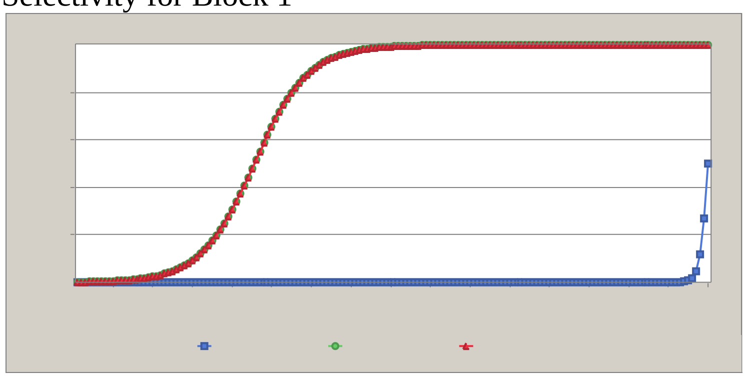
Catch Numbers Length Frequency, Year 2009



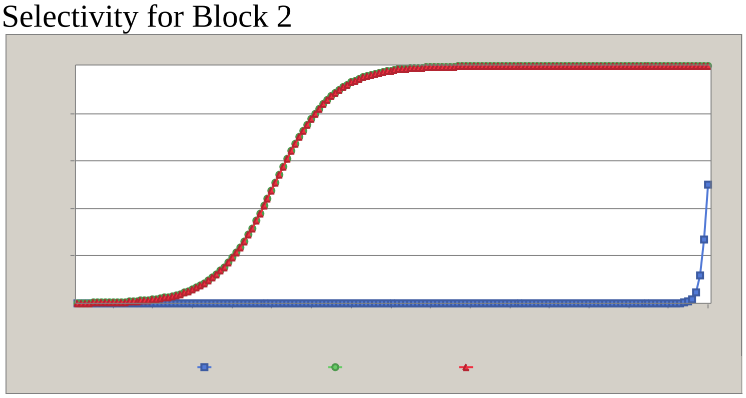
Observed vs. Predicted Catch Weight



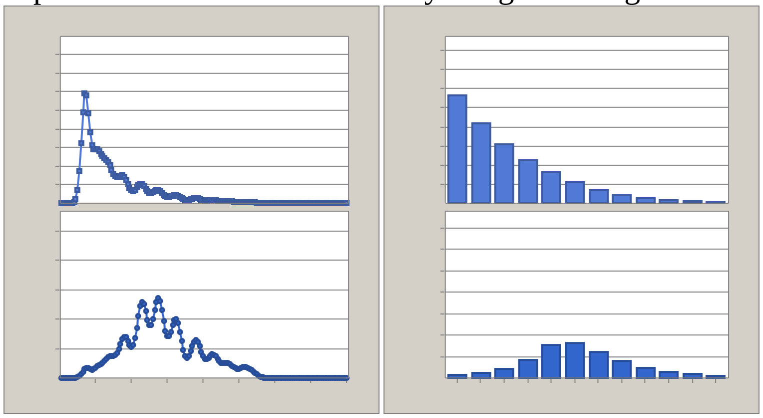
Selectivity for Block 1



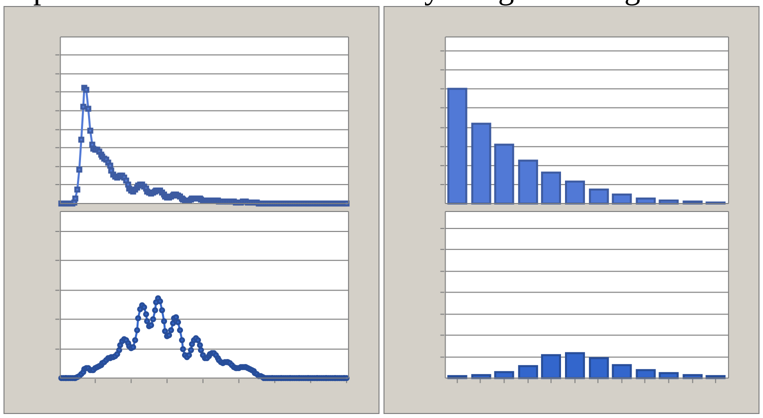
Selectivity for Block 2



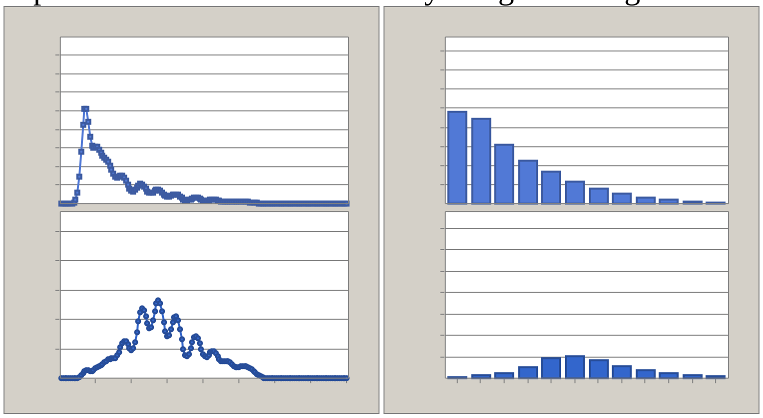
Population and Catch Numbers by Length and Age for Year 1980



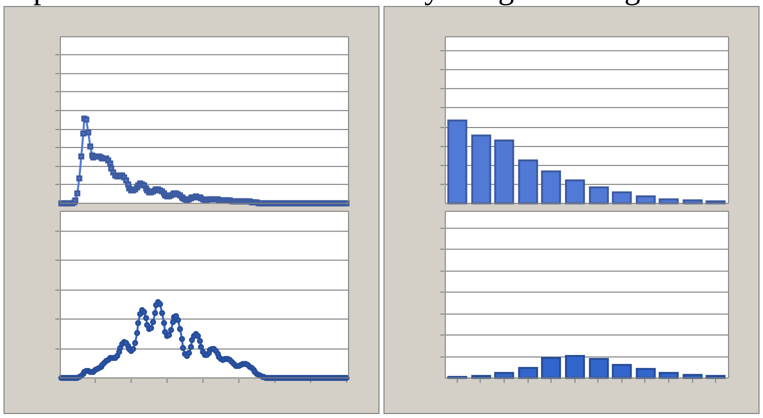
Population and Catch Numbers by Length and Age for Year 1981



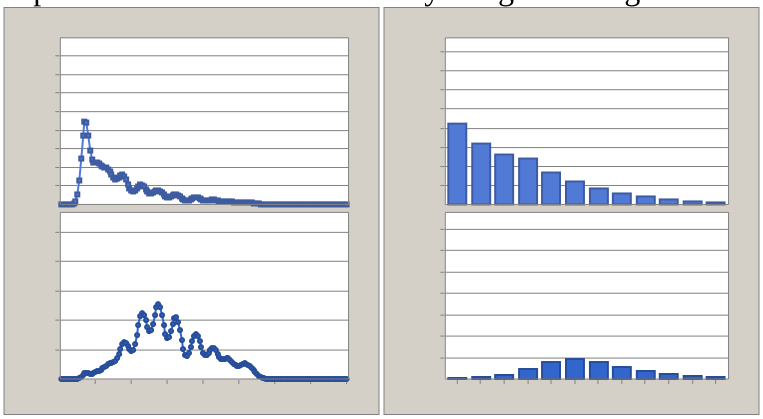
Population and Catch Numbers by Length and Age for Year 1982



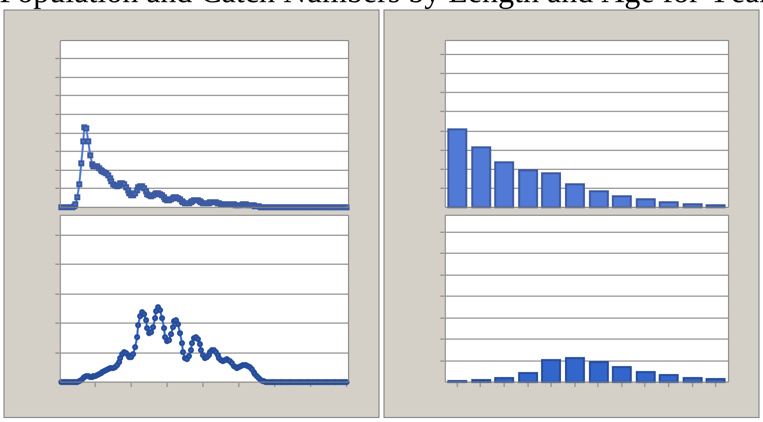
Population and Catch Numbers by Length and Age for Year 1983



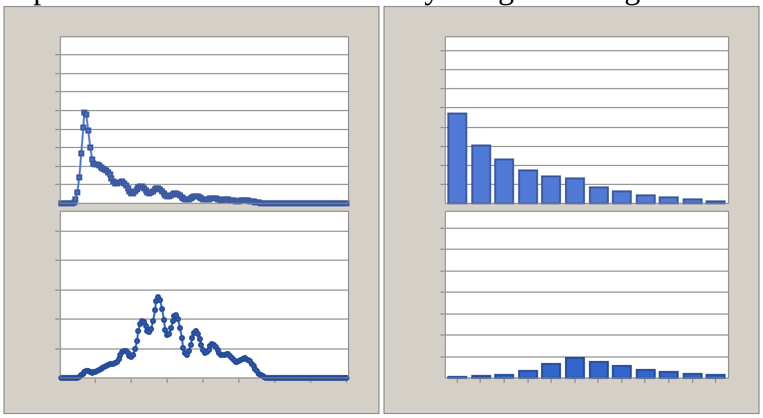
Population and Catch Numbers by Length and Age for Year 1984



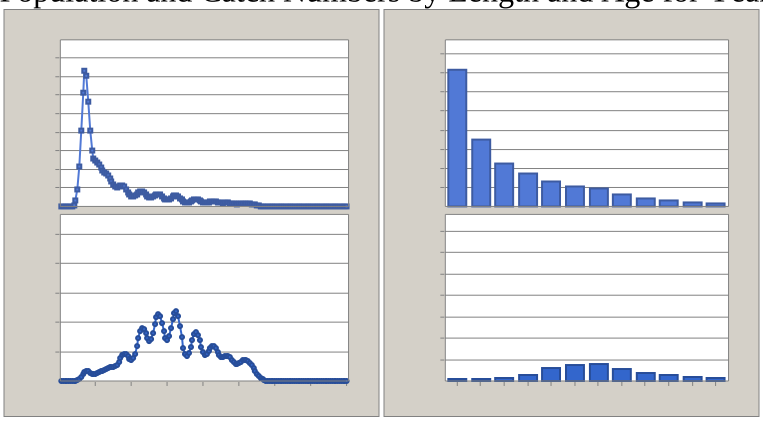
Population and Catch Numbers by Length and Age for Year 1985



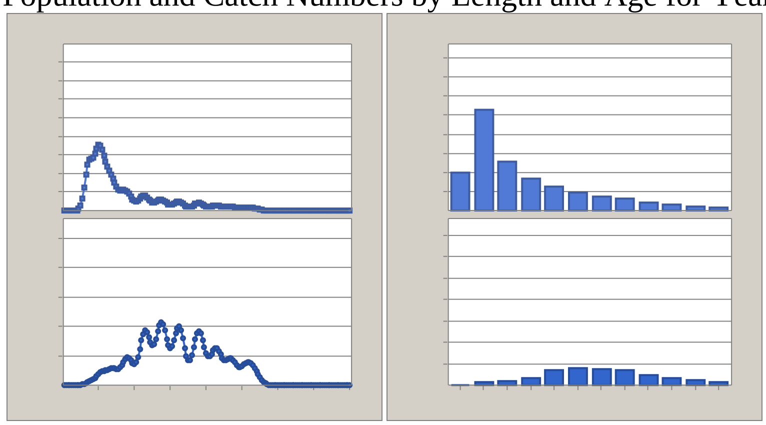
Population and Catch Numbers by Length and Age for Year 1986



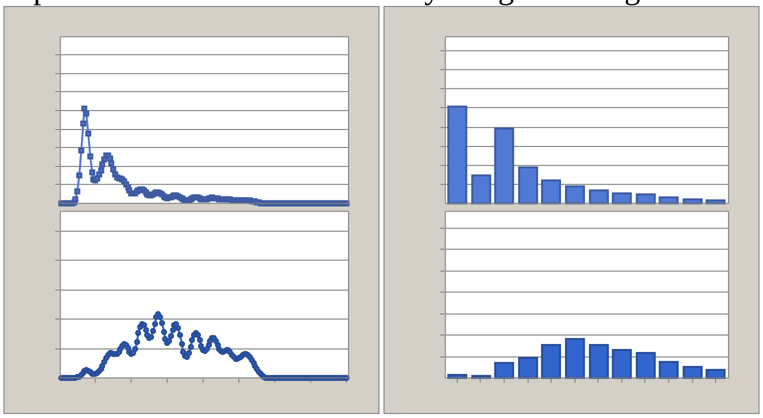
Population and Catch Numbers by Length and Age for Year 1987



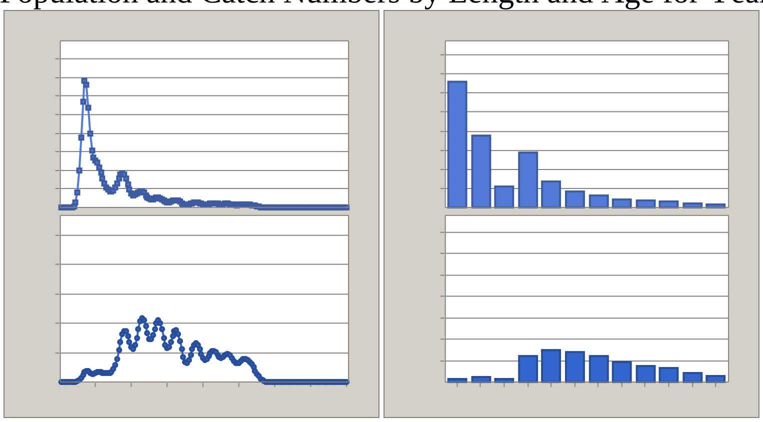
Population and Catch Numbers by Length and Age for Year 1988



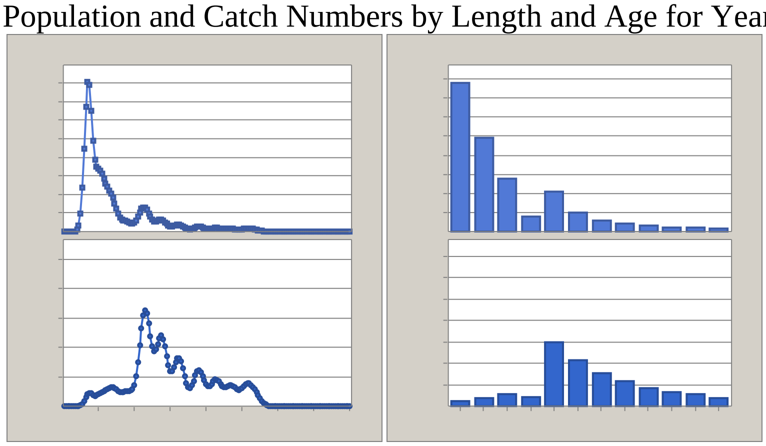
Population and Catch Numbers by Length and Age for Year 1989



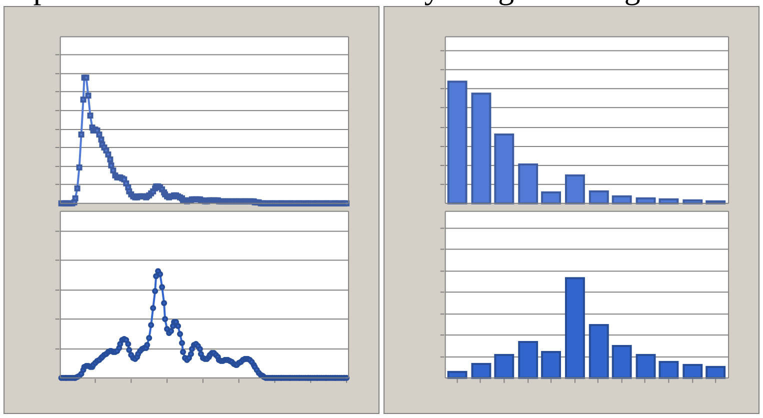
Population and Catch Numbers by Length and Age for Year 1990



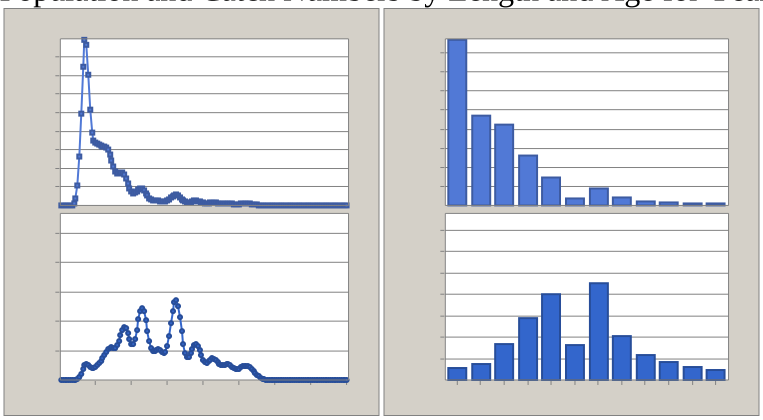
Population and Catch Numbers by Length and Age for Year 1991



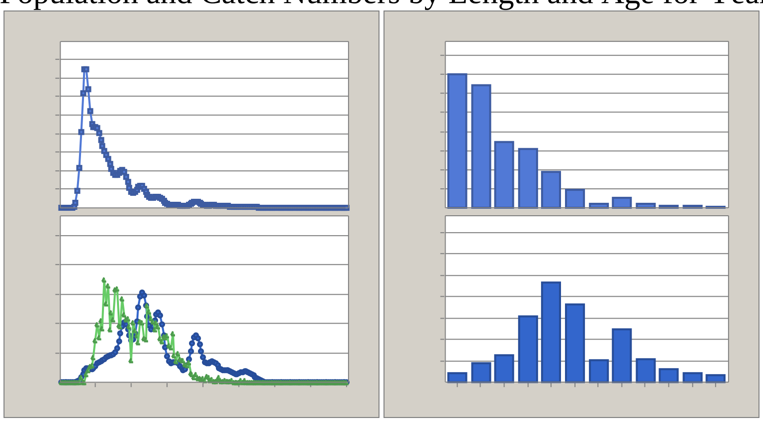
Population and Catch Numbers by Length and Age for Year 1992



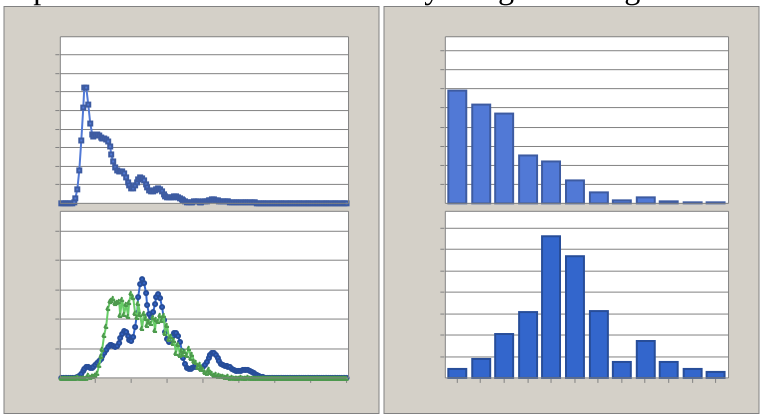
Population and Catch Numbers by Length and Age for Year 1993



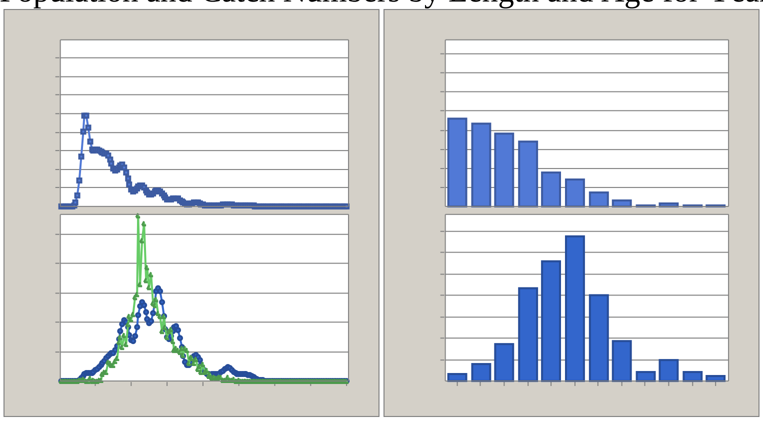
Population and Catch Numbers by Length and Age for Year 1994



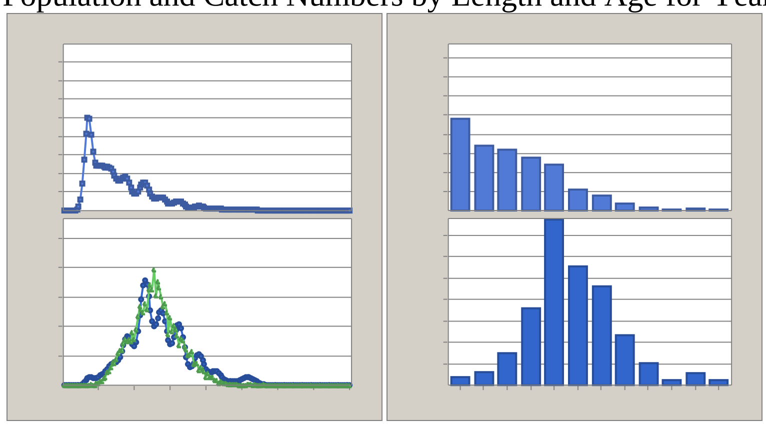
Population and Catch Numbers by Length and Age for Year 1995



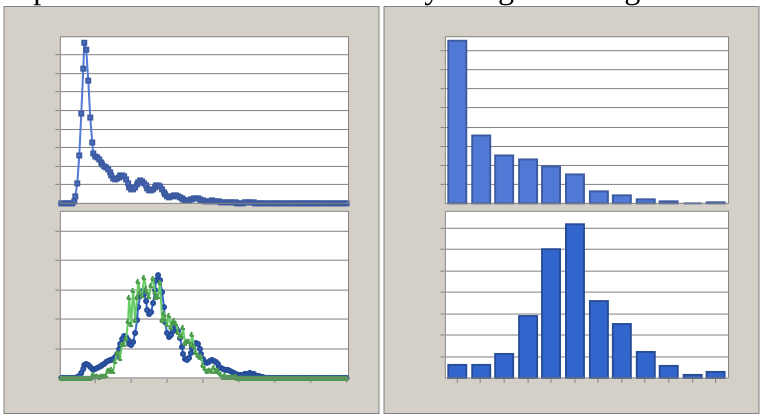
Population and Catch Numbers by Length and Age for Year 1996



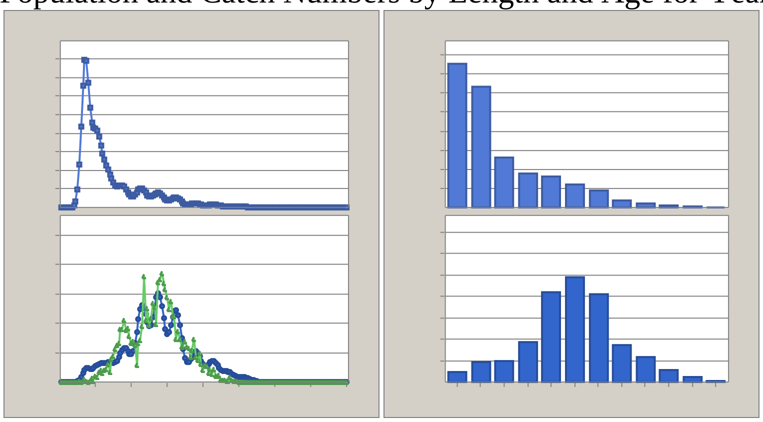
Population and Catch Numbers by Length and Age for Year 1997



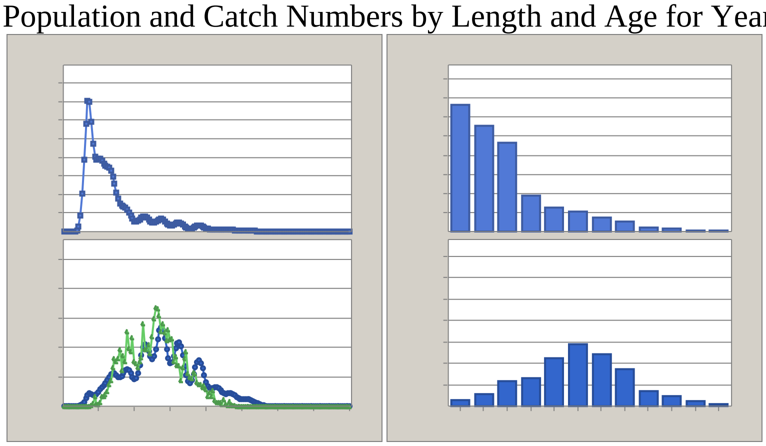
Population and Catch Numbers by Length and Age for Year 1998



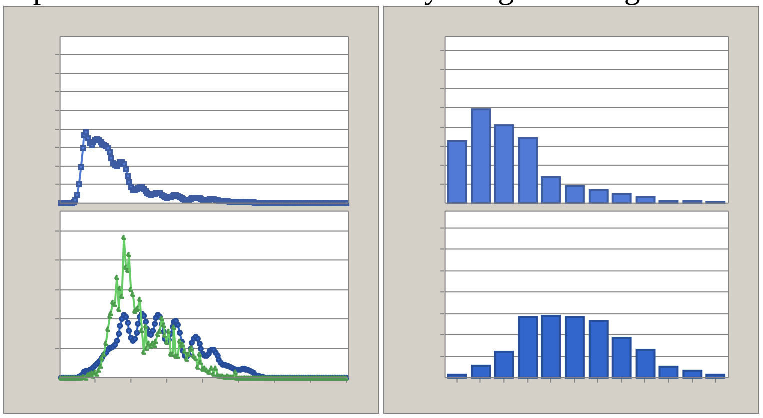
Population and Catch Numbers by Length and Age for Year 1999



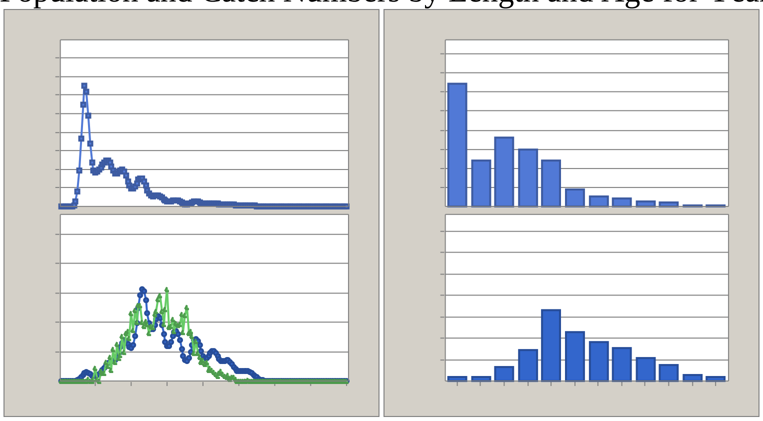
Population and Catch Numbers by Length and Age for Year 2000



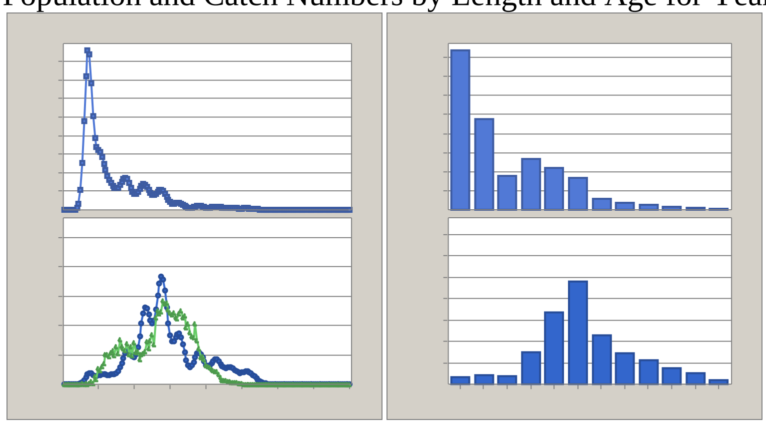
Population and Catch Numbers by Length and Age for Year 2001



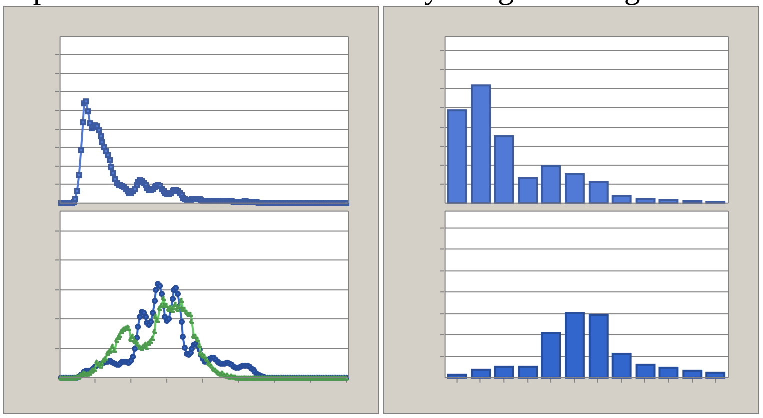
Population and Catch Numbers by Length and Age for Year 2002



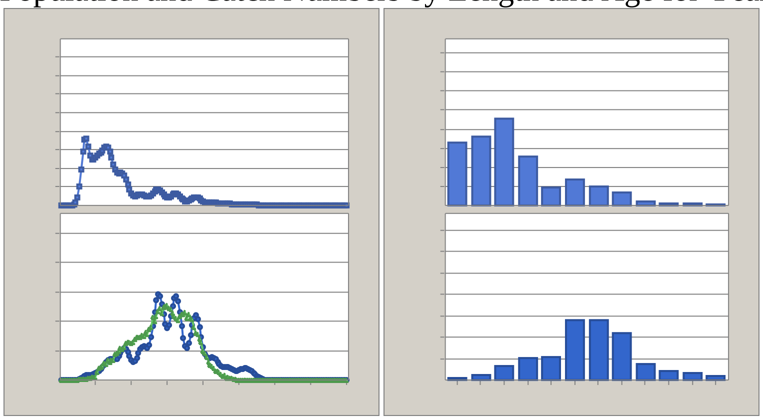
Population and Catch Numbers by Length and Age for Year 2003



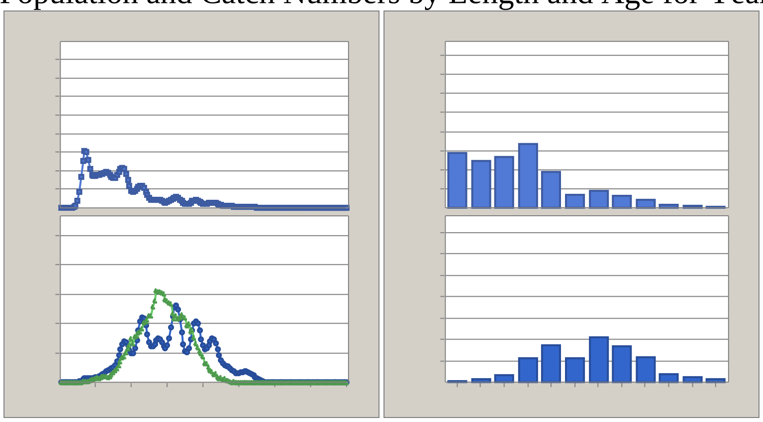
Population and Catch Numbers by Length and Age for Year 2004



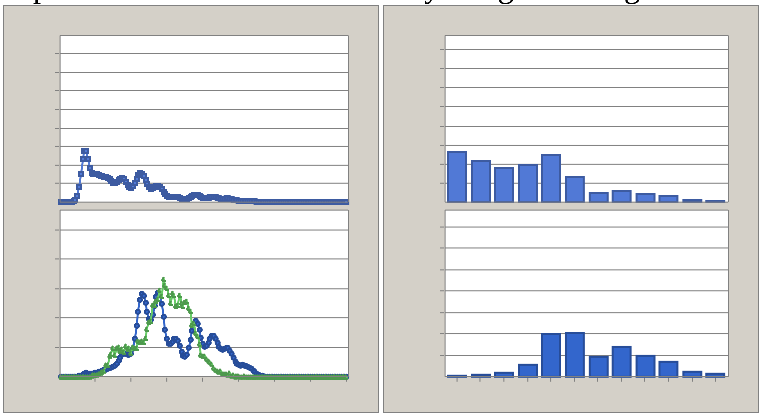
Population and Catch Numbers by Length and Age for Year 2005



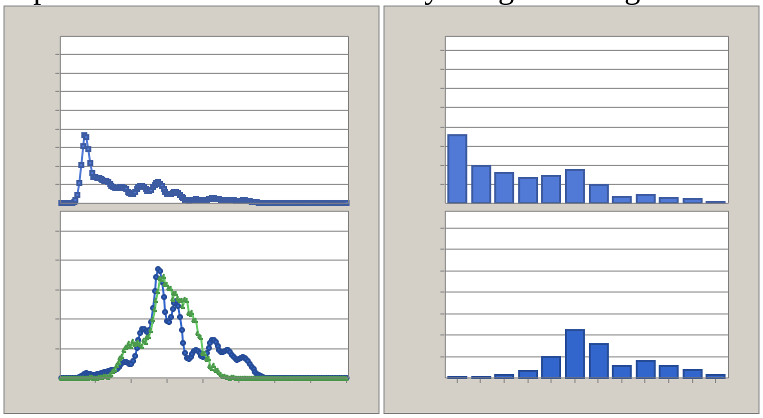
Population and Catch Numbers by Length and Age for Year 2006



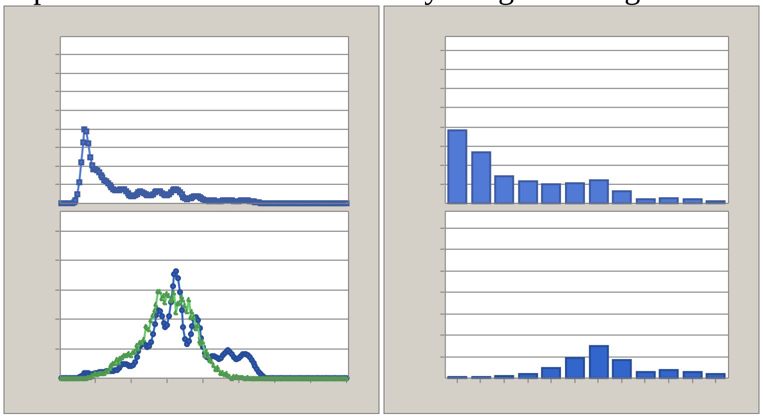
Population and Catch Numbers by Length and Age for Year 2007



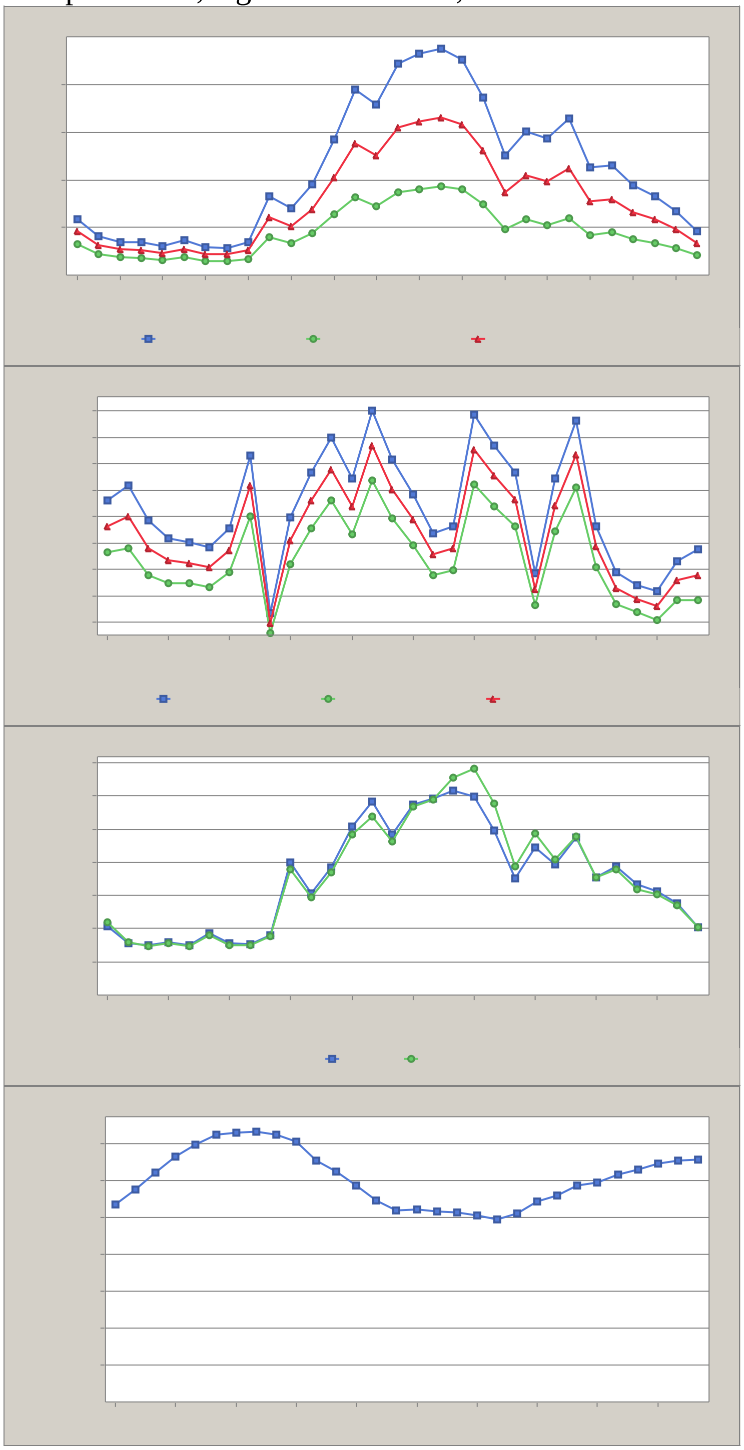
Population and Catch Numbers by Length and Age for Year 2008



Population and Catch Numbers by Length and Age for Year 2009



Grouped Fmult, Age 1 Recruitment, Observed vs. Predicted Catch Weight, and Total Biomass



Appendix A3: A tagging study to assess monkfish (*Lophius americanus*) movements and stock structure in the northeastern United States

Graham Sherwood*, Jonathan Grabowski and Shelly Tallack
Gulf of Maine Research Institute, Portland, Me 04101
*correspondence: gsherwood@gmri.org; (207) 228 1644

A conventional tagging study was conducted to examine movement and mixing rates of monkfish (*Lophius americanus*), respectively, within and between two monkfish management areas in the northeastern United States (the Northern and Southern Management Areas, or NMA and SMA). A total of 2770 monkfish were tagged and released in the autumn of 2007 and winter of 2008 (1006 in the NMA and 1764 in the SMA) and recaptures were monitored over the following 21 months. This study represents the first tagging study for monkfish in the U.S. northeast and almost doubles in effort (i.e., tag releases) the next largest tagging study for *Lophius sp*. The following is a summary of the main findings:

1) The overall reporting rate for filtered recaptures (i.e., days at liberty > 30 days) was 3.2% and this rate was higher in the SMA (3.9%) than in the NMA (1.7%).

2) Tag shedding rate (based on double tagging of all monkfish released), was found to be 18.6% which compares well to shedding rates for other species (e.g., cod).

3) Movements after 30 days at liberty were mostly in the southwest direction and ranged from 1 to 503 km; mean displacement was higher in the NMA than in the SMA: 110.4 ± 129.9 km versus 54.7 ± 58.5 km, and positively correlated with monkfish size in the SMA.

4) Mixing (straying) among management areas was found to be low and unidirectional; no monkfish tagged in the SMA were recaptured in the NMA (although reporting rates were low in the NMA), and we estimate that 9.1% of the monkfish tagged in the NMA moved to the SMA.

5) Growth rate was estimated for a subset of monkfish for which reliable length data existed at the time of recapture (n = 23) to be 10.6 ± 4.7 cm $year^{-1}$ (mean ± std) which compares well with tagging-based estimates of growth for *Lophius piscatorius*. There was a trend (insignificant) for lower growth in larger monkfish which, if coupled to further data and evidence, could call into question the validity of current aging results and the assumption of linear growth in monkfish.

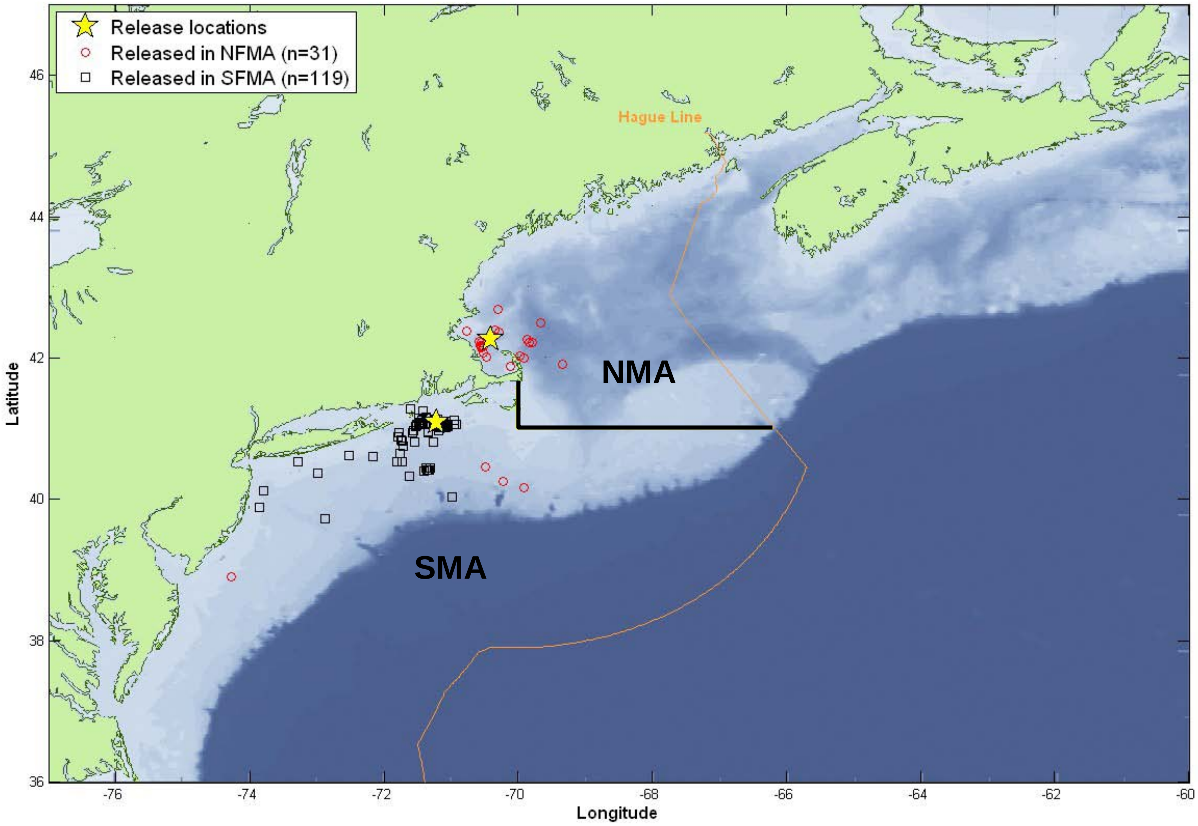


Figure 1. Map showing location of release (note that release sites are close enough within each area to be represented by one star) and recapture locations in the SMA and NMA. Open circles and squares denote the location of fish recapture sites for fish tagged in the NMA and SMA, respectively (see legend). Mean bearing for monkfish released in the NMA was 165°, or almost directly due south (although smaller range movements were to the east). Mean bearing for monkfish released in the SMA was 227° or southwest. Size of released monkfish ranged from 31 to 105 cm (total length).

Table 2. Summary of recaptures by management area and tag color* for non-filtered and filtered (days at liberty > 30 days) data.

			Total recaptures		NMA recaptures		SMA recaptures	
Release Area	Tag color	Releases	Number	Percent	Number	Percent	Number	Percent
No filtering								
NMA	yellow	906	27	3.0	25	2.8	2	0.2
NMA	blue	100	9	9.0	7	7.0	2	2.0
NMA	Total	1006	36	3.6	32	3.2	4	0.4
SMA	yellow	1595	106	6.6	0	0	106	6.6
SMA	blue	169	19	11.2	0	0	19	11.2
SMA	Total	1764	125	7.1	0	0	125	7.1
All	yellow	2501	133	5.3	25	1.0	108	4.3
All	blue	269	28	10.4	7	2.6	21	7.8
All	Total	2770	161	5.8	32	1.2	129	4.7
Filtered for days at liberty > 30								
NMA	yellow	906	13	1.4	11	1.2	2	0.2
NMA	blue	100	8	8.0	6	6.0	2	2.0
NMA	Total	1006	21	2.1	17	1.7	4	0.4
SMA	yellow	1595	59	3.7	0	0	59	3.7
SMA	blue	169	9	5.3	0	0	9	5.3
SMA	Total	1764	68	3.9	0	0	68	3.9
All	yellow	2501	72	2.9	11	0.4	61	2.4
All	blue	269	17	6.3	6	2.2	11	4.1
All	Total	2770	89	3.2	17	0.6	72	2.6

*blue tags were high reward ($100) and yellow tags were standard reward (t-shirt)